

MODEL RESEARCH



National Aeronautics and Space Administration

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**The National Advisory
Committee for Aeronautics
1915-1958**

Volume 1



The NACA Main Committee at its semiannual meeting 21 April 1921. The Committee had just met with President Harding at the White House. (Photograph used by permission of Underwood Photo Archives Ltd., San Francisco)

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**The National Advisory
Committee for Aeronautics
1915-1958**

Volume 1

Alex Roland

The NASA History Series



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NASA maintains an internal history program for two principal reasons: (1) Sponsorship of research in NASA-related history is one way in which NASA responds to the provision of the National Aeronautics and Space Act of 1958 that requires NASA to "provide for the widest practicable and appropriate dissemination of information concerning its activities and the results thereof." (2) Thoughtful study of NASA history can help agency managers accomplish the missions assigned to the agency. Understanding NASA's past aids in understanding its present situation and illuminates possible future directions.

One advantage of working in contemporary history is access to participants. During the research phase, the authors conducted numerous interviews. Subsequently they submitted parts of the manuscript to persons who had participated in or closely observed the events described. Readers were asked to point out errors of fact and questionable interpretations and to provide supporting evidence. The authors then made such changes as they believed justified. The opinions and conclusions set forth in this book are those of the authors; no official of the agency necessarily endorses those opinions or conclusions.

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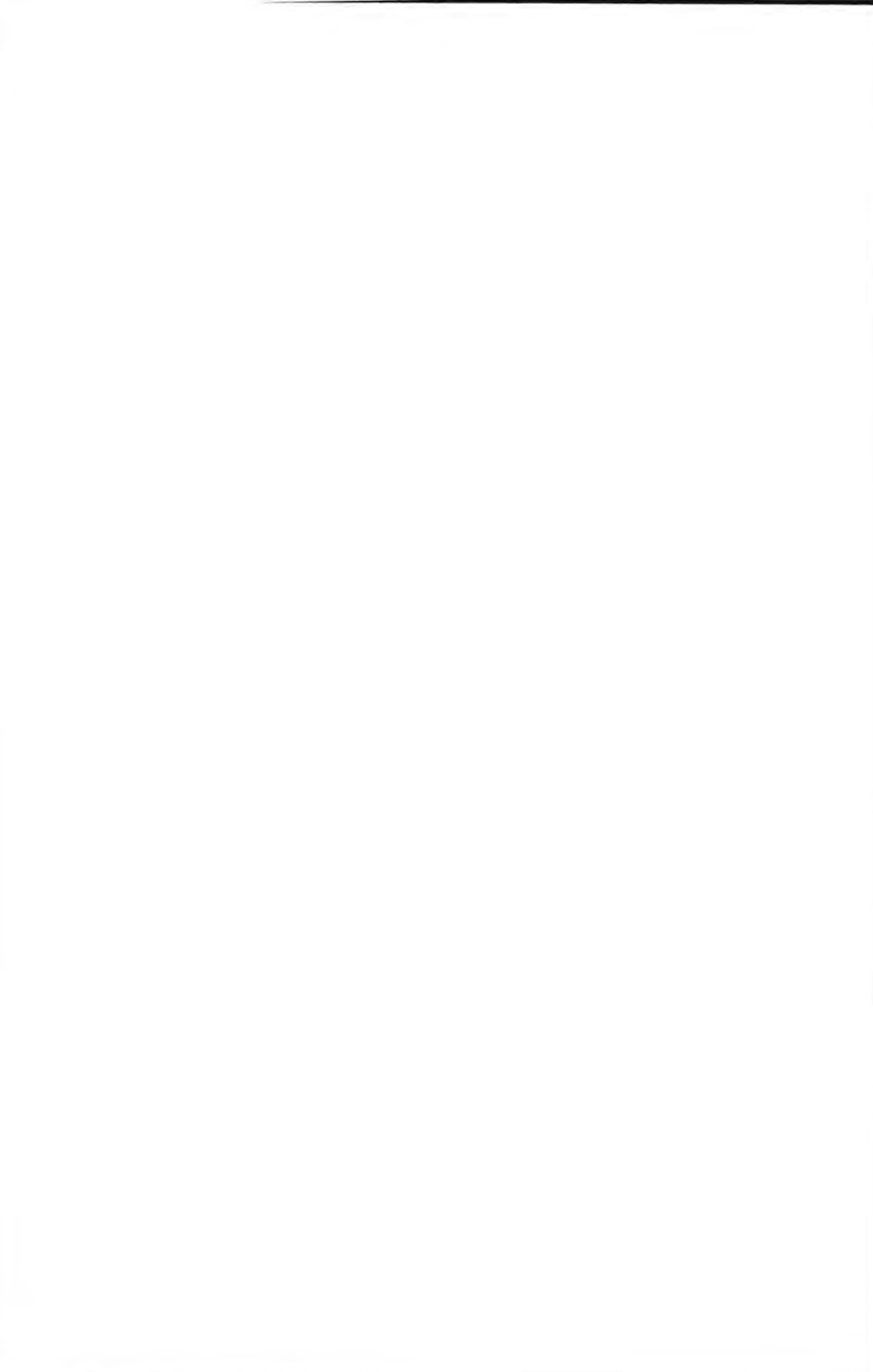
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Foreword

The National Advisory Committee for Aeronautics was an undeniable success. Its name is permanently linked to such dramatic innovations as the NACA cowling, the low-drag airfoil, the transonic wind tunnel, and the X-series research aircraft of the 1940s and 1950s. Equally significant in the evolution of flight were the incremental developments over the years: the NACA family of airfoils, solutions to the problems of aircraft icing, improved ducts and inlets, techniques of streamlining, and proper engine placement on wings and fuselage. The NACA contributed significantly to every United States aircraft built during this country's rise to world preeminence in aviation.

The reasons for this success were many. First among them were the people of the NACA. During years of association with the NACA, from my early days as a test pilot to the culminating period of 1955-1958 when I served as chairman, I never knew a more devoted, hard-working, productive staff. The same may be said for my colleagues and predecessors who served without compensation on the NACA Main Committee and its many subcommittees. Their contributions far outweighed any rewards they received.

The second major reason for the success of the NACA was its institutional structure. Although it was an independent agency directly answerable to the President, it remained remarkably free of the political forces that push and pull so many federal bureaus off course. The committees and staff of the NACA tried to focus on the needs of American aviation, particularly the aviation branches of the military services and the commercial aircraft industry. The NACA fulfilled those obligations without reference to special interests.

A third reason for the success of the NACA was its mission: "the scientific study of the problems of flight with a view to their practical solution. At once sweeping in its implications and narrowly focused in its goals, this mandate guided the NACA throughout its 43 years. It told the Committee what to do without dictating how it was to be done, and it gave the Committee latitude to select its problems even as it insisted on practical applications of the results. The NACA established and maintained its reputation in Congress and the Executive Branch by adhering to this mission.

The story of this remarkable organization is told for the first time in *Model Research*, which constitutes the official record that the NACA has long deserved. Here are not only the facts and figures that define and particularize the NACA's achievements, but also a story that brings the agency to life in the context of its times. The book traces the NACA from its modest beginnings in World War I through the successes and disappointments of World War II to its transformation into the nucleus of the National Aeronautics and Space Administration. In these pages appear the gifted persons who made the NACA work—Joseph Ames, George Lewis, Hugh Dryden, John Victory, and Jerome Hunsaker, my immediate predecessor as chairman.

Not everyone will agree with all of Professor Roland's interpretations. But I recommend the book nevertheless. The Committee that emerges from these pages is much like the one I knew, and its story is too important to dismiss over differences of interpretation. The NACA was a complex institution that appears different from different perspectives, but its reputation is secure enough to withstand analysis and criticism by any scrupulous historian. The book should stimulate further research on the NACA, and I hope historians will continue to find the NACA as interesting and significant to study as I did to serve.

JAMES H. DOOLITTLE

Preface

Throughout most of its history, the National Advisory Committee for Aeronautics was arguably the most important and productive aeronautical research establishment in the world. Between its creation in 1915 and its demise in 1958, it published more than 16,000 reports sought after and exploited by aeronautical engineers throughout the United States and abroad. It developed wind tunnels, as well as other equipment and techniques, that revolutionized aeronautical research. The data that it gathered are still employed in aircraft design. Five times the NACA and its staff won or shared the Collier trophy, America's premier aeronautical prize for the most significant contribution to flight in a given year. Though the NACA had its failures and shortcomings, its reputation for efficiency and effectiveness was so widespread and transcendent that it came to be viewed as something of a model research organization.

The idea of the NACA as a model arose early in its history and continues to the present. One NACA veteran has declared that the NACA's example of government organization for research was a greater contribution than the Committee's technical output. An early NACA chairman asserted that the NACA's unique structure was an indispensable ingredient of its technical success. In 1940, Vannevar Bush modeled the National Defense Research Committee upon the NACA and tried unsuccessfully to model the National Science Foundation upon it as well. In the 1970s much of the aeronautical community favored revival of the NACA to handle all government research and development in civil aviation.

This book examines the NACA as an institution, attempting to explain how and why it functioned and to evaluate it as a research organization. Although the NACA's technical achievements permeate the story, this book is not a technical history. The Committee's research accomplishments are set forth more directly in George C. Gray's *Frontiers of Flight: The Story of NACA Research*, Jerome C. Hunsaker's "Forty Years of Aeronautical Research," and in the Committee's own technical publications, all of which are described in the appendixes and bibliography. This book is primarily a political and institutional history focusing on the NACA as a model research organization.

The principal themes of this story are three: First are the institutional considerations. Institutions shape and are shaped by the research they conduct. In theory, the Committee's structure and independent status within the federal hierarchy made the NACA an ideal forum wherein all branches of American aeronautics could debate and develop a national research program. In practice, some voices were louder than others and independence bred not freedom but insecurity. Committees can exploit a wide variety of talents and viewpoints, but they can also elevate consensus over wisdom. Industry, excluded at first from NACA councils, came in time to dominate them. Without a solid political base, or even an unequivocal *raison d'être*, the NACA engaged in a running war for survival, guarding its flanks against criticism, fighting rearguard actions against forces of abolition or merger, courting allies where it found them—in Congress, the military services, other executive branches, the aircraft industry, and elsewhere—and outflanking enemies as best it could. Political insecurity bred habits of conservatism, self-promotion, reliance on committees of experts, deference to clients, and a concern for territoriality, all of which influenced the style and content of its research program—at least, the research program formulated in Washington. Insulated from the politics of bureaucratic survival, the staffs at the NACA laboratories saw the Committee's research program differently. In the early years, size, geographic proximity, and *esprit de corps* kept the headquarters and its single laboratory more or less in harmony, diminishing the usual tension between a headquarters and its field installations. Later, expansion weakened the bonds, enhancing the autonomy of the laboratories even as the headquarters sought to enforce its policies through a larger staff and more elaborate operating procedures.

The second theme encompasses personnel policies and how they shaped NACA research. Committed originally to the "scientific study" dictated by its organic legislation, the NACA turned within its first decade to an engineering orientation that it never thereafter abandoned. Engineers held most key positions within the NACA. Young engineers were recruited right out of undergraduate schooling and trained to the NACA style. Loyalty and teamwork were valued above brilliance. Some scientists worked successfully in this environment, and the dividing line between science and engineering often blurred beyond recognition in the complex process of aeronautical research. Still, the NACA remained primarily an engineering organization, with all the advantages and disadvantages such an orientation would entail.

Finally, research equipment shaped the NACA's program fully as much as did its organization and personnel. The wind tunnel dominates aeronautical research just as the microscope dominates biology, the telescope astronomy, and the particle accelerator nuclear physics.

The NACA achieved early success and acclaim by developing revolutionary wind tunnels for aerodynamical research. Thereafter the tunnels took on a life of their own, influencing the pace and direction of NACA research; concentrating the Committee's attention on aerodynamics when fields like propulsion, structures, and helicopters had equal merit; and becoming in time a sort of end in themselves. The NACA used its wind tunnels to great advantage, but the wind tunnels also used the NACA.

This study is both a narrative history—the author's account of what was significant in the career of the NACA—and a reference work from which the essential facts of the Committee's history can be readily retrieved. To keep the one function from intruding on the other, most of the factual data on the NACA appear in appendixes: all the major legislation affecting the Committee, the committee structure and composition, the budget and personnel histories, the facilities, the details of the NACA research process and its resulting reports, and a selection of representative and significant documents. In appendixes, this information is easier to find and does not clutter the text, which is a comparatively brief, interpretative, and analytical survey of the Committee's history directed at specialists and nonspecialists alike.

This history has been written primarily from the records of the NACA headquarters, supplemented with extensive research in the records of the NACA laboratories, in the records of other agencies and institutions, and in the secondary literature, which is lamentably sparse. But the primary perspective is that of headquarters. It was, after all, the headquarters that ran the NACA, and it is in these records that the course of NACA history can be traced most readily and fully. This account might have benefited from further research in the records of the laboratories and of the NACA's principal clients, the military services and the aircraft manufacturers. But preliminary consultation of these sources suggested that additional research would merely have confirmed the broad conclusions reached here and would have complemented, not altered, the story. Furthermore, one purpose of this book was to serve as a guide to the records of the NACA, introducing them to other researchers in related fields; that purpose was best served by making the fullest possible use of the NACA material.

Only a handful of the major characters are mentioned in the text. By design, the men and women of the NACA worked as a team, collaborating freely across institutional and disciplinary boundaries and editing each other's work until the published reports were as uniform and impersonal as a military training manual. By all reports, the people of the NACA had as much humor and liveliness as any comparable group, but it was not the kind of humor that comes across on paper, in the few instances where it was allowed in print at all. It was instead an

engineer's humor, narrow, esoteric, almost sophomoric, evoking gales of laughter from the initiate with punchlines like ". . . but he had given him a screw with a *left-handed* thread." Mostly, the record of the NACA is dry, correct, impersonal, and colorless. The few personalities that do emerge to influence the course of events are described in the text. Other key people of the NACA are named in Appendix D.

Participants in the story have been quoted at length—even, at times, without being identified—to give the reader an opportunity to interpret some of the material for himself and to convey the flavor of the literary style of the engineer, who writes with a safety factor of three. As if building a bridge that can in theory support three times the weight it is expected to bear, the typical engineer builds a sentence with enough words to repeat his message twice. Aeronautical engineers generally deal with a safety factor of 1.5 but their sentences tend to be no less weighty than those of their civil and mechanical colleagues.

One of the author's principal aims has been to keep the text brief, nontechnical, and on course. Supplementary material—illustrative quotations, historical asides, debating points, technical data, and comments on the sources—may be found in the notes, along with the normal documentation of the text. The specialist can consult the notes to amplify topics of particular concern to him; the general reader also may find the additional information interesting and rewarding. The NACA was a long-standing house of many rooms, not all of which could be fully explored in a text of this compass.

Finally, some home truths about the style and tone of this study. One NACA veteran, commenting on the manuscript, guessed that "in his heart of hearts Roland simply finds more interest and excitement in NACA's failings than in its successes." There is more than a little truth in that observation. In researching and writing this book, I was much more alive to the NACA's shortcomings than I was to its virtues.

I did not consciously plan to emphasize the negative; rather, that pattern emerged from three separate but related causes. First, as a kept historian in the employ of the agency about which I was writing, I set out with a personal and professional interest in demonstrating that official history need not be court history, that the agency historian (at least in this agency) can be critical and independent, that he can contradict the party line when the evidence warrants it without fear of censorship or recrimination. This ambition may well have led me to be overzealous in finding fault with the NACA. The good news is that I have at least proved my point—perhaps at the expense of the NACA—for NASA readily agreed to publish the manuscript, an excess of warts notwithstanding.

Second, the headquarters records—the source on which I relied most heavily—are enough to raise the hackles of even the most sympa-

thetic historian. They are filled with myopic, self-serving, politically motivated propaganda. I can appreciate that the NACA was forced into this public posturing by the nature of pluralistic politics in Washington, that all government agencies engage in such practices, and that work in the laboratories was generally untainted with the grime of public relations. Still, one cannot immerse himself in those records for several years without wanting to puncture the balloon of self-aggrandizement that was inflated in the NACA headquarters.

Finally, I remain seriously concerned about the ability of the official record to convey a critical picture of the NACA. Virtually all those in a position to knowledgeably assess the Committee had a vested interest in keeping their objections and misgivings to themselves. The NACA was not anxious to air its dirty laundry, and I think the desire to emphasize the positive finally produced an inability to acknowledge the negative—at headquarters, certainly, and to a lesser degree in the laboratories. Those in industry and the military services who relied on the NACA had every reason to praise the Committee in public lest their criticisms contribute to either a decline in the Committee's budget or a reluctance on the part of the Committee to do the work they wanted. With the possible exception of academics, I can think of no contemporary group likely to criticize the NACA freely and knowledgeably. If my book seems overly critical, it is partly to correct this imbalance in the public record.

In revising my manuscript for publication, I have sought to eliminate the imbalances, both pro and con, that appeared in the work. Some harsh judgments simply will not wash out; some bouquets are no doubt sweeter than they should be. In sum, the NACA that appears in these pages corresponds as closely as I could make it to the one I found in the Committee's files. Readers may decide for themselves to what extent it was a model research organization.

Acknowledgments

This book owes much to many hands besides mine. First among those who aided in its preparation is Walter T. Bonney, from whom I inherited the project. The former head of public affairs for the NACA and NASA, Walter undertook to prepare in his retirement under contract to the NASA History Office a history of the NACA. He had completed his research, outlining, and the drafting of three chapters at the time of his death in 1975. This book is not the one that Walter envisioned, but it has drawn heavily on his research and insights.

In the course of my own research I incurred countless other debts, only a few of which may be acknowledged here. The greatest is to Steve Bern of the Washington National Records Center, who personally pulled from the shelves and delivered to me all 480 of the boxes of NACA records I examined at Suitland. In their years of storage, many of these boxes had accumulated inside and out a clinging layer of fine, silty, black dust that blew up when the boxes were disturbed to settle down tenaciously on the lungs, hands, and clothing of any who dared to disturb them. Steve was chosen for this unpleasant job because he was the youngest, strongest, and most good-natured hand at Suitland. He performed with unfailing dispatch, accuracy, and good humor—lightening for me an otherwise onerous research task. His supervisor, James Miller, made both our jobs easier in countless ways. William Lewis facilitated the temporary loan of some of the more important boxes so that I might examine them more closely in my office.

Equally helpful service was provided at the National Archives main building by Marilla Guptil, William Cunliffe, and Lee Johnson. The staffs at the Federal Archives and Records Centers in San Bruno and Luna Niguel, Calif., did the same.

The late Alfred E. String made the NASA Headquarters Technical Library a productive place to work and helped me gain access to the resources of the Library of Congress. Grace Reader, Eleanor Burdette, and Mary Anderson were unfailingly helpful and solicitous in digging out material in the Headquarters technical library or in drawing items from other NASA libraries or libraries outside the agency. Walter Bonney spoke often of how helpful Grace Reader had been to him; Eleanor Burdette was especially helpful to me in unraveling the NACA filing system for technical publications.

NASA Archivist Lee Saegesser shared with me his files, his institutional memory, and his keen knack for ferreting out elusive information. Others who helped unearth information were Lee M. Pearson, former historian of the Naval Air Systems Command; the research librarians at the Federal Aviation Administration library; the librarians and archivists at the National Air and Space Museum; and the staff at the Smithsonian Institution Archives.

Richard Layman of Langley Research Center has been a constant source of encouragement and assistance. Largely through his efforts, Langley has developed a program that promises to preserve and disseminate the rich history of the oldest NACA research center. My research at Lewis Research Center was facilitated by Paul Bohn, and by staff members at both Lewis and Plum Brook, where most of the center's records are stored.

Duane Reed, chief of the Manuscript Division of the U.S. Air Force Academy library, opened up to me not only the rich collection of John F. Victory papers, but also his home and his infectious brand of back-country charm.

The complete draft of this manuscript was read by Ira H. Abbott, David K. Allison, Frank Anderson, John V. Becker, John Duberg, Richard P. Hallion, James R. Hansen, I.B. Holley, Pamela Mack, Axel Mattson, Homer Newell, Frank J. Rowsome, T.K. Smull, Walter Vincenti, and Monte D. Wright. All of them made significant contributions to my understanding and explication of the NACA. Some of them take strong exception to many of the interpretations in the book; by helping me to improve the manuscript, they have not assumed responsibility for the errors that have defied their counsel.

The same may be said for my editor, Eleanor Ritchie, who strove mightily to save me from myself, or rather to save the reader from my writing style. Whatever clarity has been achieved here owes much to her; for the residual murkiness she is blameless. Marion Davis typed the manuscript and prepared most of the index with quiet efficiency and patience.

ALEX ROLAND
Durham, North Carolina
January 1983

1

The Quest for a National Aeronautical Laboratory: Progress, Preparedness, and Progressivism, 1910-1915

Twelve years separated the first powered flight of the Wright brothers in 1903 from the creation of the National Advisory Committee for Aeronautics. Had Americans appreciated and understood the Wright accomplishment more fully, they might have institutionalized aeronautical research more quickly. Instead, Americans ignored and then discounted the Wrights and their achievement, embroiled them in a petty but far-reaching dispute with the Smithsonian Institution, and allowed the Europeans to take the lead in aeronautical development. When the NACA was finally created in 1915, it had to catch up with the rest of the world.

Wilbur and Orville Wright had mastered flight in a wind tunnel before they powered off the ground at Kitty Hawk in 1903. Their achievement flowed as much from broad study and scientific method as from their natural intuition and genius. But this was not widely known at the time; instead, the Wrights were viewed by many as mere bicycle mechanics, and their achievement as a fortuitous victory over their nearest American rival, Samuel Pierpont Langley, secretary of the Smithsonian Institution and scientist of flight. By extension, the Wright success was a victory over science itself, or so it seemed. Langley had studied the flight of birds for years and in the late 1890s had flown a model of an "aerodrome" almost a mile in powered heavier-than-air flight. Nine days before the Wright brothers' first flight, Langley launched his full-scale aerodrome, with a pilot aboard, from a houseboat in the Potomac River. It crashed ignominiously into the water. Langley and his enterprise were roundly ridiculed in the press, overshadowing for a while the unheralded success of the Wrights a few days later.¹

Not until 1908 was the achievement of the Wrights fully appreciated, though even then not their method. In that "*annus mirabilis* in aviation history," a turning point from which heavier-than-air flight followed a more or less straight course to the present, the Wrights performed what they had been rehearsing and refining for almost five years. They flew faster and farther, and with greater control, ease, safety, and grace, than any of their awkward imitators and competitors. Their achievement was consummate, its impact on the aviation world overwhelming and definitive. In their wake, the memory of Langley's doused and discredited aerodrome seemed even more ridiculous. To a public yet unaware of the Wrights' scientific research, it appeared that science had been bested by mechanics, scholarship and erudition humbled by mere cleverness and inventiveness. Langley seemed to contemporaries "a professor wandering in his dreams"; the Wrights were "known merely as practical mechanics."²

That was the impression in the United States, at least. University research in aeronautics was virtually nonexistent. No private contributors had come forward to endow laboratories. The government avoided any more investments that might remind the public of the \$50,000 it had sunk in the Langley enterprise. Not even the Smithsonian Institution seemed willing to venture again into these troubled waters: Dr. Langley's laboratory was closed down, to stand behind the Castle building on the Mall as a silent monument to the political hazards of aeronautical research.

About the only island in the empty sea of American aeronautics was the Aerial Equipment Association of Baddeck, Nova Scotia, and Hammondsport, New York. Funded by Mrs. Alexander Graham Bell, the A.E.A. was founded in 1907 to test the ideas of her husband and four other aviation pioneers about how best "to get into the air." Bell's tetrahedral lifting body proved a disappointment, as did the other experiments attempted by the association. The group disbanded in 1909, having contributed little to aeronautical progress beyond advancing the ideas and experiences of the executive officer and director of experiments, Glenn H. Curtiss.³

Aviation in the United States fared as badly in its first five years as did research into its principles. Not until 1907 did the military services let their first contract for an airplane, and even when Orville Wright flew one at Fort Myer the following year, meeting all the army's specifications, the government was slow to follow up. The first regular appropriation in the services did not materialize until 1911, when the navy received \$25,000. Most other flying in the United States was barnstorming and stunt-flying for show and profit, not the sort of thing to advance the state of the art.

The European experience in the decade after the Wrights' first flight differed dramatically from the American. The Europeans appreciated the achievement of the Wrights and drew no distinction between researches done in a bicycle shop in Dayton and those done in a laboratory at the Smithsonian; they brought to aviation a strong scientific tradition and a predisposition to institutionalize scientific endeavors. They saw sooner than did the Americans that progress in aviation flowed from aeronautical research, and they created a variety of institutions to support this research. In some cases, they merely expanded upon research institutions already in place.

Most of Europe's early aeronautical laboratories were in France, but by the opening of the twentieth century such institutions existed throughout the continent. Work at the Central Establishment for Military Aeronautics at Chalais-Meudon near Paris was complemented by the researches of Gustave Eiffel, working at his famous tower between 1902 and 1906, then in laboratories at the Champ de Mars and in Auteuil, and after 1912 at the privately endowed Aerotechnical Institute of the University of Paris located at St. Cyr. Like similar organizations to follow, the Institute had a director supported by an advisory committee composed of scientific and aeronautical experts from the University of Paris, the Aero Club of France, and government departments concerned with aviation. A similar privately owned university-connected laboratory was established in Russia in 1904 when the Aerodynamic Institute of Koutchino was appended to the University of Moscow. The aerodynamical laboratory of the University of Göttingen, established in the year of Wilbur Wright's first European flights, was also funded from external sources, including government, industry, and private associations, and was directed by Professor Ludwig Prandtl, with the advice of prominent scientists and engineers.⁴

The laboratory that was to reflect most clearly the impact of Wilbur Wright's demonstration of 1908 and to influence most directly the National Advisory Committee for Aeronautics was the British Royal Aircraft Factory, formed in 1909 as an adjunct to the National Physical Laboratory. Prime Minister Herbert Asquith announced before the House of Commons 5 May 1909 the creation of this research center, describing it as one step in a major policy initiative "looking toward placing [the government's] organization for aerial navigation on a more satisfactory footing."⁵ In short, the British planned to keep pace with the Americans and continental Europeans by officially sponsoring aeronautical research of their own.

The last step taken by the British in the spring offensive of 1909 was the appointment of an Advisory Committee for Aeronautics "for the superintendence of the investigations at the National Physical Laboratory and for general advice on the scientific problems arising in

connection with the work of the Admiralty and War Office in aerial construction and navigation." Distinguished scientists and engineers from public and private life were appointed to the committee, which included representatives of the armed services, the Meteorological Office, and the National Physical Laboratory, the government agencies most directly concerned with aeronautics. While many European powers were institutionalizing aeronautical research, the British were characteristically superimposing a central committee on an existing network of institutions.

Advances in aviation came quickly. In July 1909 Louis Bleriot flew across the English Channel and added national security to the other rationales for Britain's new aviation policy. The following month, the Rheims aviation week provided, as historian Charles H. Gibbs-Smith has observed, "the greatest technical stimulus to aviation," contributing to the emergence of aircraft types distinguishable from, and in some ways superior to, the Wright flyers. Bleriot's, Farman's, and Antoinettes became familiar sights in the skies over Europe. Inherent stability, monoplane design, and ailerons began to win acceptance over the Wright characteristics. Competition among scores of serious designers and manufacturers spurred a rate of progress faster than that in the United States, where only Glenn Curtiss seriously challenged the pre-eminence of the Wrights.⁶

LIKE-MINDED MEN

A small group of like-minded men in the United States found it a national embarrassment—not to say a danger—that the country where aviation began should trail so far behind the Europeans. They saw aviation as an infant Hercules with boundless potential for national defense, commerce, and even melioration of the human predicament. They were what Eric Hoffer would call true believers: enthusiasts and visionaries deeply committed to a cause in which they believed passionately, at times irrationally. They wanted to see the United States lead in every phase of aviation, and they believed with Langley and the Wright brothers (as well as with the Europeans then funding laboratories and institutes) that the advance of aeronautics would come with scientific research. Though they also wanted to see larger budgets for military aviation, the encouragement of commercial aviation, and the nurturing of an aircraft-manufacturing industry, they wanted first and foremost a national aeronautical research laboratory to rival those of Europe.

The campaign of the enthusiasts for a national aeronautical laboratory first captured public attention early in 1911, when their club, the Aeronautical Society, announced that at its first annual banquet (to be held in April) it planned "to announce definite arrangements for the

establishment of a national aeronautical laboratory."⁷ President Taft was to lend his prestige and unofficial approval to this enterprise by heading the list of distinguished guests at the dinner. The secretary of the navy, the commissioner of patents, the chief of the Weather Bureau, the chairman of the House Committee on Appropriations, the secretary of the Smithsonian Institution, and the chancellor of New York University were among the public officials, academics, businessmen, and aviators who would vote by their presence at the banquet for the advancement of aeronautics in the United States. The Aeronautical Society was only one among many such clubs forming at the time to enlist public and private support for aviation. Though the character of these groups was business, and their principal goal was the fostering of commercial aviation, they were alive to the importance of military aviation as well. Their aim was to take flying out of the hands of barnstormers and stunt men who were giving it a bad name and an alarming safety record, and place it instead in the hands of serious businessmen, sportsmen, and public officials who would give it the support and regulation it needed to catch up with European achievements.⁸ These were earnest, well-to-do, public-spirited men of established position and reliable views, men with whom President Taft could dine in comfort and congeniality. Their endorsement of a national aeronautical laboratory, especially if the announcement were made by Taft himself as was expected, would give the project a promising future.

But the endorsement never came. On 10 April, the *Washington Star* reported that the proposed laboratory was to be administered by the Smithsonian Institution and located at the National Bureau of Standards. This scoop set off a bureaucratic struggle in Washington that doomed what might have been an easy birth for a national aeronautical laboratory. The opening salvo was fired by Rear Admiral R.M. Watt, chief of the navy's Bureau of Construction and Repair. A week before the date of the Aeronautical Society banquet, he protested to the secretary of the navy that the establishment of a laboratory under Smithsonian control at the Bureau of Standards would result in a duplication of work and organization of the type recently denounced by the president's own Commission on Economy and Efficiency in Government. The experimental model basin at the Washington Navy Yard, Admiral Watt argued, was already equipped to investigate "a considerable portion of the phenomena associated with aeronautics" because "the character of motion, the effect of variation in stream lines, and the theory and mathematics of the motions are almost identical whether in water or air."⁹ This single objection, no doubt brought to President Taft's attention by Navy Secretary George Meyer, who was also to attend the Aeronautical Society banquet, seems to have dissuaded Taft

from making the expected announcement. Instead, the issue remained in Washington, where it encountered still more bureaucratic opposition. The Bureau of Engineering added its objection to that of the Bureau of Construction and Repair, noting that the Engineering Experiment Station at Annapolis was also capable of aeronautical research. The secretary of the navy then proposed that, in lieu of establishing a laboratory under the control of the Smithsonian Institution and the Bureau of Standards, the government assign responsibility for all "laboratory investigations of aeronautical matters" to the navy.¹⁰ That, of course, was unsatisfactory to the army. The secretary of war replied that, in spite of the possible duplication involved, the army would have to conduct its own aeronautical research. At this juncture the dispute was referred to the Commission on Economy and Efficiency in Government, where, not surprisingly, it died.¹¹

THE CHAMBERS REPORT

The forces behind the original Aeronautical Society proposal were not easily deterred. Two men were especially important in the next stage of the struggle. Captain W. Irving Chambers, since 1910 the secretary of the navy's special adviser on aviation matters, had been author of the first proposal for a laboratory under the Smithsonian and the Bureau of Standards, and it had been in fact his independent and irascible nature that had touched off opposition to the plan within the navy. His attachment to the European scheme of organizing laboratories and his disregard of the jealously guarded prerogatives of the navy's Bureaus of Engineering and of Construction and Repair had frustrated the first attempt to establish a laboratory. But he was nothing if not stubborn. He believed a laboratory was essential not only to the navy but also to the entire country, and he meant to secure one, if not through the Aeronautical Society, then some other way. In his second attempt he was joined by Albert F. Zahm, a man of many accomplishments: professor of mechanics at Catholic University, aerodynamic researcher of note, secretary of the Aero Club of Washington, governor of the Aero Club of America, consulting editor of the *Aero Club of America Bulletin*, and consultant to the National Bureau of Standards. Like Chambers, Zahm was a true believer in aviation. Like Chambers, he wanted to see an aeronautical laboratory on the European model established in the United States. Unlike Chambers, he was politic and deferential, unburdened by service rivalry, graced with the mantle of academic impartiality.

Together the two men led a spirited campaign in 1912 to revive the idea of a national laboratory under the Smithsonian Institution. Zahm used the *Aero Club Bulletin* to spread the gospel. In the February

issue, for instance, he contrasted the "symmetrical, rapid, and continuous" aeronautical progress being made in Europe with the "halting, haphazard, and fortuitous" advances in the United States. The difference, he claimed, was "systematic development." The United States needed "at least one broadly planned aeronautical institute or laboratory possessing ample endowment and equipment, a wise and devoted directorate, an able and a highly trained technical staff." Without mentioning the Smithsonian by name, he made clear where and how he thought the lab should be established:

Wherever an appropriation for an aeronautical establishment may be placed, it is of cardinal importance that the directorate and personnel, as well as the endowment, shall be of the same high character as those found in the leading European countries, if not directly modeled after them, and it would doubtless enhance the prestige and efficiency of the institute to have it connected with an established institution having a reputation in the prosecution of theoretical and applied science.¹²

The following month, Zahm made clear what the product of this laboratory might be and how it might be used. The "staff of trained specialists," he wrote, "shall furnish physical constants, laws, formulas, and empirical data of substantial and permanent value to the engineer, the inventor, the manufacturer, whose energies should remain free to employ such knowledge to the advancement of important industrial arts." In other words, this lab was to be an aid to American business, to the manufacture and operation of American aircraft, to what Zahm called (in the typically inflated rhetoric of these enthusiasts) "the early and complete commercial realization of a direct, rapid, and universal system of transportation."¹³

Men from other circles joined the campaign. Professor A. Lawrence Rotch, a meteorologist, seconded Zahm's views and noted that "the establishment of aerodynamical laboratories . . . marks the entrance of aeronautics into the domain of engineering," where "theoretical knowledge based on experiments" would be the foundation of progress. At the request of the Aero Club of America, Rotch served on a committee on aerodynamics chaired by Zahm "to consider the most feasible method of organizing and maintaining an aeronautical laboratory," and he agreed with the committee recommendation that a civilian laboratory be established in the United States under the auspices of the Smithsonian Institution, even though it might duplicate in some respects the research activities planned by the armed services.¹⁴ Richard C. Maclaurin, president of the Massachusetts Institute of Technology, added his endorsement to this campaign, noting that "a knowledge of similar branches of applied science should make it clear that having

reached our present level, we can go higher only by attacking the problems that remain with the patience and persistence of the scientific spirit." Although Maclaurin affirmed the need for a laboratory, he suggested that it might well be "an enormous advantage to have such experimentation conducted at an institution where there are experts in all departments of science and engineering that have any bearing on aviation."¹⁵ (Like MIT, perhaps.)

Captain Chambers also used the *Aero Club of America Bulletin* to broadcast his message and make peace with the Bureaus of Engineering and of Construction and Repair. Citing the fine contributions already made by the navy's model basin, Chambers suggested that revival of the Langley laboratory at the Smithsonian might provide "an ideal institution which will coordinate the work, not only for the best interests of commerce and business, but for the best interests of the army and navy."¹⁶ The advocates of a national laboratory were casting their nets ever wider in an attempt to appease their opponents and establish a proposal acceptable to all.

Chambers capped this activity in September 1912 with the most elaborate and detailed proposal yet made for a national aeronautical laboratory, one that seemed to answer the needs of all the participants to date: the businessmen, enthusiasts, aviators, academics, and military men. In his annual "Report on Aviation" to the Bureau of Navigation, published as appendix 1 to the *Annual Report of the Secretary of the Navy for 1912*, Chambers opened with the following summary of the "status of aviation":

The work of established aerodynamic laboratories has transported aeronautics generally into the domain of engineering, in consequence of which aviation has reached a stage of development wherein the methods of scientific engineers have replaced the crude efforts of the pioneer inventors.¹⁷

This veiled allusion to Langley and the Wrights was prelude to a proposal for "A National Aerodynamical Laboratory." Contrasting the sorry record of American naval aviation with the progress being made in the major European countries, Chambers attributed the American shortcomings to lack of appropriations and the absence of an aeronautical laboratory. He proposed a national laboratory in Washington to perform "experimental verification," i.e. tests, for "manufacturers, clubs, independent investigators, and other interested parties," and "experimental research," i.e., "systematic, thorough, and precise investigation of new ideas, or of old ideas with new applications, with the specific intention of discovering laws and formulas for advancing the progress of aerial navigation." He recommended that the work of the

laboratory be selected and supervised by "a council or board, which in England is called the 'advisory committee'" that "should be representative of other Government departments" and "independent of the director and his administrative staff."

As to the composition of the board, Chambers felt: "The council should not be a large body, but should be composed mostly of specialists of unquestioned ability, men interested in the sane development of aerial navigation in various branches of the Government and in its useful and safe adaptation to commerce and sport."

He wanted to see this laboratory located in Washington, because that city was centrally located; it already harbored similar research at the navy yard and elsewhere; it had the interested government agencies, libraries, and other resources—the Langley laboratory, room for an adequate flying field, and a suitable climate for year-round flying; and it was "a mecca for business people." Eventually, he hoped, "some philanthropic patriot of wealth and scientific interest" would endow the laboratory, as had happened in Europe and as he and many of his fellow enthusiasts had long been expecting would happen here. In the meantime, he estimated that \$200,000 would be enough to start the laboratory—provided, that is, that use could be made of the buildings already available at the Smithsonian Institution. Otherwise, "the cost could be considerably more."

Here, in fifteen tightly worded pages, were the rationale and the blueprint for the National Advisory Committee for Aeronautics. The proposal came from a military officer alive to the military and commercial potential of aviation. He was a true believer in aviation, and he saw scientific research as the key to its development. He looked to Europe and saw there a model of what should be done, and a warning of the hazards of delay. Leading a group of supporters from business, government, and academia, and seasoned by an initial failure, Chambers couched his proposal in the broadest possible terms and was careful to leave to established powers the domains they considered peculiarly theirs. The purpose of the lab, as evidenced by its name, was aerodynamics, a subtle but important change from the aeronautical laboratory of earlier proposals. And there was never any doubt that the laboratory itself was the heart of the proposal. The advisory council was simply a mechanism for ensuring that the work of the lab would be well chosen and properly executed. Establishing it within the Smithsonian Institution would ensure that the small lab had proper protection, would provide access to the Langley facilities lying dormant there, and would lend scientific respectability to an undertaking particularly susceptible to commercialism and amateurism. It would also memorialize and revive the scientific achievements of Langley, and thus rescue the science of flight from "the crude efforts of the pioneer inventors."

Chambers's proposal died aborning, but its principal ideas survived. Tracing what had to be abandoned and what retained will disclose the forces most actively at work in the creation of the NACA, forces that imprinted themselves indelibly on the Committee's history and thereby changed its course.

THE WOODWARD COMMISSION DEBACLE

At the end of his 1912 "Report on Aviation," Chambers recommended that a commission be appointed to report to the president "on the necessity or desirability for the establishment of a national aerodynamical laboratory." Before President Taft acted on that recommendation, he suffered a humiliating defeat in the bitterly contested election of 1912, finishing third, behind Woodrow Wilson and (more painful still) his former benefactor Theodore Roosevelt. Furthermore, the election delivered both houses of Congress to the Democrats and revealed that "the country was now overwhelmingly progressive in temper."¹⁸ The "sinister special interests" popularly viewed as exploiting the federal government through ties to sympathetic Republicans were to be displaced by a dynamic new government committed to a more Democratic ethic. Chambers and other members of the Aero Club of America had only the remaining four months of a lame-duck administration and Congress to achieve their goals before a new set of officials with a new political philosophy would take office. Working under this pressure, they were at once too hasty and too late.

On 16 December 1912, Secretary of the Navy Meyer recommended to Taft the appointment of the commission suggested by Chambers. Three days later (soon enough to suggest a prior agreement) Taft appointed a 19-man National Aerodynamical Laboratory Commission chaired by Robert S. Woodward, president of the Carnegie Institute of Washington. Chambers was one of the seven members representing government: two each from the army and navy, one each from the Smithsonian Institution, the National Bureau of Standards, and the Weather Bureau. Zahm was among the twelve members from private life: four from aeronautical clubs, four from academic posts, and four whose principal qualification seems to have been membership in the Republican party.¹⁹

President Taft could appoint such a commission but, if he wanted public funds to defray its expenses, he needed congressional approval. In 1909, Congress had taken exception to President Roosevelt's use of executive orders to create such presidential satellites as the Uplift Commission of the People of the United States and the Council of Fine Arts, orders which appeared to circumvent Congress and to usurp legislative function. A rider to the 1910 Civil Sundry Act required

congressional sanction before public funds could be expended or government employees could serve on such bodies.²⁰ To meet the requirements of this law, congressmen sympathetic to aviation and the purposes of the Woodward commission introduced legislation in both houses early in January 1913 to approve the commission and provide \$5000 to meet its expenses. The Senate bill passed the day after the House Committee on Naval Affairs reported favorably on the House version. Final passage appeared imminent. The commission held its first meeting five days later.²¹

Agreement was so complete among the members of the commission that the body went about its work with remarkable dispatch. At the first meeting 23 January, a proposal for "the establishment of a national aeronautical laboratory in the District of Columbia for the scientific study of the problems of aeronautics with a view to their practical solution" led quickly to the appointment of a subcommittee to draft legislation. The resulting proposal was forwarded the next day. In most respects it followed up the proposal for a laboratory contained in Chambers' 1912 "Report on Aviation." Apparently in imitation of the Woodward commission itself, the draft called for an advisory committee of 16 members, 6 government and 10 private. Only one feature of the bill was strikingly new: the laboratory was to be "an independent establishment of the government," not an appendage of the Smithsonian Institution or the National Bureau of Standards.²²

The following day, 25 January, the entire Woodward commission met, endorsed the proposal, and appointed one of its members (a former congressman) to draft legislation. The bill he circulated 29 January differed from the earlier version only in that it omitted the provision that the laboratory be independent. That single omission was critical: when a quorum of 10 commission members met 5 February to endorse the draft, seven of them came prepared to change it at the last minute to place the laboratory once more "under the direction of the Board of Regents of the Smithsonian Institution" as Chambers had wanted all along. Opponents cried foul. Naval Constructor David W. Taylor, director of the Bureau of Construction and Repair's model basin at the Washington navy yard, led the opposition. Taylor had been a principal in the navy's thwarting of Chambers's 1912 plan to have Taft establish an aeronautical laboratory in the Smithsonian, and he was not about to have the same proposition slipped past him with this bit of procedural trickery.²³

The ensuing dispute between Chambers and Taylor was more than a mere bureaucratic squabble; they differed over the nature of aeronautical research. Chambers's constant model was Europe, especially the British Advisory Committee for Aeronautics. That body had described its purpose as the scientific study of the problems of flight, a phrase

Chambers adopted almost verbatim for his proposal.²⁴ Such scientific research had been the work of Professor Langley, and its natural home seemed to be the Smithsonian, the one body in Washington (the National Academy of Sciences being currently moribund) most closely associated with science. In fact, Chambers's preference for the term "aerodynamical laboratory" reflected his concern for the aspect of aeronautics most closely associated with Langley and most nearly allied to the traditional sciences of physics and fluid mechanics. Had Langley, and science, not been so discredited by the success of the Wrights, Chambers might have been less intent on honoring them by his choice of words and institutions.

Taylor, on the other hand, viewed aeronautics as an engineering problem more properly the concern of the military services, surely out of the domain of the Smithsonian Institution. As he wrote to Professor William F. Durand, another member of the Woodward commission and a distinguished engineer at Stanford University:

This is a matter primarily and fundamentally of engineering research. It may, or may not, be of sufficient importance to warrant an independent establishment for the purpose of following this branch of engineering research. If it is of sufficient importance there should be an independent establishment. The Smithsonian so far as I am aware, has not to any extent entered the field of engineering research. There are at least three departments interested in this matter who are already in the field of engineering research and must necessarily remain therein and if this branch of engineering research is not of sufficient importance to warrant an independent establishment it should undoubtedly be under the direction of some department which is already engaged in this line rather than appropriate money to set up the Smithsonian in duplication of present governmental activities.²⁵

No one who would inflict such a paragraph on a friend should criticize others for duplication. Still, the point was of considerable importance. Before taking on the job of aeronautical research, the federal government needed to know just what it was and to which disciplines and functions it was allied. Richard Maclaurin, for example, sided with Taylor, but for somewhat different reasons. President of MIT, member of the Woodward commission as a representative of academia, and himself an engineer, Maclaurin felt that the laboratory should be located near an institution of higher education—presumably one like MIT. "The problems of aeronautics," said Maclaurin, "are engineering problems, and a national aeronautical laboratory should be developed under the stimulus of engineers," echoing a contention he had made earlier in the year in the *Aero Club of America Bulletin*.²⁶ While

admitting the Smithsonian to be "an admirable institution," he found it "not well adapted to exercise the particular functions that the Bill assigns to it."

At the 5 February meeting of the Woodward commission, the Smithsonian advocates won approval of the draft bill. Three of the ten members present—Taylor, General James Allen (author of the original language of an "independent establishment"), and Charles D. Walcott, secretary of the Smithsonian Institution—abstained. Walcott's abstention seems to have been mere decorum, for Taylor considered him to be behind the whole scheme, an empire builder for whom Chambers was a mere "catspaw." Others, though, were strongly opposed to the draft bill and intent on acting. Taylor insisted upon and was granted a final meeting at which all the members would be allowed to vote on the language of the report, and file minority reports if necessary. Another member of the commission—Dr. Samuel W. Stratton, director of the National Bureau of Standards and likewise an engineer, who would soon succeed Maclaurin as president of MIT—expressed himself the next day as "very indignant and intending to fight," reportedly because he wanted to see the proposed laboratory set up in his own National Bureau of Standards. Taylor considered Stratton's opposition alone enough to kill the proposal within the commission.²⁷

Realizing that the proposed bill would fail in a vote before the full commission, the friends of the Smithsonian scheme tried two more ploys to have their plan approved. Chambers gave copies of the draft legislation to friendly members of Congress, who introduced it in both houses on 7 February.²⁸ Five days later, Zahm circulated copies of the proposed legislation to members of the Woodward commission for their approval as part of a final report to the president. This version retained the objectionable provision to establish the laboratory under the Smithsonian, but changed the membership of the proposed advisory committee to six government members and only seven private members.²⁹ If the advocates of the Smithsonian scheme thought this alteration would make the rest of the bill palatable either to the majority of the Woodward commission or to Congress, they were soon disappointed. Their actions had served only to make the matter public and to air the "animus" that had developed within the commission.

Maclaurin filed a minority report. Taylor demanded another meeting of the commission. Charges and countercharges of empire-building and personal misconduct spread from the private correspondence of the commissioners into the newspapers. The participants saw in each other's behavior a petty struggling for place. Naval officers reportedly opposed the bill because it had the support of the Weather Bureau, which was trying to take the Hydrographic Office from them, and the Smithsonian Institution, which was trying to take the Naval Observa-



Samuel W. Stratton, director of the National Bureau of Standards and member of the NACA, 1915–1931, showing the stern resolve that he brought to bear in the Woodward commission of 1913. (LaRC)

tory.³⁰ All this, of course, lent more heat than light, and in the wrangling the real issue was largely lost to view. The only exception was a brief notice in the *Army and Navy Register*, reporting that some officers suspected an attempt by the Smithsonian Institution to lay the groundwork for a cabinet-level department of science. Whether Walcott and the friends of the Smithsonian had so grand a plot afoot, or were simply trying to restore the prestige of Langley and the good name of science, the fundamental issue was: what were to be the respective roles of science and engineering in the federal hierarchy, and in which camp was aeronautics to be located?³¹ Because the debate was never carried on in those terms, the issue was never resolved.

The idea of an aeronautical laboratory suffered even more grievously at the hands of Congress, which would not pass even a simple resolution to provide funds for the Woodward commission. When it was introduced on the floor of the House for unanimous consent, the powerful majority leader (James R. Mann of Illinois) objected on the grounds that the president had “violated the law” in appointing the commission in the first place, and that the legislative course of the authorizing resolution so far—i.e., through the friendly Committee on Naval Affairs—would give that committee “practically exclusive jurisdiction of the subject of air navigation in the House.” Another con-

gressman added the ironic objection that the need for an aeronautical laboratory seemed a foregone conclusion; he would vote for a laboratory, but not for a commission to determine the need for one.³² The resolution authorizing the Woodward commission failed.

So did the bill authorizing a laboratory, when it was introduced four days later. As *Aerial Age* summarized the issue: "While Congress almost as a whole admits the need of such a laboratory, there are questions of 'peanut politics' to be settled and various warring factions of the government to be consulted before it finally comes to a vote."³³ The main obstacle in the House seems to have been Majority Leader Mann, reportedly indignant over the manner in which the whole question had been handled—especially Chambers's attempt to locate the laboratory in the Smithsonian against the will of the Woodward commission, an effort he considered "impertinent and impudent" and grounds for court-martial and dismissal from the service. Mann was a close friend of Samuel Stratton, avowed enemy of the bill, and he was "always on the job and able to block any legislation which he [was] strongly opposing."³⁴ Although Chambers and his allies had persuaded the secretaries of the army, the navy, and the Smithsonian Institution to endorse the legislation (perhaps without telling them that the Woodward commission had not officially endorsed it), equally powerful men were contesting it. Stratton had Mann's ear, and Maclaurin was writing from MIT to key senators.³⁵

Considering time to be their enemy and seeing that the 62nd Congress would expire on 4 March before considering their bill, the Chambers forces tried attaching a rider to the Sundry Civil Bill to get some aeronautical research funds for the Smithsonian in the current session. But that plan failed as badly as the bill had; the problem was not time, but lack of support. The Smithsonian advocates had too many enemies and not enough friends in the 62nd Congress. The gap widened in the 63rd. The same bills, reintroduced the following month in the new Congress, died in committee.³⁶

THE SMITHSONIAN TRY

After the failure of the Woodward commission and the Chambers proposals for a laboratory, the leadership of the movement changed. Chambers was transferred to other duties in the navy, and Zahm receded into the background. In their place emerged Charles D. Walcott, the powerful and influential secretary of the Smithsonian Institution who was believed (by Captain Taylor at least) to have been the force behind the movement all along.

Walcott was a remarkable man with a remarkable career already behind him in 1913. Leaving school at age 18 without even the equiva-



Charles D. Walcott, secretary of the Smithsonian Institution (1907-1927) and chairman of the National Advisory Committee for Aeronautics (1919-1927). (NASA History Archives)

lent of a high school diploma, Walcott had followed a natural interest in and talent for paleontology that led him through an assistantship with the state geologist of New York and into the United States Geological Survey, which he joined in 1879. When he left the survey 28 years later to become secretary of the Smithsonian, he had established a worldwide reputation for original research, had published widely, and since 1892 had headed the entire survey, a position given him because of his recognized abilities to get along with people (especially congressmen) and his gift for explaining and justifying scientific research to laymen. These same gifts made him an ideal secretary for the Smithsonian, and from this post he increased the scope of his already catholic activities in behalf of the advancement of science in the United States. He was, for example, instrumental in founding the National Park Service and the Carnegie Institute, in the rejuvenation of the National Academy of Sciences, and less successfully in numerous attempts over the years to arouse interest in a department of science within the federal government.³⁷ His association in the minds of many with the latter movement made his activities in the field of aeronautics somewhat suspect, but his unparalleled political gifts more than overcame that handicap. In sum, he was just the man to guide the aeronautical-

laboratory movement through the labyrinth of bureaucratic intrigue and congressional politics.

Walcott began his campaign early in 1913 by unilaterally reopening the Langley Aerodynamical Laboratory within the Smithsonian Institution. For this he needed only the approval of the Smithsonian board of regents, which was quickly forthcoming.³⁸ One of the immediate purposes of this move was to honor Langley and his cherished research in "aerodromics," but there was more to it than that. Walcott and the Smithsonian had grandiose plans afoot and the reopening of the laboratory was only the first step. Walcott was so anxious to proceed auspiciously and correctly that he even got President Wilson to endorse the scheme beforehand.³⁹

The laboratory activated by Walcott looked remarkably like the one proposed by Chambers. It was to be run by a director, who would be a member of an advisory committee composed of representatives of government agencies concerned with aviation and private interests "acquainted with the needs of aeronautics," the total membership not to exceed 14. The advisory committee would be assisted by subcommittees whose chairmen would be drawn from the main committee, though the other members need not be. These subcommittees would supervise and direct the work of the laboratory in conducting and reporting on aeronautical research.

In two respects this laboratory differed from the one envisioned by Chambers. First, it was intended to be merely a nucleus to which would be added "other laboratories and other essential agencies" leading at last to a "Bureau of Aerodromics."⁴⁰ Walcott was empowered by the Smithsonian's board of regents to use \$10,000 of the institution's Hodgkins Fund to reopen the laboratory, to use \$5000 a year for five years thereafter to operate it, and to request from Congress \$50,000 "for the continuation of aerodromical [aeronautical] investigations under the direction of the Smithsonian Institution."

The most marked difference, however, between Walcott's scheme and the one proposed by Chambers the previous year was a heightened concern for the Progressive ethic recently affirmed by election of Wilson and a Democratic Congress. While the laboratory would conduct such research "as may serve to increase the safety and effectiveness of aerial locomotion for the purposes of commerce, national defense, and the welfare of man," it was in no way to "promote patented devices, furnish capital to inventors, or manufacture commercially, or give regular courses of instruction for aeronautical pilots or engineers." It was to "exercise its function for the military and civil departments of the Government of the United States, and also for any individual, firm, association, or corporation within the United States provided, however, that such department, individual, firm, association,

or corporation shall defray the cost of all material used and of all services of persons employed in the exercise of such functions." In sum, the laboratory would use and complement the resources of the federal government for the advancement of aviation in general, scrupulously avoiding the kind of favoritism to special interests that had besmirched the record of Taft and his Republican predecessors in the age of the trusts and the robber barons. Finally, the composition of the advisory committee was modified again from the original Chambers proposal: now, half the members would be from government, the other half from either government or private life. Walcott had in mind eventual government funding for this laboratory, and he clearly wanted its organization and purpose described in terms of the national interest to free it from the taint of Aero Club commercialism and partiality.

The advisory committee met three times, in May, June, and December. It consisted of 11 men: seven government representatives, and four private.⁴¹ Virtually all of its work was divided among 16 subcommittees, ranging from Publication and Dissemination of Aeronautical Information to Applied Aerodynamics. All the subcommittees but one were chaired by government members of the advisory committee; the ratio of government to private membership of the subcommittees was about two to one, roughly the same as that of the advisory committee itself.⁴²

The group's first year was devoted almost entirely to surveying the state of the art. Subcommittees in each branch of aeronautics determined what work needed to be done and how it might best be accomplished. Most notably, the full committee sent its recorder, Albert F. Zahm, on a survey of Europe's aeronautical laboratories. Zahm traveled to all the important research establishments in the company of Jerome C. Hunsaker, a young naval officer who went along to prepare himself for teaching a new course in aeronautics at MIT that fall. The two men were greatly impressed with what they saw, and on their return communicated their enthusiasm in reports that reinforced the sentiment within the American aeronautical community favoring a national laboratory.⁴³

But, before this impact could be felt, a new crisis arose. In December 1913, after the third meeting of the advisory committee, Walcott discovered that the same law that had made the Woodward commission technically illegal applied also to the Smithsonian advisory committee. Government members were not allowed to sit on any such committee without congressional approval. Walcott brought this to the attention of the Smithsonian board of regents at their December meeting and was directed by them to take the matter before Congress. Specifically, he was empowered to request of Congress \$50,000 to support the work of the laboratory.⁴⁴ Should such a request be granted, it would have



Jerome C. Hunsaker was to be a member of the NACA from 1922 to 1923 and again from 1938 until the Committee's demise in 1958; he would chair the Main Committee from 1941 to 1956. (LaRC)

the dual effect of supplementing the limited moneys the Smithsonian was able to supply through the Hodgkins Fund and of giving tacit congressional approval to the committee, thereby resolving the legal technicality that had brought down the Woodward commission.

Walcott took his proposal before Congress in March 1914, arguing before the House Committee on Appropriations that funding the Aerodynamical Laboratory would be in the best interests of the government. It would, he said, help foster commercial aviation in the United States, bringing the U.S. abreast of the Europeans and encouraging an important new means of transportation and communication. At least one of the members of the committee, however, saw in this the nose of the camel: Would not Walcott's laboratory grow into a great new bureau with ever-increasing budgets and scores of new government buildings to fill up the District of Columbia?⁴⁵ Since the original resolution of the Smithsonian board of regents empowering Walcott to establish the advisory committee had specifically directed the secretary to look to the addition of other agencies and the grouping of them into a "Bureau organization," he could hardly deny the congressman's charge. The current enthusiasm in Washington was for efficiency and streamlining; the prospect of another new agency, perhaps even a "Bureau of Aerodromics," worried some on Capitol Hill more than did

the prospect of a lagging and uncoordinated industry. The proposal never got out of committee. In May, Walcott wrote the comptroller general for confirmation of his belief that the advisory committee was illegal. It was confirmed.⁴⁶ So Walcott disbanded the Committee and once again deactivated the Langley Laboratory. Another attempt to establish a national aeronautical research establishment had died aborning.

CAESARIAN SECTION BY DR. WALCOTT

Walcott took up the cause again the following December. In the intervening months, Europe had embarked upon a war that threatened to draw in the United States. President Wilson was determined to remain neutral, but advocates of preparedness insisted that the United States must be ready for war should it come. Although the election of 1914 had endorsed Wilson's neutrality and marked something of a turning away, at least temporarily, from the Progressive enthusiasms that had elected Wilson two years before, still there was in the air in late 1914 enough residual Progressivism and active preparedness to make the aeronautical laboratory idea more appealing to Congress than ever.

If Walcott was to succeed with his project now, he had to avoid the pitfalls fatal to earlier attempts. Bureaucratic objections about duplication of work and infringement of jurisdiction must be answered. The appearance of commercialism or control by private interests, so easy to associate with early Aero Club sponsorship, must be avoided. Congress must not be offended by any show of circumventing congressional intent by unilateral appointment of commissions or committees. A friendly forum must be found on the Hill for introducing the legislation and getting a committee endorsement before bringing it to the floor. Finally, any suspicion entertained by the appropriations committee the previous year that sponsoring a laboratory would inevitably lead to a large new establishment must be dispelled.

The sorry record of past attempts to establish a national aeronautical laboratory may have led Walcott to conclude that his best procedure in 1914 was to propose formation of a modest committee, perhaps on the European model. It should be independent of the Smithsonian Institution, to allay the fear of the military services that empire-building was afoot. Members drawn from private life should not outnumber government members. The armed services should endorse the proposal in draft, and it should then be submitted through friendly congressmen to equally friendly congressional committees, perhaps those on military or naval affairs, where the preparedness fever was at its height.

The more fundamental issue—whether aeronautics was properly in the realm of science or of engineering—would be skirted altogether. In the year since the second closing of the Langley laboratory, Walcott had done everything in his power to restore the reputation of Langley at the expense of the Wright brothers because he was unaware that their use of and respect for science were as great as Langley's. Glenn Curtiss and other Langley supporters had taken the 1903 aerodrome from the Smithsonian to Hammondsport, New York, where they repaired it, altered it, and flew it, proving to their own satisfaction (and for their own purposes) that Langley, as the Smithsonian's *Annual Report* for 1914 put it, "had succeeded in building the first aeroplane capable of sustained free flight with a man."⁴⁷ This episode would return to haunt Walcott and his successor, but in 1914 it left the secretary secure in his convictions and free to ignore the comparative ranking of science and engineering in the laboratory he was planning.

Whether or not Walcott consciously considered all the factors at work, his subsequent actions avoided most of the mistakes of the past. In December 1914 he went once again to his board of regents with the idea of establishing a laboratory. The regents empowered him to form a committee with four of their members, including one representative and one senator, to work out a proposal to present to Congress. By the time this committee met in the Capitol on 30 January 1915, all the groundwork had been laid. Walcott had drafted a memorandum outlining the history of the Smithsonian Advisory Committee for Aeronautics, the advances being made in Europe, and the advantages the government might expect from similar activities in the U.S., especially a rationalization and coordination of the aeronautical research already being conducted by the federal government within the armed services and the National Bureau of Standards. This memorandum, which served as the basis of the proposal to Congress, left the laboratory in the background and put the primary focus on the advisory committee. The stated aim was prevention of duplication. The model was the British Advisory Committee for Aeronautics, the European establishment that had most impressed Zahm and Hunsaker in the summer of 1913. The proposal was modest. There was no mention of a "Bureau organization."⁴⁸

When Walcott presented this proposal to the regents' committee on 30 January 1915, it was quickly and wholeheartedly endorsed. In fact, so greased were the rails that the Senate joint resolution had already been introduced by Benjamin R. Tillman, chairman of the Committee on Naval Affairs. The day after Walcott's presentation, one of the members of the regents' committee, Congressman Ernest W. Roberts, introduced an identical resolution in the House. A slightly modified copy of Walcott's memorandum accompanied each bill.⁴⁹

The two resolutions were remarkable for their modesty and simplicity.⁵⁰ Hardly anything in them was controversial. Five short paragraphs gave the rationale of the legislation: The United States, where aviation began, was lagging in aeronautical development behind European nations that were pursuing aeronautical research under government auspices, while aeronautical research in the United States remained scattered, uncoordinated, and wasteful for lack of a central body to provide continuity and prevent duplication. The recommended advisory committee was to consist of 14 members: two each from the War and Navy Departments; one each from the Weather Bureau, the Bureau of Standards, and the Smithsonian Institution; and "not more than seven additional persons who shall be acquainted with the needs of aeronautical science, either civil or military, or skilled in aeronautical engineering or its allied science." The purpose of the committee was "to supervise and direct the scientific study of the problems of flight with a view to their practical solution, and to determine the problems which should be experimentally attacked and to discuss their solution and their application to practical questions." The first half of this formulation was lifted verbatim from the British Advisory Committee for Aeronautics; the second half was a paraphrase of what the British had outlined for themselves. The British had required that their committee "research and experiment into these subjects in a properly equipped laboratory, with a trained staff."⁵¹ That sounded too much like the "Bureau organization" that had raised objections the previous year; the only reference to a laboratory in the 1915 resolution was the proviso that "in the event of a laboratory or laboratories either in whole or in part being placed under the direction of the committee, the committee may direct and conduct research and experiment in aeronautics in such laboratory or laboratories." As if to emphasize the modest role envisioned for this committee, and to eliminate any fears of its being the foundation of a new empire in Washington, the resolution asked for funding of "\$5000 a year, or so much thereof as may be necessary, for five years." Gone were the \$200,000 and the \$100,000 figures bandied about the Smithsonian in earlier years; gone even was the \$50,000 Walcott had requested in 1914. This was not a proposal for a national aeronautical laboratory but a modest arrangement for supervising and coordinating the conduct of aeronautical research already being carried out at existing institutions.

There is little evidence of opposition to this seemingly innocuous piece of legislation, at least not within the friendly naval affairs committee to which it was referred. The real problem was time. Would there be enough time to pass the bill before the 63rd Congress expired on 4 March? The major effort was concentrated on the House, where earlier

attempts to pass such legislation had been stalled. Two steps were required.

First, approval had to be obtained from the navy. This was forthcoming on 12 February, when Acting Secretary Franklin D. Roosevelt wrote to the chairman of the House Committee on Naval Affairs that he "heartily [endorsed] the principle" on which the legislation was based, though he had two caveats.⁵² First, he asked for deletion of a section of the resolution lamenting the dearth of aeronautical research carried on by the government, for he believed the navy had "done a great deal to develop the art and the science of aeronautics." "However," he continued, "we will be only too pleased to have an advisory committee that will bring about the cooperation of the private activities," an interpretation of the committee's role considerably less grandiose than Walcott and other enthusiasts seem to have had in mind. Roosevelt went on to suggest reduction of the total committee membership to ten, with only three unspecified members joining the seven government representatives identified in the original draft. Said Roosevelt:

The departments of the Government most interested in the development of aeronautics will be the ones that will be coordinated by the advice of this committee, individually carry out the work required, and be responsible for the expenditures of money appropriated by Congress. Therefore, the representatives of the Government should always have the controlling interest in the activities of this proposed committee. The interests of private parties must be more or less commercial and influenced by such considerations. We should guard against even any suspicion that the work of this committee is thus influenced.

Besides restating his concept of the modest role the advisory committee was to play, Roosevelt's qualified endorsement was also good Progressive doctrine. It clearly demanded that the committee place the interests of the government foremost and that its primary function be coordination (i.e., improving efficiency through elimination of duplication and waste).

The second hurdle the joint resolution had to face in the House was Walcott's testifying before the Naval Affairs Committee. He appeared on 19 February, just two weeks before the termination of the 63rd Congress and just one week after Roosevelt's letter was sent to the committee.⁵³ The letter was one of the topics Walcott was asked to address, and he and Congressman Roberts, sponsor of the House resolution and one of the Smithsonian regents, quickly dispensed with the membership issue in what now looks like a prearranged compromise. Walcott said he agreed with the Navy Department that the com-

mittee "should be controlled by the people in connection with the Government who are interested so as to have the Government actually in control of the committee," and that he was not particularly set on having the seven at-large members proposed in the original draft. When Roberts suggested that they compromise at five members from private life to serve with the seven government members, Walcott quickly agreed. All else in Walcott's appearance before the committee was harmony and cordiality. The committee made a few minor changes in wording and sent the draft legislation to the full House the same day.⁵⁴

By that time, however, chances of passage before the termination of the Congress appeared slight. The crush of business was simply too great. Once more, there was little opposition to the bill, but many doubted that it was important enough to win space on the crowded calendar.⁵⁵ So Walcott used a tactic he had learned in the Geological Survey in the 1880s, "a period when legislation normally got through only by stealthily clinging to appropriation bills";⁵⁶ he suggested adding the advisory-committee resolution to the naval appropriations bill, a piece of legislation assured of passage, what with the war in Europe and the bipartisan support then abounding for a strong navy. Chambers had tried this expedient in 1913 and Walcott himself had attempted it in 1914; the difference now was that the Naval Affairs Committees of the two houses had already seen the advisory-committee legislation and were generally in favor of it. They were the two bodies with the opportunity—and the power—to amend the naval appropriations bill and see the amendment through to passage. That is just what they did. The naval appropriations bill, containing the joint resolution on an advisory committee for aeronautics, passed both House and Senate on 3 March 1915. President Wilson signed it into law the same day, thus formally creating the Advisory Committee for Aeronautics, as it was called in the legislation, on the last day of the 63rd Congress.⁵⁷

What, in retrospect, can be said about congressional intent? Not much, except that it differed from the intent of the enthusiasts who had been promoting the legislation for more than four years. Those men wanted to establish an aeronautical research capability in the United States to rival those in Europe and restore the birthplace of modern aviation to a preeminent position. They clearly wanted to create a government laboratory. Most of them wanted to see it established in the name of and on the site of the old Langley laboratory at the Smithsonian Institution, fitting tribute to a man they felt had played a critical role in the advance of American aviation. Others of their number, while willing to involve the United States more actively in aeronautical research, would have preferred to expand existing laboratories like those at the Washington Navy Yard or the Bureau of Stand-

ards. They, like the other enthusiasts, considered it essential to have aeronautical research funded by the government and conducted in government laboratories.

Nothing in the history of the 1915 legislation suggests that a majority of congressmen shared this view. What Congress approved was a five-year lease on life for a small advisory and coordinating body, whose purpose was modeled on that of the British Advisory Committee for Aeronautics and whose goal seems to have been that of keeping up with the Europeans. No more than a handful of congressmen, most of them in the two committees on naval affairs, really knew much about the purpose or intent of the amendment to the Naval Appropriations Act. The wording was vague and general, silent on where the advisory committee might go and what it might do. The section about a laboratory seemed an afterthought, and no funds were provided for its operation.

The factors responsible for passage of the legislation were the persistent and enthusiastic sponsorship of a small group of true believers in aviation, the backing of scientists and engineers associated with aeronautics but uncertain how to divide the field between themselves, the good offices of the Smithsonian Institution (which wanted in part, at least, to memorialize the work of Langley), the skillful political maneuvering of Secretary Walcott, the assistance of a few well-placed congressmen, the war in Europe that aroused concern for American preparedness, the Progressive enthusiasm for efficiency and distrust of special interests, and the modest scope and general language of the legislation.

The NACA's organic legislation was not a mandate but an opportunity.

2

War Business: A Laboratory and Licensing; Committees and Engines, 1915-1918

If the men responsible for creating the NACA had a goal when they set out, the Committee's organic legislation failed to make clear just what that goal was or how they might achieve it. The legislation, in fact, contributed to the confusion surrounding American aviation and added yet another agency to the number of government and private institutions struggling to penetrate the chaos. More than a year after the NACA was created, Charles Walcott could still lament "that things are very uncertain about aeronautics . . . ; in fact, that we are almost ignorant of what aviation means."¹

WHAT TO DO

This uncertainty and lack of direction was evident when the NACA met for the first time 23 April 1915 in the office of the secretary of war. Brig. Gen. George P. Scriven, chief signal officer of the army and ex officio head of army aviation, was elected temporary chairman, apparently because the meeting place was an army office and Walcott happened to be absent. Also, Scriven had presented to the Committee* a long letter outlining a proposed system of organization and suggesting that the Committee use its influence to support requests by the military services for increased aviation budgets. As if to balance the services within the NACA, Naval Constructor Holden C. Richardson was elected secretary. With these officers installed, the Committee took its first official action: adding the word *National* to its name, filling out the acronym NACA by which it was thereafter known and distinguish-

* The proliferation of committees and subcommittees within the NACA, itself a committee, creates some problems of terminology. The capitalized term "Committee" will be used synonymously with the NACA as an agency throughout this study, and "committee" will refer to whatever committee is being discussed. The "Main Committee" (i.e., the NACA) and "Executive Committee" will be so identified where necessary.



Brig. Gen. George P. Scriven, chief signal officer of the army and first chairman of the NACA. (LaRC)

ing itself from the British Advisory Committee for Aeronautics after which it was modeled and named.²

The first substantive business was to approve a set of operating rules, which had been called for in the organic legislation, drafted by Walcott, and circulated in his absence. The Committee readily agreed to meet twice a year, in October and April, and at such other special meetings as the chairman might call. The members also agreed that a seven-man Executive Committee elected by and from the membership of the Main Committee "shall control the administration of the affairs of the Committee, and shall have general supervision of all arrangements for research, and other matters undertaken or promoted by the Advisory Committee," acting, of course, "in accordance with the general instructions of the Advisory Committee." As Walcott put it some years later, the Executive Committee was to be "the working organization."³

All this was structural; nothing functional was accomplished at this first meeting. Rather, the NACA followed the path it would take throughout its history when faced with a problem: it formed a committee. It elected an Executive Committee, instructing the members "to

consider a program of investigation and procedure which shall be intended to carry into practical effect the purposes of the Act creating the Advisory Committee and to report the same with recommendations." The Executive Committee met the same afternoon, chose Walcott chairman in absentia, and adjourned until he could be present.⁴



The National Advisory Committee for Aeronautics had its first meeting in the office of the secretary of war, 23 April 1915. Seated, left to right: Professor William F. Durand, Stanford University; Dr. S.W. Stratton, director, National Bureau of Standards; Brig. Gen. George P. Scriven, chief signal officer, War Department; Dr. Charles P. Marvin, chief, United States Weather Bureau; Professor Michael I. Pupin, Columbia University. Standing: Naval Constructor Holden C. Richardson; Professor John F. Hayford, Northwestern University; Captain Mark L. Bristol, director of naval aeronautics; Lt. Col. Samuel Reber, Army Signal Corps, in charge of aviation section. Also present but not in the picture were Professor Joseph S. Ames, Johns Hopkins University, and the Honorable Byron R. Newton, assistant secretary of the Treasury. Absent was Charles D. Walcott, secretary of the Smithsonian Institution. (LaRC)

Even before Walcott chaired his first Executive Committee meeting, he began to make his presence felt. The Main Committee had deleted from the draft of rules and regulations sent to President Wilson the original suggestion by Walcott that the NACA should appoint subcommittees, chaired by members of the Main Committee but including outsiders as well. Scriven had been opposed to having any subcommittees at all, feeling that they were "apt to lead to confusion and lack of progress." He wanted to see the Main Committee subdivided into an administrative board of government members, a science board of private members, and an executive council of three members

to run the organization day-to-day. It was apparently at his urging that Walcott's provision for subcommittees was dropped from the rules and regulations. Learning of this action, Walcott appealed directly to President Wilson, at whose request the provision was restored.⁵ This alteration, of little immediate significance beyond demonstrating where the real power in the Committee lay, in later years would open the NACA to thousands of men from all walks of American aeronautics who would serve on NACA technical committees. Probably no provision in the original rules and regulations would be more important than this one.

When Walcott finally did take the chair of the Executive Committee, his personal influence was usually less pronounced. The Committee devoted most of the first year's budget to subsidizing research at private institutions, the reports of which came to be published as addenda to the Committee's annual report to Congress. The Committee sought headquarters more suitable than the temporary office provided by the army, beginning a long series of moves into a variety of public and private buildings around Washington, but never far from the army or the navy. At the Committee's direction, the secretary conducted a survey of aeronautical activity in the United States, confirming what was already suspected: there was precious little activity, and it was in a sorry state compared to the progress being made in Europe.⁶

The aeronautical survey entailed correspondence with 112 universities, 22 aero clubs, 10 manufacturers, and 8 government departments, a mailing that prompted the hiring of the first employee of the NACA: a clerk. John F. Victory—already secretary to Holden C. Richardson, officer in charge of the navy's aeronautical laboratory and now secretary of the NACA—was a natural choice for the new post when it appeared. Skilled at shorthand and typing and familiar with the operations of government agencies, Victory had galloping ambition, an enormous appetite for work, a need to succeed (to contribute to the support of his orphaned younger sisters), and a punctiliousness equal to the demands of the bureaucratic career on which he was embarking. Like the Committee he was joining, he was young and lean and looking for the main chance. He and the Committee grew together, mirrors of each other and inseparable from each other's history.⁷

The Committee's great work of 1915 was the promotion of a laboratory. Beginning with the Aero Club scheme of 1911, and through all its reincarnations in the locality of the Smithsonian Institution, the idea of a research laboratory had been at the heart of the enthusiasm for a national aeronautical research establishment. Neither the vague wording nor the lack of funding for such a laboratory in the NACA organic legislation was going to deter the true believers on the Com-

mittee from achieving the goal that had always been foremost in their minds. Within six months of the Committee's creation, while the method and direction of the Committee's activities were still being debated, the issue of a laboratory was officially raised.

Curiously, it seems to have been interservice rivalry that first brought the issue into the open. In September 1915, Secretary of the Navy Josephus Daniels had asked his newly appointed Naval Consulting Board for advice on setting up "an experimental and research laboratory," which he had been told was "now considered an essential part of every great manufacturing establishment." General Scriven cited this letter in recommending to the NACA in October that the Committee "make an urgent appeal for money for the purpose of establishing an aerodynamical laboratory."⁸ It is not clear whether he was simply seconding the proposal of Daniels or was trying to keep the navy from establishing a monopoly of government-sponsored aeronautical research. Certain aspects of subsequent jockeying over a laboratory site suggest the latter; whatever the motive, Scriven's letter brought the issue out of the shadows.

Within two weeks the question came before a special meeting of the NACA, where a budget request of \$85,000 for fiscal 1917 was discussed and approved. It included \$53,580 for a laboratory, close to the figure of \$50,000 proposed by Scriven in April. There was some talk of hiring a director for the laboratory, but the budget contained no funds for such a salary. At this stage the Committee requested only two more clerks, two technical assistants, two draftsmen, two laborers, and three mechanics. This proposal was forwarded to Secretary of the Navy Daniels for inclusion in the navy's budget, of which the NACA's \$5000-per-year allotment was still a part.⁹

Daniels would have none of it. As he explained to President Wilson in a letter the following month:

The Advisory Committee has sent over estimates for next year to the amount of \$85,000.00, and requested me to include them this year in the Navy Bill. The increase in our estimates is so large that I hesitate to include them because this Advisory Committee was effected for the development of aviation generally, and not particularly for the Navy. It seems to me they are asking for a very large sum, and that in-as-much as I am asking money for the Naval Consulting Board I ought not to ask for this as well in the Naval Bill. They maintain that this is the only way their appropriation can be obtained. Undoubtedly this Advisory Board can do important work, but it seems to me that *when they ask for buildings and equipment they are getting outside of their position as advisors merely, and are beginning a new establishment.*¹⁰ [Italics added.]

“ . . . Beginning a new establishment” had been the very objection raised when Walcott tried to get \$50,000 in 1914 to fund the Langley laboratory. Whether Daniels was looking to his own interests here, reserving aeronautical research to the navy, or merely concerned about an increase that might endanger his already substantial budget request, he was surely voicing a reservation not new in Washington. Wilson replied that he was in complete agreement. He said: “I think the committee would make a great mistake in extending its expenses as proposed and might imperil the success of the whole plan of advice.”¹¹

This was a job for Walcott. When the proposal came back from Daniels rejected, Walcott was appointed with Stratton, the influential head of the National Bureau of Standards, “to take the necessary actions.” By the time the Executive Committee met again, Walcott was able to report that he had “had interviews” with the secretary of the navy and the president, testified before the same House Committee on Naval Affairs that had approved the NACA legislation the previous year, and submitted detailed estimates of the Committee’s proposed expenditures for fiscal year 1917. Walcott’s papers contain no record of any meeting at all with President Wilson during this period, nor do they reveal the substance of the conversation Walcott and Stratton had with Secretary Daniels when they called on him on 17 February. The result of these activities, however, was unmistakable. The full amount of \$85,000 was appropriated by Congress on 29 August 1916 and quickly signed into law by President Wilson. Within two months the masterful Walcott was chairing a new subcommittee to select a site for the laboratory.¹²

The clarity of vision exhibited by the Committee in pursuit of a laboratory contrasted sharply with the lack of purpose and direction that marked its other activities in 1915 and 1916. Like the Smithsonian advisory committee before it, the NACA in 1916 took to covering every problem with a subcommittee, so that the list of subcommittees constitutes at once a catalog of the perceived problems in aeronautics and a guide to the NACA’s territory. In the 1916 *Annual Report*, for example, the list of ten subcommittees corresponds readily to the “General Problems” outlined by the Committee on the very next page. Some of these subcommittees, like Motive Power, were to see long and important service; others, like Radiator Design, proved unnecessary and shortlived. Three of the subcommittees had only two members; the rest had no more than six, at least three of whom were members of the Main Committee.¹³

No doubt the NACA was using this mechanism to find its way in uncharted waters, and some of the silliness that went on in those early days reveals just how little was known about aeronautics at the time, and how many basic decisions and discoveries had to be made before

the Committee could shape a rational course.¹⁴ For instance, the subcommittees on Standardization and Investigation of Materials and Nomenclature for Aeronautics were both at a loss to define a right-hand engine. The NACA sought the counsel of the Society of Automotive Engineers, but even with that assistance it took 17 years and 6 technical reports to finally settle on a definition. No agreement could be reached on whether to use the term *engine* or *motor* in aeronautics, until General Squier observed that engines could be shipped at a lower freight rate than motors; engines it became.¹⁵ A two-man committee was appointed to determine what kind of paper the annual report should be printed on. As chairman of the subcommittee on Governmental Relations, Walcott investigated whether a hangar should be constructed on the Mall below the Capitol to accommodate transient aviators. The Superintendent of Public Buildings and Grounds did not think highly of that idea, suggesting instead that the military services might be able to provide a landing field and hangar. So Walcott added a navy and an army representative to his subcommittee, and continued his inquiry.¹⁶

Meanwhile, however, some important work was also being accomplished. The survey of aeronautical activities, the hiring of Victory, and the funding of the laboratory are clear examples. There were others as well. John H. DeKlyn, an engineer with the Curtiss Aeroplane & Motor Corporation, was hired as a draftsman, the first technical employee of the NACA. The Office of Aeronautical Intelligence was formed to serve as the Committee's clearinghouse of aeronautical information, published and unpublished, from all over the world. As early as 1916, the Main Committee met with a representative of the Post Office Department and thereafter enthusiastically supported government subsidy and encouragement of airmail service. In another landmark action the Committee laid down a publication policy: All reports of the NACA would be published as addenda to the annual report, and there would be no prior publication. Work done or funded by the NACA would appear under the NACA banner before being published or copied elsewhere.¹⁷

Until its laboratory was constructed, the Committee continued to rely on contracts for aeronautical research. Most of the contracts were with academic institutions; by far the largest was with William F. Durand of Stanford, for experimentation with propellers. As Durand was a member of the Main Committee, contracts with him would today be called a clear conflict of interest. He participated actively in the process that selected him for the job, and the contracts were let to him personally, not just to his institution. Yet the Committee members seem to have harbored no notion of a conflict at the time, although they were keenly aware of the need to keep business representatives off the Committee lest they influence the NACA's work to their own

benefit and win for themselves what the Progressives would call "special privileges." Perhaps the Committee members simply felt that since Durand was the best man for the job—he probably was—there was no reason not to contract with him. That he happened also to be a member of the Committee was simply a natural consequence of his standing in the field. After all, the NACA wanted the best members they could get and the best contractors as well; small wonder if they turned out to be the same person. If the members thought this way about Durand, they were indulging the rationalization that would one day see representatives of business and industry win places at the NACA conference table even while their companies were seeking use of NACA facilities and performing contractual work for the federal government.¹⁸

Important as these early steps were, none was to have a greater impact on American aviation in World War I than the work the NACA did with engines. Engines drew the NACA into its first major association with industry, and that association put the NACA in a position to resolve the great patent dispute of 1916 and 1917.

ENGINES AND INDUSTRY

Industry representatives may have been excluded from NACA membership, but the NACA was not deaf to their needs. On the contrary, the members of the NACA believed to a man that the future of aviation in the United States depended on a healthy and prosperous aircraft-manufacturing industry, and that it was the NACA's duty to help where it could. From the outset, the NACA was an industry booster limited only by its need to be fair and impartial in disbursing favors and assistance. The first clear evidence of this boosterism was its handling of the aircraft-engine problem in 1916.

At the time, automobile manufacturers were the principal builders of aeronautical engines. Without the stimulus of war, which was precipitating such great advances in Europe, American manufacturers were falling increasingly behind the Europeans. As the possibility of U.S. entry into the war grew larger, this situation grew more perilous. Everyone was dissatisfied, but no one could provide the coordination necessary to get manufacturers and government officials together.

Into this breach stepped the NACA. The Committee called a public meeting of the Executive Committee for 8 June 1916, inviting representatives of all the major aeronautical-engine manufacturers and the heads of the military aviation procurement offices. The meeting was an overt attempt to bring together the consumers and the producers, to identify what was holding back engine production in the United States, and perhaps to decide on a remedy. Chairman Walcott stated the

problem bluntly in his opening remarks: "There is not a good American motor made." It was, he said, up to the people in that room of the Smithsonian building to correct the deficiency.¹⁹

Soon enough the need for such a meeting became evident. Howard E. Coffin, the most emphatic and critical industry spokesman, lamented the red tape and confusion in Washington that kept manufacturers from cooperating more fully with the government. An executive of the Hudson Motor Company and a member of the Naval Consulting Board, Coffin had seen the problem from both sides. To him, the solution was clear: rely on engineering instead of bureaucracy; imitate the cooperation that had been achieved between the automobile industry and the Society of Automotive Engineers. "There is no question whatever," he maintained, "but that the whole development of the motor car art, not only in an engineering line, but in a commercial way, is based absolutely on the work of the engineers." The same solution could work for the aviation industry, he said, for "the problems confronting the aircraft industry are wonderfully simple compared with those of the automobile industry." What was wanted, in fact, was a "merging of the gas engine interests in this country in one strong central organization" modeled on the SAE. Such an organization could create the cooperation and coordination within industry necessary to produce the aircraft engines wanted in Washington.²⁰

Another problem, however, was less tractable. Attempts by Coffin to coordinate the work of the producer (the aircraft-engine industry) with that of the consumer (the military aviation branches) had collided with the same 1909 law that had scuttled President Taft's Woodward commission in 1912 and the Smithsonian's Langley Laboratory Advisory Committee in 1914. Efforts to bring together manufacturers and the military services had failed, said Coffin, because some government representatives claimed they were not at liberty to serve on boards and committees without congressional approval. Some of the NACA members tried to tell Coffin that he had "the wrong idea" about the limitations on cooperation, and the exchange got a little heated. When Coffin told Captain Mark L. Bristol that he [Bristol] could not attend a meeting of the Naval Consulting Board if invited, Bristol replied curtly "Oh, yes, I could." Samuel W. Stratton told Coffin that what he was reporting was absurd; Coffin was quick to agree, but insisted that all he was doing was quoting the law. He asked that the exchange be incorporated in the record of the meeting.²¹

Before the conversation could deteriorate further, Chairman Walcott intervened to review the NACA's sad experience with the law that had been thwarting Coffin, and to observe that the NACA enabling legislation was intended in part to get around just that bureaucratic obstacle. "One of the strong arguments for the organization of

this committee," Walcott noted, "was to bring together all the agencies of the Government, and any outside agencies we could get to cooperate. That was the fundamental thought in the organization of the committee."

To this, Coffin replied with all the pent-up frustration of half a year:

That is one of the worst features of dealing with the Government down here. I have been dealing rather intimately now for six months with nearly every Department. It keeps one lying awake nights to determine the channels through which one should handle certain lines of work. Patriotism is all right, but when one has been bandied from one department to another for a while, patriotism ceases to be a very potent influence. This is exactly the condition that most civilian activities are up against when they try to cooperate with the Government. The Naval Consulting Board has gotten around it because we have refused to be insulted, but that situation does exist. Therefore, I think that any act that you gentlemen may take which will definitely and for all time establish the channel of contact between the aeronautical interests of the Government and the civilian aeronautic interests, will be a long step in the right direction.²²

It was becoming increasingly clear why the United States had no satisfactory airplane engine, and why an organization like the NACA could be of real service.

Failure to get an engine, however, had not been due to lack of government interest, as Captain Mark Bristol took pains to make clear. Emerging as the most forceful and insistent government representative at the meeting, something of an official counterpart of Coffin, Bristol repeated over and over again: "We want a motor!" Replying to criticism from another industry representative that "the one cry" common to everyone in the industry who had tried to deal with Washington was "lack of interest and cooperation," Bristol said to the whole group: "I want to get one idea in the minds of you gentlemen—get a motor, no matter what it costs!"²³

The meeting was dissolving into a rite of blame-laying. The industry representatives felt they knew how to cooperate among themselves—witness the automobile industry from which most of them came—but they lacked clear direction from Washington about what was wanted. The government officials professed a willingness to allow handsome profits to any company that would step into the breach and make the engines they needed. These veiled accusations were laced with appropriate niceties characterizing this meeting as a new and promising departure in government-industry relations, but a stiffness and rancor in the room boded ill for any real progress.

To break the ice, Chairman Walcott had sent word to his wife to prepare one of her elegant lunches in the dining room at the Smithsonian. When everyone at the morning session had had his say, Walcott suggested that they resume discussion in the afternoon and recess for luncheon. By the time they returned, the whole tenor of the meeting had changed.²⁴ The byword now was *cooperation*, or (as Coffin came to call it) "a committee of co-operation,"²⁵ a mechanism that would overcome the obstacles to the industry's designing and building the aircraft engine the government wanted. The mechanism was to be the NACA's Committee on Motive Power, a forum where representatives of industry and government could work out the specifications of the engine and the procedures for producing and marketing it.

Summarizing the philosophy behind the agreed plan of action, a consulting engineer to the War Department stated how all such engineering problems should be handled, and how the NACA might act:

We get together the producer, the consumer, and the neutral, if there be any neutrals. Those interests must take up any problem—I don't care what it is, even if it is the establishment of a lock washer as standard. We must have all our fights in committee. What is the result? The combined knowledge of everybody concerned is brought out. All the gobbies are killed—evaporated—thrown overboard, and the result is a boiled down, engineering piece of construction that is *beyond criticism at the moment of its adoption.*²⁶ [Italics added.]

He concluded on an optimistic note reflecting the tone taken on by the entire meeting as it drew to a close: "Cooperation as suggested here today will lead to a motor in a year, as good as can be produced in a short time by any method." That is a fair description of the Liberty engine which in fact resulted from the cooperation established at this meeting.

THE CROSS-LICENSING AGREEMENT

In view of the NACA's successful intervention in the aircraft-engine problem, it was natural for the services to turn to the Committee again when the next dispute with industry occurred. Within the same year a new and more serious problem appeared that threatened to shut down all aircraft manufacture in the United States just as involvement in World War I seemed imminent. The NACA's role in this second issue was its finest hour in the Great War; it was also a source of controversy and unpleasantness that would darken the Committee's history for many years to come.

The problem arose from the same issues that had sparked the Wright-Smithsonian controversy of earlier years, a controversy that

had yet to run its course. In 1903 the Wright brothers had patented a "wing-warping" technique of lateral control in which the wings were actually twisted in opposite directions to create a differential lifting force, the same result achieved later by ailerons.

In a series of patent lawsuits the courts had generally sided with the Wrights, agreeing that this creation of a differential lifting force was a unique contribution to flying. Glenn Curtiss, who became the Wrights' principal antagonist, disagreed, claiming the the aileron used on his many planes was fundamentally different from the Wright brothers' wing-warping technique and independent from it. Unable to win his case in court, Curtiss in 1914 refurbished the Langley aerodrome for the Smithsonian Institution as a means of trying to prove "prior art," i.e., to show that manned heavier-than-air flight had been possible before the introduction of the Wright invention.²⁷

After Wilbur's untimely death in 1912, Orville made few original contributions to aviation; but he continued to defend tenaciously what he considered to be the rights and the precedence he and his brother had earned. Even after selling his interest in the pivotal patent, Orville continued to defend his reputation and that of his brother.

The Wright-Martin Company that bought him out, however, was primarily interested in recovering the more than \$1,000,000 it had paid for the rights to the patent. In December 1916, the company notified other aircraft manufacturers that they would have to pay a royalty of five percent on each aircraft sold, with a minimum annual royalty of \$10,000 per manufacturer. Wright-Martin demanded this royalty on all aircraft, whether they achieved differential lifting by the wing-warping technique of the Wrights or the far more popular ailerons employed by Curtiss. This was the final straw. Lawsuits and threats of suits had already frightened many manufacturers out of the field. The patent royalties that Curtiss was demanding for his numerous inventions—partly, no doubt, in retaliation against the Wright patents—were already making aircraft prices prohibitive. And now came the Wright-Martin demand. Just when the services wanted more airplanes than ever before, when it looked as if the United States would inevitably be drawn into the war in Europe, the nascent American aircraft industry faced an impasse.

The armed services turned once again to the NACA. In January 1917, Acting Secretary of the Navy Franklin D. Roosevelt and Acting Secretary of War W.M. Ingraham asked for the good offices of the Committee in arriving at some equitable solution. The first response considered by the Committee was confiscation. As the minutes of the 11 January meeting of the Executive Committee recorded it:

Professor Pupin suggested that the time is ripe and the concrete case exists in this instance to recommend to Congress a change in the patent law to effect compulsory license.²⁸

That was tough talk, not the type of thing these sober and established men—believers all in the system of free enterprise and minimum government intervention—took lightly. But this was a tough case and the security of the nation seemed to hang in the balance. At the next meeting, on 1 February, the Executive Committee resolved to recommend to the president that the government buy the basic aeronautic patents. But, before sending the letter, the Executive Committee met with representatives of the Wright-Martin Aircraft Corporation. Wright-Martin was willing to sell the patent to the government but, in the course of the meeting, it was also suggested that a cross-licensing agreement might be worked out.²⁹

Everyone's model for such an agreement was the one used in the automobile industry and administered by the National Automobile Chamber of Commerce. It had been worked out after the noted patent attorney, W. Benton Crisp, broke the Selden patent for Henry Ford, a patent as basic for the automobile as the Wright patent for the airplane. Crisp had subsequently represented Howard E. Coffin in the Hudson crankshaft patent case, and Coffin was soon to move from the Naval Consulting Board to the chairmanship of the new Aircraft Production Board. Crisp was now attorney for the Curtiss Burgess company in its suit to break the Wright patent. The ties between the automobile industry's cross-licensing agreement and the patent problems of the aircraft industry were many and complex, and it was inevitable that the model that had worked so well in the earlier case would be introduced into the aircraft dispute.³⁰

First, however, the NACA needed some leverage. Two days after meeting with the Wright-Martin representatives, Walcott wrote to President Wilson recommending an amendment to either the naval or the military appropriations bill to provide \$1,000,000 for the purpose of acquiring "by purchase, condemnation, donation, or otherwise, such basic patent or patents" as the government might need.³¹ Although Walcott's letter mentioned only the Wright patent, the wording of the proposed law left the government free to secure to itself any patents it deemed necessary.

Within little more than a month, the desired legislation was enacted as a rider on the naval appropriations bill, giving the NACA the power it needed to negotiate with industry. On 8 March it appointed a Subcommittee on Patents consisting of two NACA members and one representative each from the army and the navy. On 22 March the entire Executive Committee of the NACA met with the principal air-

craft manufacturers, including the members of the Aircraft Manufacturers Association, a cooperative newly formed to resolve the industry's problems internally. So far it had been signally unsuccessful.³²

Walcott opened the meeting by contrasting the rapid strides in European aircraft production with the sorry history of American manufacture. The industry was not entirely to blame; in the eight years before 1916, for example, the army had ordered only 59 airplanes, receiving only 54, of which only 22 were from the same manufacturer. Now, however, the threat of war had increased the demand. The army had ordered 366 planes in 1916 but had received only 64. Walcott estimated that the military services would need 4000 planes annually by 1919; if that figure was to be reached, the current deadlock in production would have to be broken.³³

Walcott assured the meeting that the NACA viewed legal action against the existing patent only as a last resort. Preferable to the Committee, and no doubt to the manufacturers as well, would be a cross-licensing agreement similar to the one used by the automobile industry. The agreement would require all aircraft manufacturers to join the Aircraft Manufacturers Association, effective 2 March 1917. Each member would pay into the Association \$200 for each airplane manufactured. Of that amount, \$135 would go to Wright-Martin, \$40 to Curtiss, and \$25 to the Association for operating expenses. Payments to Wright-Martin would cease on 22 May 1923 when the Wright patent expired. Payments to Curtiss would cease on 30 October 1933 when the last Curtiss patent expired, or whenever the total royalty paid to Curtiss equalled what had been paid to Wright-Martin. This plan tacitly recognized the Wright and Curtiss patent claims as being equally fundamental and valuable.³⁴

On 24 March, Walcott reported these conclusions to the secretary of war, admitting the NACA's inability to calculate how much money the Wright-Martin and the Curtiss Burgess companies might realize from the agreement. He suggested that the government might prefer simply to buy the patent rights from each company for \$1,000,000 apiece, a figure that the company representatives presumably had found acceptable in the course of the meeting.³⁵

Before anything could be done, external events intervened. The United States declaration of war against Germany on 7 April 1917 instantly changed the outlook for airplane manufacture. Soon French and British missions were in the United States talking about a tenfold increase in the number of planes to be provided by the U.S. Aircraft in such numbers meant that the royalties accruing under the proposed agreement to the Wright-Martin and Curtiss Burgess companies before their patents expired could reach entirely unanticipated levels. Negotia-

tions within the Aircraft Manufacturers Association over the exact terms of the cross-licensing agreement broke down.³⁶

Once more the NACA had to step into the breach. The Subcommittee on Patents was expanded to include Crisp, the patent lawyer responsible for the automobile industry's cross-licensing agreement. A lawyer representing the Wright-Martin company was added to counter-balance Crisp's ties to Curtiss, and William F. Durand was appointed acting chairman. On 14 June, the Executive Committee of the NACA resolved that the total royalties accruing to the Wright and Curtiss companies under any cross-licensing agreement should not exceed \$2,000,000. Thereafter, the Patents Subcommittee took over to work out the details. In a series of meetings in June and July with representatives of the Aircraft Manufacturers Association, Crisp and the subcommittee were able to produce an agreement that was acceptable, if not entirely pleasing, to all parties.³⁷

On 12 July 1917 the Subcommittee on Patents submitted to the Executive Committee a proposed cross-licensing agreement that differed in some respects from the one prepared by the NACA in March. Besides a ceiling of \$2,000,000 on payments to Wright and Curtiss, the new agreement stipulated that it did not cover engines, that royalties for future inventions would be determined by the Aircraft Manufacturers Association on a case-by-case basis, and that the government could hand over designs of one company to another company for manufacture, provided that the latter paid a royalty of one percent of the purchase price of the aircraft. The settlement also established criteria for membership in the Aircraft Manufacturers Association. As finally enacted, in accordance with the views of all the parties, the agreement came to be administered by an entirely new organization: the Manufacturers Aircraft Association, Incorporated. Critical decisions affecting the industry were to be made by a three-man board of directors, one of whom was Joseph S. Ames—professor of physics at Johns Hopkins University, a charter member of the NACA, its future chairman, and a man of unquestioned integrity and impartiality.³⁸

In effect, the cross-licensing agreement of 1917 established that the American aviation industry would operate without major patents. Small royalties would be paid for certain contributions within the Manufacturers Aircraft Association, but in general the ideas and techniques of aircraft manufacturers were to be shared openly among the members.

Durand reported the accomplishment to the secretary of the navy in language expressing the genial optimism and self-satisfaction felt by the interested parties. "It is expected," concluded Durand, "that this agreement will bring about harmony and co-operation in the industry, and that it will aid materially in the progress of the art and the quantity production of aircraft." Daniels replied, thanking Durand and the

NACA for the "amicable settlement of the perplexing patent situation" and for saving the government in the process the \$1,000,000 that had been appropriated to buy up the patents. Within a week the NACA discharged its Subcommittee on Patents with thanks for a job well done.³⁹ The whole complex mess thrown in the Committee's lap in January could hardly have been resolved more quickly or satisfactorily.

Into that blissful atmosphere of self-congratulation the first cry of *Foul!* burst like a bombshell. The Aeronautical Society of America—successor to the group that had been campaigning for an aeronautical laboratory ever since that fateful banquet of 1911 at which President Taft was supposed to endorse the plan—wired President Wilson on 14 August that it was hard pressed to construe the agreement as anything less than an aircraft trust. The president had no idea what they were talking about. Soon enough the telegram came to Durand for a reply, but his efforts to appease the Aeronautical Society were unavailing. Society President F.W. Barker took little comfort in the precedent of "the vicious Selden patent trust," which he thought had been "deliberately created to 'keep out the small fellows.'" He felt that the aircraft cross-licensing agreement was a similar trust in restraint of trade whose effect would be to sacrifice "the interests of investors" to the profits of the large manufacturers, profits he considered unwarranted by any aeronautical patent granted so far. He was disturbed that the Justice Department had not been consulted on the legality of the agreement, and he told Durand that the society believed the whole matter lay "entirely beyond the purpose of your training, and in fact, even beyond the powers granted by Congress to your organization."⁴⁰

After a fruitless exchange of letters, Durand refused to carry on any further correspondence. Barker refused his invitation to come to Washington to discuss the matter in person, so communications broke down completely. On 4 September, Durand wrote to Walcott that "we are just now having a merry round with the Aeronautical Society of America," but there was little merriment in the outcome. A "virtual hymn of hate" poured from the small but vocal minority opposed to the cross-licensing agreement. It was little abated when in October 1917, at the NACA's request, the Justice Department examined the agreement and pronounced it legal and proper. The opposition was even refueled the following year when the government amended the agreement by halving the royalty paid to Wright and Curtiss, a tacit admission that the original terms had been too generous.⁴¹

Time did nothing to lessen the acrimony of the debate over cross-licensing. Defenders of the agreement claimed its critics were paid by, and in the service of, enemies of the United States. The critics for their part used every possible occasion to roll out the cross-licensing agreement and rehash the old charges of "aircraft trust." These charges

were never substantiated, though even the most ardent defenders of the agreement could not deny that it worked to the advantage of large established companies at the expense of the small private inventor.⁴² Thus in its earliest days the NACA was drawn into a controversy over favoritism and special privilege, the very charges it had tried so hard to dispel both in its membership policies and in its all-encompassing boosterism. The image of being in bed with industry, while never very pronounced in the early years, was lurking in the background ready to come into focus whenever the cross-licensing agreement came up for another public airing.

Reading through the internal papers on the negotiations leading up to the cross-licensing agreement, one sees in the NACA's words and actions signs of real patriotism and sincerity, a zealous concern for the national security, a selfless enthusiasm for the future of aviation, and a genuine desire to serve the public interest. But at times the public interest overlapped the interests of the members of the NACA and those with whom they dealt in a way that was perhaps inevitable but surely unfortunate. However pure their motives, however constrained they might be by necessity and circumstance, however successful their handiwork, the members of the NACA would live out their years amidst whispers and suspicions, under the shadow of the cross-licensing agreement, an agreement they had regarded at the time as their finest achievement.⁴³

BUILDING A FUTURE

The part played by the NACA in the cross-licensing agreement was just a special case of the Committee's general wartime role as an inventions board for the War Department. Unsolicited inventions and suggestions relating to aeronautics were sent from outside sources to the Committee for screening and evaluation. Most proved worthless and were summarily rejected. Some, however, showed promise (or at least possibility) and were referred to the army or the navy for further test and evaluation.⁴⁴

This function of the Committee was essentially advisory, as was most of its work during World War I. When Secretary of the Navy Josephus Daniels asked the Committee to consider how the United States might best develop and produce aircraft for the impending military crisis, the NACA recommended establishment of an Aircraft Production Board as an adjunct to the Council of National Defense. This board, duly established, went on to become the major mechanism for government procurement of aircraft. The NACA also recommended adoption of the metric system and government underwriting of insurance for aviators. To the secretary of agriculture, it recommended

extension of the Weather Bureau's aerological work in support of aviation.⁴⁵

Two members of the NACA were sent to Europe on official missions. William F. Durand, who in 1917 had been elected chairman of the NACA when Walcott declined the nomination, was sent to Paris under joint orders from the secretaries of war and the navy to serve in the Research Information Service, recently created by the National Research Council to funnel technical information from the fighting front to the United States. Durand retained his NACA membership throughout his service in Europe, even though he could not participate actively in routine Committee business for the remainder of the war.⁴⁶

Joseph S. Ames of Johns Hopkins University in nearby Baltimore, who was one of the NACA's more active and promising members, led a scientific mission to Europe in the spring of 1917, also under the auspices of the National Research Council. The commission succeeded in its major goal—the rapid exchange of war-related scientific and technical information between the Allies and the United States—but it had an unfortunate consequence for Ames personally and for the NACA. It established Ames in the minds of some as an expert on the role of the U.S. in World War I and lent disproportionate weight to his pessimistic view of American aircraft manufacture, formed during an inspection tour the following November made in the company of three other NACA members. After that trip, Ames wrote to a friend of an acute “feeling of depression” about the shortage of airplanes, mechanics, and aviation instructors that persisted long after promises to the contrary had been made to him personally. He concluded:

It is very hard to place one's finger on the man or committee responsible for this condition. As far as I could see, the evil is a fundamental one. This country and its officials are possessed with the idea that everything must be labeled 'Made in America,' and the difficulties into which we are now running are those which any man might have foreseen. As a matter of fact, within three days after my return from Europe in June I made this whole matter the subject of my report to the Aircraft Production Committee. No one believed me, and although I had a good solution it was refused.⁴⁷

This letter found its way into the pages of *The Atlantic Monthly*, and from there into an editorial in *The Outlook* revealingly entitled “Is All Well with Our Airplane Programme?” The *Outlook* editorialist used Ames' experience in Europe and his unquestioned “authority” to raise the spectre of “indolence and lassitude” in official circles, of “the paralysis of official red tape hidden under the plea of military secrecy.”⁴⁸

Among those officials who were incensed by Ames's remarks and the use to which they had been put were several members of the NACA. The Committee sent a formal letter to Ames, asking him to substantiate his charges. Ames replied that the comments were personal and not intended for publication; in hindsight, he realized they were ill-advised, if not incorrect. He apologized, agreed to sign a retraction, and offered to resign from the Committee. Although it did not require him to resign, the Executive Committee did resolve that in the future no member should "express comment for publication without having copy of such matter as it is intended to publish submitted and approved before publication."⁴⁹ Thereafter—with one glaring exception—the Committee spoke with one voice or not at all.

Other advisory duties of the NACA during World War I were less controversial as well as less substantial. The Committee contracted for a number of reports, none of which was of particular use in the war. As Alice Quinlan has demonstrated in her paper, "World War I Aeronautical Research," the NACA spent its early years looking out for its own long-term survival and made little effort to be of immediate service.⁵⁰

One reason for the NACA's failure to play a greater role in the war effort was the welter of government agencies with which the Committee had to compete for position. During World War I, more than 5000 agencies were created in Washington, some of which took on roles and missions that the NACA might otherwise have adopted or had forced upon it. The NACA even had to fight absorption by a proposed Department of Aeronautics, an arrangement that would have robbed the Committee of its independence and autonomy and handed over to others the decision about its wartime role.⁵¹

The agency that came closest to duplicating the role of the NACA was the National Research Council.⁵² Created in 1916 by the National Academy of Sciences to provide a means whereby the nation's scientific talent scattered in academic, industrial, and government research establishments could be pooled in the interests of national defense, the NRC soon became the research arm of the Council on National Defense. This development raised the possibility of conflict with the NACA in the field of aeronautical research. To prevent such a conflict, members of the NACA Executive Committee were made the "Aeronautics Committee" of the NRC, a polite fiction that allowed both bodies to act as they pleased without seeming to duplicate each other's work.

In practice, the NRC pursued one course in aeronautical research, the NACA another. The NRC, which aggressively sought out war-related aeronautical research tasks, soon established itself as the agency to which the army turned. In fact, so successful was the NRC in making this field its own during the months leading up to American participation in World War I that, upon the declaration of war, Army Chief

Signal Officer Squier turned for aeronautical research to the NRC instead of to the NACA even though (or perhaps because) Squier was himself a member of the NACA. By the end of the war, the NRC had come almost entirely under military control; instead of becoming the nucleus of a permanent research organization within the Academy of Sciences as its early sponsors had hoped, it became (at least in the field of aeronautics) the nucleus of a military research structure that would come into its own between the world wars.

Not so the NACA, which looked to its future throughout the war. While the NRC was devoting most of its effort to war-related projects, the NACA was using more than half its total budget for the years 1915-1919 in construction of a laboratory at Langley Field, a laboratory that did not begin operating until after the end of the war. Creation of a national aeronautical laboratory had been the dream and the motive of the enthusiasts who created the NACA in the first place, and not even World War I was going to stand in the way of realizing that dream. The Committee spent only 11 percent of its wartime funds on reports and only 12 percent on subcommittee work. Almost all the latter expenditure went to the Subcommittee on Power Plants, which in turn contracted its work out to the National Bureau of Standards. Of the money spent on reports before mid-1918, half went into the propeller studies being made by Committee member William F. Durand and an aeronautical bibliography; more than half the reports issued under the NACA heading were volunteered from outside sources. As Quinlan has concluded, "the Advisory Committee for Aeronautics made virtually no technical contribution to the war effort."⁵³

Although this conclusion is based on evidence appearing in the Committee's annual reports for the war years, it hardly springs from the pages. In fact a superficial reading of those reports leaves exactly the opposite impression. The emphasis throughout the reports is on "the manifold miscellaneous activities resulting from the existing state of war," everything from defining and standardizing technical terms to continual mediation of disputes between industry and the military services. But the Committee never really tried to conceal its principal interest. Its *Annual Report* for 1917 concluded that "the preceding years of the committee's activities must . . . be viewed in some degree as preparatory for the more effective service which the committee hopes to render through its laboratory facilities at Langley Field and through the enlarged technical and scientific staff contemplated in connection therewith."⁵⁴

This is not to say that everything except the laboratory was transient or unimportant. Some significant institutional steps were taken as well, steps that were to mold the Committee and its activities in future years. The NACA twice amended its rules and regulations: once in

1917 to extend membership on the Executive Committee to any Committee member resident in or near Washington and giving his primary attention to the business of the Committee, and again in 1918 to make John F. Victory assistant secretary to both the Main Committee and the Executive Committee.⁵⁵ Establishment of the Office of Aeronautical Intelligence as a war expedient proved to be the first step toward making the NACA the central clearinghouse for aeronautical information in the United States.⁵⁶ The Committee hired the first of its technical assistants, and though none of the wartime hires stayed with the Committee very long they played an important part in setting the NACA's course in the formative postwar years.⁵⁷ And, finally, the Committee adopted the stuffy formalism of prewar America and made it a long-lived NACA tradition. When Samuel Stratton recommended to a meeting of the Executive Committee the hiring of four new people at the Langley laboratory, "these recommendations were referred to the Personnel Committee and were immediately reported back approved by the Chairman, Dr. Ames." (Ames and Stratton were the only two members of the Personnel Committee present, meaning that Ames went into hasty consultation with himself and then notified the other members of the Executive Committee that it sounded good to him.) At a meeting early in 1918, the Executive Committee resolved in closed session to hire a technical director for the NACA. John Victory recorded the climax of this dramatic resolve in the minutes of the meeting: "On expiration of the executive session, the doors were opened and the above resolution was spread upon the records of the meeting."⁵⁸ This kind of pompous formality clogged the records of the NACA throughout its history and set the tone for the Committee's actions as well.

DEFINING THE FUTURE

When peace came in November 1918 the NACA faced an uncertain future. As one historian has observed, "the NACA spent most of its war years in finding itself."⁵⁹ And it still had a way to go. It had served commendably as an advisory and consultative board, but had been eclipsed entirely by the National Research Council in sponsoring research of immediate use to the military services. Its greatest contribution, no doubt, was the cross-licensing agreement; but fairly or unfairly, that settlement had been the object of considerable criticism, and there was more to come. When the American aeronautical effort came under severe scrutiny after the war, the cross-licensing agreement was again cited as an example of foul play and mismanagement, charges that tarred the Committee as well as the industry.

And it was not only among the cranks, outsiders, and naysayers that the NACA was in bad odor at war's end. The acting director of the Bureau of Aircraft Production reportedly regarded "the Advisory Committee as a body which is necessarily altogether ineffective." E.B. Wilson, a distinguished MIT engineer and a frequent adviser to the Committee, confided to the president of the National Academy of Sciences that "the second *Annual Report* of the National Advisory Committee was pretty poor stuff . . ." "It is my opinion," he continued, "that the board contains mostly executive persons and eminent scientists more or less unfamiliar with aeronautical problems, except on the administrative side, or in a very general way."⁶⁰ Wilson may have been the first to hold this opinion of the NACA, but he was by no means the last.

Nor was the criticism all from outsiders. Joseph S. Ames, the outspoken Committee member whose comments on the aircraft industry had raised a furor earlier in 1918, spoke out again in August in a letter to Chairman Durand. Complaining that "the lack of an established program" was precluding any serious work by the subcommittees on which he served, Ames said: "I think the most important thing of all is for the Executive Committee to form a policy . . . so that every one connected with the committee may know what its real purpose is. . . . At the present time our work is 99% clerical and there is no vision as to what the future should offer us."⁶¹

Others connected with the Committee voiced similar opinions. Even the normally reticent and deferential John Victory was emboldened to suggest to Durand that the Executive Committee should prepare a "comprehensive statement of policy" for "the information and guidance" of the employees of the Committee and those outsiders who had to deal with the NACA.⁶² The most comprehensive critique was that of Senior Staff Engineer Leigh M. Griffith, one of the Committee's earliest technical employees. Coming from industry, Griffith found the methods of the NACA "loose and disorganized." He expressed the same sentiments stated by Ames and suggested by Victory:

I, together with other members of the personnel, have very hazy ideas regarding the nature of the services that this Committee is endeavoring to render, or is capable of rendering . . . Until it is known what we are trying to do, it is impossible to formulate any system or build any organization for the doing of that thing.⁶³

If the NACA was to survive and become the national aeronautical research organization envisioned by its founders, it would have to

resolve in the immediate postwar years the two questions implied in these criticisms: What was the place and the role of the NACA in American aeronautics and aviation, and how was it to execute that role? The NACA spent the next eight years answering those questions.

3

Advice and Politics, 1919–1926

World War I had engendered a full-scale aviation manufacturing industry in the United States. In 1914 the Census Bureau listed only 16 aircraft manufacturers, whose combined total output was 49 planes. By the end of the war, 175,000 workers in approximately 300 plants were manufacturing airplanes with a potential output of 21,000 per year. Between April 1917 and November 1918, this fledgling industry delivered 13,844 aircraft and 41,953 engines.¹

For such an industry, or at least a substantial nucleus of it, to survive in peacetime, the federal government would have to either sustain a sizeable military aviation program, or else foster civilian commercial aviation on a comparable scale. The government's response to the first alternative was swift and unmistakable. Within days of signing the armistice, the United States cancelled \$100,000,000 in contracts for military aircraft and parts, cutting the industry to an estimated ten percent of its wartime size and reducing production from its wartime high of 14,000 aircraft in 1918 to a low of 263 in 1922. The answer on civilian aviation came more slowly. The United States never subscribed to the direct subsidy of commercial aviation adopted in many European countries. But would the government provide indirect support—airmail contracts, airports, and aids to navigation—that private firms could afford neither to buy nor to do without? Most important, would the federal government regulate aviation in order to make it safe, reliable, and economically sound? In the course of answering these questions, the NACA would undergo one of the most complicated and damaging episodes in its history.

A NATIONAL AVIATION POLICY

Shortly before the armistice ending World War I, the general manager of the Manufacturers Aircraft Association wrote to the National Advisory Committee for Aeronautics suggesting federal legislation to regulate civil and commercial aviation. To the manufacturing

industry it seemed that only federal assistance and regulation could give civil aviation the boost it needed, and the NACA seemed the logical place to start. The Committee's helpfulness in the wartime controversies over aircraft-engine manufacture and cross-licensing were well remembered. At the moment, the military services were dismantling the war machine so recently put together and were in no position to undertake the advancement of civilian aviation; they also were mindful of the good offices of the NACA in resolving their wartime disputes with the aviation industry. But it was the industry most of all that prompted the NACA to move. After World War I, "business was the dominant and most active sector of the nation"; and, in the field of aviation, business took the lead in encouraging the NACA to do what everyone else agreed was necessary. Several congressmen assured Chairman Walcott that in their opinion the NACA had full authority to initiate civil-aviation legislation.²

The Committee did not hesitate. Its *Annual Report* for 1918, sent to the president within three weeks of the armistice, recommended federal legislation to promote and regulate civilian and commercial aviation. To this end, it reported the formation of a committee in conjunction with other government agencies concerned with aviation: the War, Navy, Commerce, and Post Office Departments. The issues taken up by the committee were the same ones confronted more than seven years later when legislation was finally enacted: First, what action should be taken to ensure a healthy aviation industry, both as a commercial enterprise worthy in its own right and as a reliable source of military aircraft in the event of war? Second, how much regulation did flying require to make it a safe, attractive, and profitable means of transportation? And third, what organization of government agencies would be most conducive to these ends? Disagreement on the first two issues was minor, technical, and negotiable. Disagreement on the last was intense, divisive, and finally bitter. It held up passage of civil-aviation legislation for more than seven years.³

This interdepartmental committee proved an unsatisfactory mechanism for dealing with these questions. It formulated a proposal quickly enough, recommending that the president appoint a joint interagency board to control civil aviation. But the NACA lacked authority to submit this proposal without the approval of the agencies concerned. While the draft circulated through these agencies, 1918 slipped away, several of the military members of the committee were transferred, and the interdepartmental committee itself dissolved for lack of replacements. By February 1919 little hope remained that the proposal for a joint board could be considered by the 65th Congress before it expired in March. Meanwhile, the aviation situation was becoming increasingly desperate. The army was licensing domestic aviation under wartime

emergency legislation. Surplus military aircraft were being put on the open market with virtually no control over how and where they might operate. Aviation anarchy loomed.

In haste, Walcott (with the approval of the secretaries of war, navy, and commerce) recommended to the president new emergency legislation empowering the secretary of commerce to license and regulate interstate civilian flying in the United States. Though President Wilson endorsed this recommendation and forwarded it to Congress on 26 February, it was lost in the crush of legislation in the last week of the 65th Congress.⁴

Unaccountably, the NACA let the entire first session of the 66th Congress slip by before it renewed the campaign. On 7 March 1919 the Executive Committee had decided to resubmit the February legislation immediately after the new congress convened. But, in April, Dr. Ames reported that the great public interest in the subject demanded "much study" of it. He recommended the appointment of a "strong subcommittee" to make an "extensive study" of the matter. This suggestion won quick endorsement, but it was not until 25 November, after the end of the first session of the 66th Congress, that the Committee got around to appointing the Special Committee on Organization of Governmental Activities in Aeronautics, with Joseph S. Ames as chairman.⁵

Thereafter, things moved more quickly. Ames began gathering data and opinions from the United States and abroad. By early December, he had concluded that the European experience clearly demonstrated what *not* to do: do not form a central department of aeronautics as the British had done in their Air Ministry. Carrying great weight with Ames was a recent report by Captain H.C. Mustin, a member of the Crowell commission that visited Europe in 1919 to study the aviation lessons of the war. Ames found in Mustin's report "conclusive arguments against combining all aviation work in a central bureau or department." This position soon solidified into a tenet of NACA policy.⁶

By early February, Ames's special committee was able to enunciate four basic principles:

1. The military services would be responsible for their own training, personnel policies, procurement, and "engineering development."
2. The Post Office Department would handle its own aviation.
3. The duties of the NACA would remain the same.

4. An Air Navigation Board should be created within the Department of Commerce. Its membership should be drawn from all the federal agencies concerned with aviation, and it should be responsible for the regulation and encouragement of civil aviation.⁷

When approved by the Executive Committee, these principles were embodied in draft legislation "To Create a Bureau of Air Service in the Department of Commerce . . ." Three provisions of this draft bill are crucial to a study of NACA history, for by following them it is possible to follow all subsequent civil-aviation legislation and see where the NACA stood. First, the main purpose of the bill was to create an organization within the Department of Commerce to regulate and encourage civil aviation. Second, it precluded a single, unified department of aeronautics for the entire federal government, calling instead for autonomous aeronautical bureaus within the Departments of War, Navy, Post Office, and Commerce, in addition to the National Advisory Committee for Aeronautics. Finally, the bill provided for a "Joint Board" to be composed of the heads of these autonomous bureaus. The board would meet to coordinate the various aeronautical activities of the federal government, a role that the NACA had been filling unofficially since its creation and that it would continue to fill in the area of aeronautical research. It was on this last issue—the coordinating function—that the NACA would be drawn into overstepping its bounds in the fight for civil-aviation legislation.⁸

On 19 May 1920, Congressman F.C. Hicks introduced a bill "To Create a Bureau of Aeronautics in the Department of Commerce . . ." Modeled on the draft NACA legislation, the bill was the joint product of Hicks on the one hand and Dr. Walcott and two military members of the NACA on the other. Hicks reportedly said that the principles it embodied were the same as the Committee's. A more limited piece of legislation, providing only for the regulation of air commerce by a bureau within the Department of Commerce and containing no provisions for governmentwide coordination, had been introduced six days earlier by Congressman Julius Kahn. While not at odds with either the Hicks or the NACA proposals, the Kahn bill did not go as far in outlining the entire government structure for aeronautics; it was silent on the pivotal issue of coordination.⁹

As far as most members of the NACA were concerned, there was not much to choose between the Hicks and Kahn bills. Either would provide what was needed most—a government organization within the Department of Commerce to administer civil aviation—but the military members of the Committee preferred the Kahn bill, which limited itself to the control of civil aviation and did not intrude upon military

prerogatives. The Hicks bill, in contrast, gave its proposed commissioner of aeronautics broad power in areas such as transfer of aircraft between government agencies and approval of expensive research projects, aspects of coordination that the military had approved in the abstract but disliked in the flesh—or at least disliked in the Department of Commerce.

During the summer and fall of 1920, the NACA examined the two bills and reached an agreement of sorts on amendments to both. The Committee's *Annual Report* for 1920 expressed unanimous support for the revised Kahn bill. The revised Hicks bill, said the report, was an acceptable second choice if Congress should insist upon legislation barring duplication of expenditures and activities within the military—i.e., enforcing a coordinating role on some government agency.¹⁰

It was in the revised Hicks bill, however, that the Committee most clearly revealed the role it wished to play, or at least the role some of its members would prefer. The issue was how to coordinate government aeronautical activities, both military and civilian. The original Hicks bill had sought to resolve the issue by creating within the Department of Commerce an Aeronautics Board with broad powers over all government aviation. This provision satisfied congressional demands for coordination and prevention of duplication, but proved distasteful to representatives of the armed services, who saw in it civilian interference in military affairs. The NACA tried to settle the issue by simply transplanting all those coordinating functions from the Department of Commerce to the NACA, where the military would at least have a voice in decisions that affected its aviation branches. This tactic may have been entirely innocent, but it had all the markings of a sweeping grab for power by the NACA. The most flagrant provisions of the revised bill warrant quotation at some length:

Sec. 3. That all rules and regulations herein provided for, except as otherwise provided for in section 12 hereof, shall be formulated by the Commissioner of Air Navigation, who shall submit the same to the National Advisory Committee for Aeronautics for consideration, criticism, and recommendation to the Secretary of Commerce, who, if the same meet with his approval, shall formally promulgate the same; when approved and duly promulgated by the Secretary of Commerce, such rules and regulations shall be legally binding and enforceable from the date of such promulgation unless otherwise provided therein. *Provided*, That hereafter the National Advisory Committee for Aeronautics, in addition to the exercise of its present function, is authorized to act in an advisory capacity in connection with the formulation and promulgation of such rules and regulations, for the consideration of questions of policy affecting the development of civil or commercial aviation, including recommendations from time to

time for amendments to this act or subsequent acts, and for the coordination of the aeronautical activities of the various departments of the Government.

The said National Advisory Committee for Aeronautics shall have authority to consider and recommend to the heads of departments concerned, on questions of policy regarding the development of civil aviation, with particular reference to education, preliminary training, commercial production of aircraft, establishment, elimination, and consolidation of all flying fields and air stations, and all other matters in connection therewith.

Sec. 4. That hereafter the War, Navy, and other departments of the Government shall prepare programs for experimental research and development work in aeronautics, and for the purchase or construction of air craft [sic], engines, accessories, and hangars, and the acquisition of land for purposes in connection with aviation, and shall submit same to the said advisory committee for consideration and recommendation before contracts are made or orders are placed for the purchase, manufacture, or construction of the same.

Sec. 5. That the National Advisory Committee for Aeronautics shall have authority to recommend to the heads of the departments concerned the [transfer] of aircraft and aircraft equipment and accessories from one department to another for the civil uses of the Government. The heads of the various departments concerned are authorized to make such transfers of aircraft, equipment, and accessories when recommended by the said advisory committee.

Sec. 6. That the said advisory committee shall consider and report upon any question dealing with aviation referred to it by the President or by any of the departments, and shall initiate, report, and recommend to departmental heads desirable undertakings or developments in the field of aviation, and each department shall furnish the said advisory committee such information as to its aviation activities as may be requested.¹¹

Stopping just short of giving the NACA control over all aeronautical and aviation activities of the federal government, these provisions would have put the NACA at the center of all such activities and made it a central clearinghouse not only of information, which is a power in its own right, but of action as well. Virtually nothing could have been accomplished by the federal government in the field of aviation without consulting the NACA.

How this particular wording found its way into the revised Hicks bill is not entirely clear. Congressman Hicks, in drafting his original legislation, had apparently expanded upon the suggestions of the NACA. He gave to the Aeronautics Board powers that the NACA had not recommended, powers which reflected "that sentiment in Congress which has sought to prevent duplication of expenditures and effort in the military and naval air services." When Walcott came to suggest

revisions to the bill, he found himself caught between Congress and the military. Congress wanted the strong coordinating function; the military did not want it in the Department of Commerce. So Walcott simply transferred the function to the NACA and presented the results to the Executive Committee on 11 June 1920. In subsequent meetings during the summer, the Executive Committee in Walcott's absence moderated the powers ascribed to the NACA; the final result, quoted above, nevertheless retained the appearance of a power grab by the Committee. Hicks, who apparently approved and might even have encouraged the change, accepted the NACA recommendations.¹²

Not everyone on the Committee approved, however. For example, Col. Thurman H. Bane, director of the Army Air Service Engineering Division at Dayton, Ohio, protested as early as July of 1920 that he did not believe that "an organization of scientists and physicists such as the National Advisory Committee for Aeronautics, should assume executive functions" such as those provided in the draft revision of the Hicks bill. "I very greatly fear," he went on, "that the National Advisory Committee would be making a very serious mistake to pass from under the very enviable position of the critic to the very undesirable position of the responsible party for aeronautics in this country." Similar fears were voiced by John F. Hayford, a charter member of the NACA and a distinguished engineer at Northwestern University. "The N.A.C.A. is adapted to function well as an advisory committee," he counseled, "but not to function satisfactorily as an administrative body."¹³

In keeping with these admonitions, the Committee was far more circumspect in what it advanced as "A National Aviation Policy" in its *Annual Report* for 1920. Advocating strong government support of military and civil aviation, this policy favored civil-aviation legislation, a government-sponsored aviation competition, adequate appropriations for military aviation, the creation of a naval bureau of aeronautics, extension of the Air Mail Service in the Post Office Department, and a "program of scientific research in aeronautics formulated by the committee." Nowhere was there any mention of the broad powers and functions ascribed to the Committee in the modification of the Hicks bill.¹⁴

Nor did the Committee claim so much for itself in its proposed modification of the Kahn bill. This more limited piece of legislation elicited a similarly limited recommendation from the NACA. Of the four sweeping provisions in the revised Hicks bill, only one found its way into the revised Kahn bill. Though this was the broad section 3, granting to the NACA its largest and most pervasive advisory function, it was free of such specific irritants as letting the NACA tell other agencies how to transfer aircraft. This made it more palatable not only to the military members of the NACA, but also to a majority of all

Committee members.¹⁵ The proposed amendments to the Hicks bill stayed on the record, however, as testimony to the aspirations of Walcott and at least some of the other members of the NACA to make the Committee the kingpin of government aviation.¹⁶

THE DANGERS OF CONTROVERSY

Neither the Hicks nor the Kahn bill passed in the third and final session of the 66th Congress, or in the special session of the 67th Congress that followed immediately thereafter. There seems to have been little of the opposition that the NACA felt might face the Hicks bill. Rather the legislation failed for lack of interest and active support. Congress was not opposed, just indifferent and preoccupied with other business. This experience led the members of the NACA to seek more cooperation among the government agencies that favored the legislation and more assistance from the White House—specifically from the new Harding administration. On the initiative of the NACA, a meeting was held at the War Department 31 March 1921. A subcommittee was appointed to draft a letter for the signature of President Harding, calling upon the NACA to investigate the subject of civil aviation and report to him on what steps were needed.¹⁷

The president signed the letter on the afternoon it was presented to him, and four days later the NACA's Subcommittee on Federal Regulation of Air Navigation held its first meeting. With Walcott as chairman, Victory as secretary, and other members drawn from the War, Navy, Commerce, and Post Office Departments as well as from private life, the subcommittee set about answering the questions posed by Harding: What could be done without further legislation, and what legislation and appropriations would be necessary to effect whatever recommendations the subcommittee might make? Using the National Aviation Policy recently published by the NACA as foundation, the subcommittee drafted a set of recommendations in three consecutive days.¹⁸

All went smoothly for the first two days, as the subcommittee considered line-by-line revisions of the NACA policy statement; only minor revisions or rewordings were suggested. But, on the third day, when the subcommittee began to draft its report to the president, major new issues arose. The president of the Manufacturers Aircraft Association suggested appointment of an industry representative to the National Advisory Committee for Aeronautics. More disturbing still, Sidney Waldon, a Detroit engineer and veteran of the Air Corps and Aircraft Production Board, recommended that the government grant the aircraft industry a direct subsidy to encourage and support civil and commercial aviation, and that it consider establishment of a separate

air force. All three of these industry suggestions had precedents in England, and all three were anathema to the NACA. Dr. Stratton replied that the NACA had considered the question of a separate air service and could not recommend it, though nothing in the proposed policy necessarily precluded it. The other two recommendations by these industry representatives were simply ignored.¹⁹

The following day, in discussing the draft of its report, the subcommittee reached an impasse on the issue of a separate air service. Some members sought inclusion of a disclaimer that nothing in the report precluded establishment of an independent air service, but the subcommittee was unable to agree on wording and the matter was tabled. The rest of the report was approved and the subcommittee adjourned, its work done, its report ready for approval by the NACA Executive Committee that afternoon and submission to the president the following day.²⁰

That evening, however, Waldon submitted to Walcott a memo signed by himself and three other members of the subcommittee, urging the president to reconvene the subcommittee for the purpose of considering the relative merits of (a) the existing system of government organization for aviation, (b) a department of air, (c) a unified air service, and (d) an independent air force.²¹ The existing situation was that favored by the NACA. A department of air would have gathered all government aviation activities, military and civilian, into one federal agency. A unified air service would have placed all military aviation in one branch; an independent air force would have created a coequal military service of the air corresponding to the army on the land and the navy on the seas. Distinctions between the three latter suggestions were never entirely clear, even to their most ardent advocates,²² but all three aimed at eliminating what were felt to be abuses of aviation as it was then being handled in the military services, especially the army. Believers in the need for change were soon to find their most colorful and most effective spokesman in the person of Billy Mitchell, the flamboyant and outspoken deputy head of army aviation. Throughout the battle for civil-aviation legislation, a shifting coalition of military and civilian believers would look to Mitchell for leadership and identify—at least in their own minds—the fostering of civil aviation with reform of military aviation.

Walcott, however, considered this issue a dangerous diversion from the main point, the need to establish in the Department of Commerce a bureau to regulate and encourage civil aviation. Although he advised the president of the sentiments of the four members who had petitioned him, he did not forward their memo; instead, he recommended that the president accept the position of the majority of the subcommittee and leave to another time the issue of government organization of

aviation activities. Not surprisingly, Harding took the advice. He forwarded the report to Congress, recommended passage of legislation, and (as if to express his approval of the NACA's position) joined the Committee at its semiannual meeting of 21 April.



John Victory (far left) and George Lewis (sixth from left) pose outside the White House with the members of the Main Committee after meeting with President Harding, 21 April 1921. (National Archives)

The veneer of consensus began to crack as soon as Harding left the meeting. On a routine motion to approve the minutes of Executive Committee meetings, Thurman H. Bane, newly reverted from colonel to major, took exception to the Executive Committee's action at its 8 April meeting endorsing the report of the Subcommittee on Federal Regulation of Air Navigation for submission to the president. This action, asserted Bane, precluded the later establishment of a separate air service and ensured that army aviation would remain organized as it then was, a situation Bane considered "perfectly impossible." Reflecting what was probably the majority position in the NACA, one of the members "expressed the opinion that remarks of Major Bane may in effect be resolved into the question of whether the National Advisory Committee for Aeronautics should consider the alleged failure of the Army to adequately recognize and provide for the development of the Army Air Service, and it was recorded as the sense of the meeting that the Committee was not called upon at this time to take up the question."²³ Lacking support, Bane's objection died. With it died the NACA's chance to serve as mediator in the storm of controversy that would soon consume the careers and passions of many leading American aviators and manufacturers. With it also lapsed the opportunity for

quick passage of civil-aviation legislation. Sides had been chosen for a fierce and bitter debate, and though the NACA would have preferred to remain above the controversy, feelings ran so high that neutrality proved impossible. To the advocates of a separate or unified air service, you were either with them or against them. From this time on, many of them believed that the NACA was against them.

Within days, this dispute in the meeting room of the NACA spilled into the press. The *Baltimore Evening Sun* and the *New York Times* reported "suppression of a minority report." Lester Gardner, editor of *Aviation* magazine, was in touch with both Walcott and Waldon, but the editorials he published were strongly on the side of the critics of the NACA.²⁴ There was no sure formula for picking sides in this dispute, but alliances were being formed nonetheless. One side included the Mitchell forces within the Army Air Service, who felt that the air arm was not getting its due. Allied with them were some aircraft manufacturers who foresaw greater promotion of aviation and thus more contracts for themselves if a separate air service was established. Attached to this alliance were some small manufacturers and inventors still smarting over the cross-licensing agreement and looking for a way to open up what they regarded as the aircraft trust. That these men now found themselves in league with the very forces they claimed were monopolizing the aircraft business is only one of the many ironies in the convoluted politics of what was to become the Air Commerce Act.

Arrayed against this alliance was what may be termed the establishment, consisting primarily of the government agencies concerned with aviation—the army, the navy, the Post Office Department, and the NACA. To call the NACA a government agency is valid in two senses. First, it was in fact an official branch of the federal government. Second, it was then, as always, controlled by its Executive Committee, and in 1921 Joseph Ames was the only member of the Executive Committee who was not also a representative of a government agency. This was one reason that critics of existing government policy felt that the NACA would not or could not give them a fair hearing, a belief especially strong in the aircraft industry, which was specifically barred from membership. When the Subcommittee on Federal Regulation of Air Navigation ignored the recommendation that industry be represented on the NACA, it condemned the Committee to an appearance of bias and partiality in the eyes of many in the aircraft industry.²⁵

The public flap over the minority report embarrassed the Committee and reinforced the commitment to unanimity of opinion that had resulted from the 1918 controversy over the Ames letter published in *The Atlantic Monthly*. It did not, however, alter NACA policy. The Committee's majority report to the president recommended passage of the modified Kahn bill it had favored in the previous session. Congressmen

Kahn and Hicks resubmitted similar bills to the new Congress. Kahn's bill was still in a sense a "stop-gap" measure because it did not resolve the question of government organization of aviation activities, but provided merely for the creation of a bureau of aeronautics in the Department of Commerce. Still, most in government agreed with Ames that "all agencies should unite in support of that measure at this time, and not injure the prospect of securing such legislation by the consideration or urging of legislation for a general reorganization of aviation activities."²⁶

The other side was not without its friends in Congress. In a move attributed to supporters of a united air service, Senator William E. Borah introduced a resolution 17 June to abolish the NACA and transfer its functions to other government agencies. The parallel between the intent of this resolution and the actual experience of the British at this time makes one suspect that the NACA's enemies must have been looking to England. When the Air Ministry was created there in 1918, the Advisory Committee for Aeronautics (on which the NACA had been modeled) was transformed into the Aeronautics Research Committee, shorn of much of its power and independence, drained of funds, and transferred to the jurisdiction of the Aircraft Factory. In the opinion of one informed British critic in May 1921, "research has been almost abandoned." C.G. Grey, outspoken editor of the British magazine *The Aeroplane*, described to an American correspondent at about this time "the delightfully chaotic arrangements" under which aviation then suffered in England, and observed that "apparently your Government is trying to produce a state of affairs which is just about equally irrational."²⁷

The NACA's enemies might deny that the arrangement they were trying to create was irrational, but they were obviously attempting to duplicate the British Air Ministry situation, assuring for the NACA the fate that had befallen the British ACA. Nor was emasculation of the NACA their only ploy. A group of manufacturers, reportedly led by Lester Gardner of *Aviation* magazine, petitioned President Harding to direct Secretary of Commerce Herbert Hoover to appoint an aviation consulting committee composed entirely of manufacturers, to prepare a national aviation policy for the approval of the president—an obvious counter to the policy already drafted and presented by the NACA. Secretary Hoover actually agreed to appoint such a board, falling (said John Victory) into a "trap laid by selfish interests" who wanted a separate air service "and innocently concurred in by others influenced by their propaganda."²⁸

Although the NACA succeeded in blocking appointment of an industry committee, advocates of the separate air service also succeeded in blocking the NACA's preferred legislation. So by the spring

of 1921 a stalemate arose that was to dominate and frustrate all attempts to get civil-aviation legislation for the next five years. Neither side was strong enough to get its position adopted, but either side was strong enough to block the other. Ironically and tragically, both sides wanted federal encouragement and regulation of civil aviation, but each side would hold such legislation hostage to its own view of how the government should be organized for aviation activities. As Walcott put it in a letter to Assistant Secretary of the Navy Theodore Roosevelt, son of the late president, when discussing the chances for passing the Hicks bill: "There are influences which hold that a separate Air Service, of a Department of Aeronautics, should be established, and while they recognize the absolute need for Federal regulation of air navigation for the development of aviation in America, they have announced their intention of opposing the measures recommended."²⁹

The means used by the "influences" to oppose the NACA-supported legislation was the Department of Commerce. A group of manufacturers centered in Detroit and led by Howard Coffin met with Secretary Hoover in mid-July, expressed dissatisfaction with the Hicks bill, and offered to draw up their own substitute. The following month, identical legislation was introduced in both House and Senate. Although modeled on the original NACA-supported legislation, these new bills contained significant modifications: the commissioner of aeronautics would not be a member of the NACA, and the commissioner would be empowered to establish his own aerological services and to undertake research. All three of these changes were opposed by the NACA.³⁰

With two sets of conflicting legislation before both houses of Congress, both sides turned to compromise. On 8 December 1921, representatives of the NACA and the aircraft manufacturers met in Washington to work out their differences. With deceptive ease, they concurred in modifications to the pending legislation, prompting George Lewis to report shortly after the meeting that "for the first time in the history of aviation in this country an agreement was reached by all parties concerned." New House and Senate bills incorporating the agreement were quickly introduced and the NACA took charge of a campaign to see them through to passage. John Victory, then working on a degree in international law at Georgetown University night school, coordinated the exchanges between the congressional friends of the bill and the various private and government interests who were following the legislation.³¹

Just when success seemed imminent, a new obstacle arose: the Constitution. Several legal questions about the bills came up in Congress early in 1922, most importantly whether they were in conflict with the International Convention on Air Navigation recently signed at

the peace conference in Paris, and whether the federal government had the power to regulate intrastate flying. Legal opinions were sought both inside and outside the government, and yet another version of the bill was introduced in the Senate. This latest draft was a political compromise worked out in the Senate Commerce Committee to head off objections on the Senate floor. While the NACA forces believed this version contained "a number of objectionable changes," they also thought it good politics to support the bill in the Senate and seek amendment in the House. It passed the full Senate on 14 February 1922 and went to the House Committee on Interstate and Foreign Commerce, chaired by Representative Samuel E. Winslow. There the bill died.³²

Winslow himself was now the obstacle. Influencing him were two groups opposed to the legislation worked out between the NACA and the manufacturers. One was a group of midwestern manufacturers who viewed the bill as the work of eastern manufacturers trying to monopolize the industry, a suspicion reminiscent of the old charges of an aircraft trust. The other group, in strange alliance with these forces, was a faction in the Department of Commerce who felt the secretary of commerce should have a stronger voice in regulating civil aviation than the bill provided. Leading these forces was Judge William E. Lamb, former solicitor general of the Department of Commerce. He submitted to Winslow the draft of an entirely new piece of legislation calling for a unified air service, broader power for the secretary of commerce, and transfer of the NACA to the Department of Commerce.³³ This last provision was the first in a series of attempts throughout the NACA's history to transfer the Committee to the Department of Commerce. Many motives inspired these efforts, but this first one apparently sprang from parallel desires to strengthen the hand of the secretary of commerce and at the same time to eliminate the opposition of the NACA to the plans of those who would create a separate air force and break up what was seen as an aircraft trust.

The initiative for drafting civil-aviation legislation had now shifted from the NACA to the Department of Commerce. The department disavowed Lamb's draft, so Winslow decided to draft his own bill for introduction in the next Congress and to seek support from the forces behind Lamb's version. From this time on, the NACA would be in the uncomfortable position of opposing legislation that it badly wanted. Many of the subsequent bills made transfer of the Committee to the department a keystone of any plan to organize the government for administration of civil aviation. This was too great a price for the NACA to pay; it would not sacrifice itself to the need for civil-aviation legislation.

COMMERCE TAKES OVER

Winslow's draft of civil-aviation legislation seemed to rely heavily on recommendations of the Department of Commerce. This did not mean, however, that the NACA was without a voice. The Commerce recommendations were, after all, based on the NACA's original proposals for legislation, and the NACA had its chance to comment on the Winslow draft. Although the new bill was not entirely to the Committee's liking, it appeared on the whole to "possess much merit." The NACA would act in an advisory capacity to the secretary of commerce without actually coming under his jurisdiction; in turn, the new commissioner of aeronautics would not intrude upon the NACA's research responsibilities. Here were the makings of a compromise.³⁴

When the Winslow bill was finally introduced in January 1923 it contained a "joker" that had not been present in the draft that the NACA had approved the previous month. The bill now called for a civil aeronautics consulting board, a reincarnation of the industry consulting committee recommended by the Detroit manufacturers the previous year. Officially and publicly, the NACA maintained that such a committee would create an unacceptable conflict of interest. As Ames put it in the Committee's formal reply to Winslow,

the development of the bureau's activities and general policy ought not to be controlled or even influenced by any group of men, whether serving without compensation or not, who are representatives of those who are financially interested. The appointment of such a board would also serve to prevent the development of a national aircraft industry by concentrating power or influence in a few so-called "representatives," to the exclusion of all others.³⁵

This merely restated the NACA's own reasons for excluding industry representatives from its membership and was thoroughly in keeping with past Committee policy. But, in private correspondence, John Victory revealed that there was far more to this issue. A paper he drafted concluded:

Leaders among the aircraft manufacturers today are working quietly for a united air force, believing that it will mean larger appropriations for aircraft. The National Advisory Committee for Aeronautics has incurred the enmity of certain aircraft manufacturers by recommending to the President and to Congress the principle of an Army Air Service under the Secretary of War, and naval aeronautics under the Secretary of the Navy. These manufacturers, ignoring the importance of the Committee's research work, desire it abolished in order to remove the first obstruction to the amalgamation of Army and Navy aeronautics (under General Mitchell).³⁶

Victory had written to Samuel Stratton at about the same time that "the undermining and dissolution of the Advisory Committee are essential to certain interests that have never been able to control the Committee's policies." Although the Winslow bill did not explicitly require abolition or absorption of the NACA, many believed with a correspondent who wrote to Lewis in January that "if this bill passes in any form within a year, [the NACA] will be under the Department of Commerce."³⁷

The NACA therefore took the lead in defeating the legislation or at least so modifying it as to bring about its failure. Meeting with representatives of the military services, the National Aeronautics Association, and the Aeronautical Chamber of Commerce, Victory achieved a compromise on the Winslow bill, but too late for passage in the 67th Congress. Thus civil-aviation legislation was delayed for yet another year, as the 68th Congress did not convene until December 1923. In that month Winslow submitted a new bill, described by John Victory as "a mere rearrangement of the former bill with no important changes."³⁸ Again the NACA led a campaign to modify the bill.

Here began a round of mudslinging that was to poison negotiations over the legislation and permanently embitter many of the principals. John Victory discovered that members of Congressman Winslow's subcommittee had been subjected to "secret propaganda" that the NACA was "useless" and had "never done anything for aviation." Victory reacted in kind by calling the proposal for a Civil Aeronautics Consulting Board "obviously vicious" and in need of crushing. Howard Coffin, now aligned against the industry coalition working with the Department of Commerce, was even more abusive. He telegraphed George Lewis about "the motives and methods of a small group of agents responsible for cunning and vicious propaganda clearly intended to hamper American aviation development and wreck the industry," about "the running sore that is ceaselessly spreading in Congress and in the public mind poison and suspicion of any and all things relating to aviation," and about "the unscrupulous and infinite cunning with which advantage had been and is being taken of every opportunity to sow lying misinformation to discredit [and] endeavor to prevent vitally needed legislation and to wreck constructive accomplishments."³⁹

What had exasperated Coffin and Victory was a new coalition formed against the NACA and its government allies. Roughly, the coalition consisted of the apostles of a separate air service, becoming ever more vocal under the leadership of Billy Mitchell; diehard believers in an "aircraft trust" who were still smarting over the cross-licensing agreement; and a growing number of aircraft operators who feared they would be hampered by restrictions on flying in the proposed

legislation. Surely an alliance of necessity, it was no less strong for that. One of the staunchest members, an old foe of the NACA from World War I days, was using his influence to promote congressional investigation of the aircraft industry. As one NACA official reported it, the man "called at the office, shook his finger in my face, . . . and stated that one of the ambitions of his life was to put the Committee out of business. One of the pleasures that he anticipates is drawing Dr. Ames and others before the investigating committee and have them explain the cross-licensing agreement."⁴⁰

Slowly but inevitably, the dispute was progressing toward an airing of the controversy by public investigation. The administration was already racked by scandals involving corruption and special interests. Billy Mitchell's crusade was about to culminate in a public court-martial. And the issue of government organization for aviation, which was indirectly related to both of these crises, was bound to be investigated in its turn. When Winslow's bill failed again in 1924, the die was cast.

SAVED BY THE BILL

The committee investigations that dominated 1924 and 1925 were in part a result of the continuing stalemate over aviation legislation; in part they were merely a reflection of their times. Throughout their course, the NACA clung to the basic tenets of the policy it had enunciated at the outset: a bureau of civil aviation in the Department of Commerce, no separate air service, no abolition or absorption of the NACA. The NACA did, however, make some significant changes in its approach. It now kept a lower profile, leaving the initiative for shaping legislation to the Department of Commerce and the lawyers and industry representatives working through that agency. And the NACA claimed for itself a considerably reduced role, a concession that helped win final approval for the Air Commerce Act of 1926.

The first committee investigation to bear on the NACA's place in the scheme of government organization was a fortuitous one as far as civil-aviation legislation was concerned. The Congressional Joint Committee on Reorganization of the Executive Departments reported in October 1924 that the NACA should be transferred to the Department of Commerce, echoing the recommendation of the Lamb faction at the Department of Commerce the previous year. This is not to say there is a connection between the two recommendations, only that many who examined the structure of the federal government during the NACA years concluded that the Committee should not be an independent agency. In this case, as always hereafter, the NACA's response was pragmatic and persuasive. Writing to the president late in November,

Chairman Walcott said that the success of the Committee could be attributed to the caliber of the members and the freedom they enjoyed in determining their research program.

The distinguished members of the Committee would not serve, he felt, for mere salary, nor if they were reporting to anyone but the president, and they would not be free to choose the best course of action if they were answerable to an official like a secretary of commerce who had concerns other than aeronautical progress. Walcott also suggested that Coolidge's letter of transmittal for the Committee's annual report should contain an encomium of the Committee members that would conclude by observing that "the status of the committee as an independent Government establishment has largely made possible its success." Coolidge complied, and no more was needed to blunt the recommendation of the Joint Committee.⁴¹

Potentially more threatening to the NACA was the investigation by the House Select Committee of Inquiry into Operations of the United States Air Service, popularly known as the Lampert committee after its chairman, Florian Lampert. Some of the pressure for these hearings came from advocates of a separate air service who saw in the NACA an obstacle to their designs. The investigation looked back to World War I and the cross-licensing agreement to determine the causes of, and a reasonable solution to, the continuing debate over aviation organization. Unlike the Joint Committee on Reorganization, however, the Lampert committee gave the NACA a fair hearing, even going so far as to visit the Langley laboratory. In the Lampert committee's report the NACA fared better than its enemies would have wished, but not well enough to be satisfied with the results. During the hearings, which dominated the aviation scene in the second half of 1924 and the first half of 1925, there was what John Victory called "rampant sensationalism and distortion of truth," much of it from the mouth of Billy Mitchell, whose crusade for an independent air force was becoming increasingly public and intemperate.⁴²

Though the Lampert committee was still deliberating when the second session of the 68th Congress convened in December 1924, a bevy of new and contradictory measures was introduced: the Winslow bill again, a bill for a department of aeronautics, a bill for a direct government subsidy to the aircraft industry, and others. None received enough support to be passed, but that did not prevent their reintroduction during a March special session of the 69th Congress. As Victory put it the day after adjournment, "the last session of Congress had the aeronautical organizations of the Government going around in circles."⁴³ While the NACA persisted in demanding a bureau of civil aviation in the Department of Commerce and in opposing a department of aeronautics, it turned its attention more and more to its own

research work. The debate over government organization for aviation seemed endless; in the midst of it the NACA took to concentrating ever more exclusively on the one mission that was clear and uncontested— aeronautical research.

Unexpectedly, September 1925 became a watershed in aviation history. On 1 September, contact was lost with the Navy seaplane PN-9 which was attempting to fly from San Francisco to Hawaii. Until the plane and crew were found afloat and well on the 10th, a disaster was widely assumed. On the 3rd, the airship *Shenandoah* crashed in Ohio killing 14 of 43 men aboard. Billy Mitchell seized the opportunity to accuse the army of “criminal negligence” and to launch what Victory called a “publicity stampede.” Mitchell’s criticisms precipitated his court-martial, which opened dramatically in October and ended with his conviction before the year was out. Following Mitchell’s lead, both press and public called for reform of the situation that had led to the *Shenandoah* and PN-9 disasters. President Coolidge responded on 12 September by appointing a President’s Aircraft Board under Coolidge’s old friend and confidant, Dwight Morrow.⁴⁴

The convening of the Morrow board signaled a turn of events in favor of the NACA. The Coolidge administration approved of the army’s move to “get” Billy Mitchell, and it approved of the NACA’s position on civil-aviation legislation. William F. Durand was appointed to the Morrow board and Victory was made secretary. The NACA was cautiously optimistic. As Victory wrote to Walcott in September: “The aeronautical atmosphere is heavily charged this year, and as far as questions of policy are concerned, I think the Committee should stick to its beaten path and say as little as necessary, or else ignore the political situation entirely and endeavor to focus its attention on the real problems of aviation development and the need for the continuous prosecution of scientific research.”⁴⁵ The NACA had not really been beating that path for very long in the fall of 1925, but the Committee was to stay on it for the rest of its life. Threatened and buffeted during its years at the center of a political fight over civil-aviation legislation, the NACA had lowered its profile—sitting on the Morrow board, for example, but not sponsoring it—and had publicly restricted itself to what it now called its exclusive mission, aeronautical research. Never again would it try to claim for itself the broad advisory, administrative, and coordinating responsibilities staked out in the revised Hicks bill of 1921.⁴⁶

This new political caution or circumspection appears clearly in the testimony of Joseph Ames before the Morrow board. Asked by Senator Bingham if he would care to express an opinion on the advisability of organizing a separate department of aeronautics, or a united air force, Ames replied, “That question has never come up before our commit-

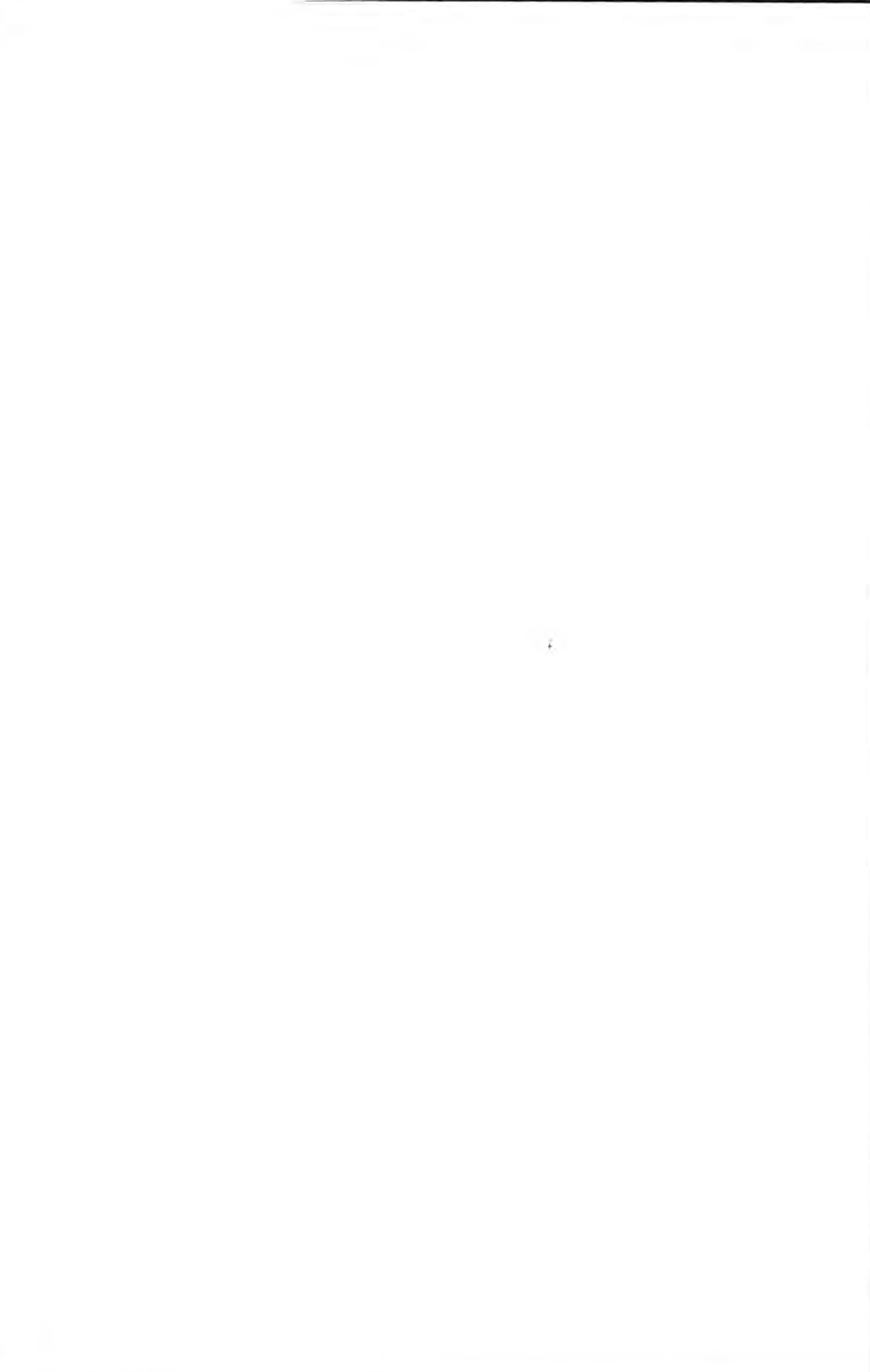
tee. Our duties and work are very sharply defined, and we want to keep within our own fences." At best, that answer was evasive and misleading. Ames might have meant that the matter had never come up for a formal vote before the full committee; but, as early as 1921, "Dr. Stratton stated that the committee had given a great deal of consideration to this question"⁴⁷ which was never far removed from the Committee's numerous consultations and recommendations over the ensuing four or five years. Ames's statement demonstrated that the NACA had retreated from the battlefield and wished to be excused from further debate. Hereafter the NACA would keep within its own fences, in the narrow area of fundamental research, and leave to other bodies the broader field of aviation policy. This was a concession of the first water, just the sort of compromise that helped pave the way for passage of civil-aviation legislation.

The Morrow board completed its work quickly and efficiently, contributing to a groundswell of support for civil-aviation legislation in the 69th Congress. It endorsed the niche in the federal hierarchy that the NACA had chosen for itself, and it recommended legislation similar to what the NACA had been supporting all along, prompting Victory to describe the report as a "beacon light of good sense in the aeronautical haze."⁴⁸ Events of the latter half of 1925 had stirred public interest in the issue, creating in turn some real interest in Congress. Congress as a body had never been opposed to the legislation; it simply had been unable to decide among the positions of the numerous and shifting interest groups lobbying for one proposal or another. Now all the interest groups were exhausted by the fight, and many like the NACA were willing to accept flawed or incomplete legislation rather than go on fighting to no good end. The solution was one familiar to Congress: make the bill simple, noncontroversial, and vague if necessary. Amendment was always possible, after some experience had been gained. But—for now—pass something.⁴⁹

S. 41, introduced on 8 December 1925, provided for a Bureau of Aeronautics within the Department of Commerce through which the secretary of commerce would establish rules and regulations for the control and encouragement of civil aviation in the United States. There would be no separate air service, no direct subsidy to industry. The NACA would neither be the central advisory and coordinating body it formerly had tried to become, nor would it be transferred to the Department of Commerce; rather, it would remain an independent aeronautical research organization.

All things considered, the Committee had every reason to be pleased with S. 41, and still more pleased when five months later it became the Air Commerce Act of 1926. In the same year, apparently swayed by the same enthusiasm, the Congress passed the Army Air

Corps Act providing for a 5-year expansion program and for appointment of an assistant secretary of war for air, and a similar act for naval aviation. Combined with the Kelly Air Mail Act of the previous year, these laws meant that the federal government would now give precisely the support to aviation in the United States that the NACA had set out to obtain in 1918.⁵⁰ Along the way the NACA had ceased to be an advisory committee and had become instead a research agency, chastened by its encounters with Washington politics and resolved to be more circumspect in the future.



4

Tunnel Vision, 1919–1925

Even as the NACA was backing away from the advisory function implied by its name, it was gravitating toward the role its founders had had in mind all along: aeronautical research at a national laboratory. As early as 1915, suggestions appeared before the Committee on how it should formulate and execute a research policy, but the exigencies of war had prevented much progress in that direction.¹ Only with the armistice did the NACA take up the subject in earnest, addressing itself first to the structure of a research program and then to its content.

GEORGE LEWIS: THE ORGANIZATION

The NACA emerged from World War I in poor shape. The criticisms by Joseph Ames, John Victory, and Leigh Griffith quoted at the end of chapter 2 had surfaced before the end of the war, echoing similar objections from less sympathetic observers outside the Committee and noting a lack of purpose or direction in the NACA's course to date. Ames spoke for them all when he lamented the "lack of . . . an established program . . . [and a] vision as to what the future should offer us." Victory voiced a common sentiment when he called for a clear statement of the "methods and program of work" the NACA meant to pursue.²

The Main Committee took scant notice of this chorus of concern until postwar budget reductions began to squeeze the NACA. In the spring of 1919 the Committee's budget request for \$325,000 was cut almost in half, to \$175,000, prompting Victory to recommend to the Executive Committee that the "research programs of the various subcommittees be coordinated and consolidated into one general program." This in turn led to an examination of the entire committee system within the NACA and a resolve to reorganize.³

In its first four years, the NACA had created no less than 32 subcommittees, of which 18 were still in existence at the close of the war. These ran the gamut from the sturdy and perennial Power Plants

for Aircraft to the short-lived Fireproof Coverings. The number and variety of these subcommittees reflected both the NACA's inability to define the major issues in aeronautics and the Committee's tendency to answer every problem by creating a new subcommittee. For example, when the chief signal officer of the army asked the NACA in 1916 about general specifications for aeronautical instruments, the Committee created a Subcommittee on Specifications for Aeronautic Instruments. The following year the title was changed to just Aeronautic Instruments. In 1918, this subcommittee was absorbed by a new Subcommittee on Navigation of Aircraft, Aeronautic Instruments and Accessories. But after two years and as many changes in title, the subcommittee had done nothing. Late in 1918 the chairman could report that he had just then obtained from the army the "necessary information . . . to make up a program."⁴

In the spring of 1919, the NACA abolished all but two of the 18 World War I subcommittees and replaced them with only four new ones. These six were full technical committees, no longer called "subcommittees" as they had been at times in previous years. Three of them were to last the duration of the NACA and account for 88 percent of the reports published by the Committee. They were the old committee on Power Plants for Aircraft, and the new committees on Aerodynamics and on Aircraft Construction, the latter then called Materials for Aircraft. (Appendix B lists all the NACA committees and explains the titling convention used in this volume.) These three technical committees were to monitor NACA research.⁵

The other three committees formed in 1919 reflected the NACA's concern with the administrative structure that would make the research possible. The Committee on Governmental Relations formed in 1916 was continued, a clear indication of the NACA's intent to cooperate with other government agencies. The new Committee on Personnel, Buildings, and Equipment, concerned at first with outfitting the laboratory facility it had acquired in 1917 at Hampton, Virginia, concentrated on finding adequate staff and office space in Washington as the field installation grew more self-reliant. By far the most important of the nontechnical committees to emerge from World War I was the Committee on Publications and Intelligence. This committee supervised not only the production and distribution of all NACA reports but also the work of the Office of Aeronautical Intelligence, through which the Committee hoped to become the clearinghouse for aeronautical information. Partly, this office was intended to aid the research staff at the Virginia laboratory and to assist the Committee in Washington in making intelligent decisions about what research had been done and what needed doing. But it was also intended to make the NACA indispensable as a source of information.⁶

To ensure that the Committee received the latest and most comprehensive reports of European aeronautical activity, the NACA appointed a technical assistant to head an office in Paris. Military attachés in Europe objected forcefully to this arrangement, labeling the NACA representative "the fifth wheel to a wagon" and insisting that they could do their job better without such interference. These protests won some adherents within the Air Service in Washington and led to considerable pressure to eliminate the NACA post. The first incumbent fed this discontent by several times overstepping his bounds and by getting on rather badly not only with U.S. military attachés but with French and Italian officials as well.⁷

The NACA, convinced of the importance of technical advances in Europe, was determined to retain a Paris office through which news of these developments could be funneled quickly and directly to its Office of Aeronautical Intelligence. In 1921, the Committee replaced the first appointee with John Jay Ide. A descendant of the first chief justice of the United States, Ide was wealthy, aristocratic, and cultured, with considerable charm and *savoir faire*. He was also an accomplished diplomat in the mold of the distinguished ancestor for whom he was named. Within months of his appointment, he had smoothed the feathers ruffled by his predecessor and had established such cordial relations with the European aeronautical community that the NACA could cite his achievements as proof against the army's insistence that the office be abolished. Although Ide never got the diplomatic passport he wanted and never entirely succeeded in eliminating the suspicions of some military attachés that he was encroaching on their domain, he was so successful in eliciting information from Europeans—often over expensive lunches apparently paid for out of his own pocket—that even the military services came to depend on the information he dispatched to the NACA. As one visitor to Europe reported in 1922: "The Committee has a tremendous asset in Mr. Ide. He knows everybody, and everybody likes him. He knows what he wants, and speaks this scientific language so that people find it a pleasure to discuss their work with him."⁸

Ide's operation rounded out the Office of Aeronautical Intelligence, and that office in turn rounded out the staff and committee structure adopted by the NACA in 1919. Other committees added through the early 1920s were in general mere elaborations of the structure already established. Only one—the Committee on Patents, formed in 1926 and retitled the following year as the Committee on Aeronautical Inventions and Design—deviated much from the pattern. This was the only committee the NACA ever formed in response to a legislative mandate. The Air Commerce Act of 1926 required the NACA to review patents for the military services, a function it had in

any case been fulfilling since the war.⁹ The NACA saw fit to appoint a committee to oversee this essentially staff function.

With the committee structure taking shape, the need increased for someone to run the show. As early as 1915 the NACA had been warned that its "first and most important step was to secure the services of a suitable technical assistant who could devote his entire time to the purely theoretical and scientific problems involved in aviation, preliminary to the establishment and development of a laboratory."¹⁰ The Committee simply did not have the technical expertise to run a research program; indeed, its failure to obtain a technical director during World War I accounts in large measure for the NACA's erratic record at war's end. The failure, however, was not for want of trying. During the war the Committee had offered the post of director of research to several established scientists and engineers. Each time it met rejection, perhaps because then the NACA had very little research to direct and a very uncertain future to promise. With the war over and a laboratory under construction, the NACA decided to lower its sights and simply hire an executive officer, an individual admittedly less qualified and less experienced in science and engineering but capable of managing the day-to-day routine of the NACA.¹¹ For that position, George W. Lewis seemed ideally suited.

Lewis came to the attention of the NACA through Clarke Thomson Research, a private Philadelphia foundation established by its sponsor in 1916 for research in aeronautical science, especially propulsion. After taking bachelor's and master's degrees in mechanical engineering from Cornell University, Lewis had taught for seven years at Swarthmore College before joining Clarke Thomson as engineer-in-charge in 1917. Late in that year, Thomson placed the services of his organization at the disposal of the NACA to direct as the Committee saw fit. Lewis quickly came to know William F. Durand, the engine research staff at the National Bureau of Standards, and others connected with the NACA program in engine research; in 1918 he became a member of the Subcommittee on Power Plants. Eighteen months later, Joseph Ames recommended Lewis to the NACA as executive officer partly on the basis of his professional experience and talent, but largely because of his "forceful personality" and "leadership." Ames judged that at age 36 Lewis had the right mixture of youth and maturity to get along with the young NACA staff and grow with the job. Furthermore, Lewis provided a nice counterbalance to John Victory. He was physically plump where Victory was thin, temperamentally cordial where Victory was abrasive, and self-effacing and reserved where Victory was priggish and garrulous. Lewis joined the NACA in 1919 and rose quickly. Like most of the NACA staff, he was brought on young and inexperienced and trained up to take on all the responsibility he could handle. Within



George W. Lewis, NACA director of aeronautical research 1919-1947. (NASA Archives)

five years he was promoted to director of research, a title that described what he had been doing almost from the start.¹²

THE BUDGET

One of Lewis's first duties as executive officer was to prepare the Committee's budget. In the years immediately following World War I, the NACA budget grew steadily. In 1918, the last year of the war, it had surpassed \$100,000; in 1926 it passed \$500,000. Only once in the intervening years did any year's budget fall below that of the previous one, and then by only \$30,000.¹³ This record was due partly to the procedure by which the NACA was funded and partly to the nature of its research program.

In 1917, the NACA budget was removed from the naval appropriation bill of which it had been a part since the Committee's creation in 1915. Thereafter, the NACA's funds appeared annually in the Civil Sundry Act, later called the Executive and Independent Establishments Appropriation, still later the Independent Offices Appropriation. In-

stead of coming before the military affairs committees of the two houses of Congress to have its budget authorized, the NACA appeared only before the respective appropriations committees, where its requests usually received short and sympathetic consideration. The military affairs committees were generally sympathetic to the NACA throughout its history and helpful when they could be. Surely the NACA had not suffered greatly before them during World War I. But the Independent Offices Appropriations bill afforded the NACA an autonomy and freedom from controversy that it probably would not have maintained had it stayed under the umbrella of the navy budget. Furthermore, the title "independent office" better suited the Committee's self-image and kept up the NACA defenses against later suggestions that it be absorbed by the armed forces. Not until after World War II did the NACA come under the congressional scrutiny of the authorizing process; then the blessings of exemption in earlier years became all too obvious.¹⁴

The other key to NACA success in the budget process was its relationship with the Bureau of the Budget. BoB was created by Warren G. Harding in 1921 to rationalize the federal budgetary process and place it on a more businesslike footing.¹⁵ The NACA, like other agencies of the federal executive, had to submit its request for appropriations to the bureau at formal hearings in the fall of each year. This submission usually followed informal negotiations with the BoB staff to determine the general level of funding that might be acceptable to the president. The final decision on the amount the NACA could request from Congress depended on the size of the federal budget and the administration's judgment of the NACA's proper share of the total.

This process gave the NACA its share of headaches, as it did other federal agencies. Congress too felt the sting of BoB interference in an essentially legislative function, and more than once rebelled at the action of the bureau. In 1922, for example, the NACA sent the BoB a preliminary estimate of \$400,000 for fiscal year 1924; BoB cut that to \$215,000. The NACA protested and won approval from BoB for a request to Congress for \$260,000. Congress in turn appropriated \$307,000.¹⁶

In spite of occasional disagreements like these, the NACA got on well with the Bureau of the Budget, establishing a reputation for honesty and economy that few if any other agencies in Washington enjoyed. John Victory, who was principally responsible for this, personally saw to the mechanics of preparing and presenting the NACA's budget requests, which were notoriously voluminous, detailed, and correct. Aside from swamping BoB in the sea of paper that was its annual budget book, the NACA played it straight with the bureau, which treated the NACA well in return.

From time to time the Committee ran afoul of BoB, as in 1924 when it publicly advocated increased appropriations for the military air services after the bureau had cut these requests. And at times the Committee found the pinch of economy unbearable and sought relief in transfers of funds from other agencies to finance the research its own budget would not allow. But the latter tactic was used only in the early years; until World War II, the NACA got pretty much what it wanted, or at least its fair share. In 1925, the director of the Bureau of the Budget cited the Committee as an example of true cooperation with a degree of efficiency unexcelled in the government; a majority in Congress echoed the sentiment by regular approval of NACA appropriations.¹⁷

Closely tied to the mechanics of getting appropriations was the related issue of how the appropriations were divided between construction and general-purpose funds. In the NACA budgets that went before Congress while the United States was involved in World War I (i.e., 1917 through 1919), the Committee won approval for \$147,000 worth of construction. For fiscal 1917, its construction budget was \$69,000 and general-purpose funds were \$18,515.70. The entire \$69,000 went into laboratory construction at Hampton, bringing in its train a requirement for new personnel, first to supervise construction of facilities and then to operate them. Consequently, the general-purpose budget for the following year (fiscal 1918) quadrupled. In the ensuing decade, construction funds varied widely but never regained the levels voted in the enthusiasm of World War I. The general-purpose budget, however, grew with unrelenting regularity from less than \$20,000 in 1918 to almost half a million dollars in 1926.¹⁸

Most of the increases in general-purpose funding in those years went to personnel costs. When Congress approved the first construction project, the NACA had only one employee, John Victory; by 1926 it had 145 employees, of whom 121 were staffing the laboratory. Each year's increases in staff were justified as necessary to operate the laboratory facilities authorized by Congress in previous years. Whether anyone in Congress realized it at the time, those first appropriations for a laboratory virtually assured two things: the NACA would continue to exist and to grow, and it would conduct a research program with built-in pressures to expand. The staff hired to operate the new facilities soon became an established body with ambitions and designs of its own. Always the researchers wanted new and better facilities, and the approval of these would ensure the further enlargement of the staff to man them. In turn the new and larger staff would demand new and larger facilities. The push and pull between staff and facilities went on throughout the NACA's history. Its foundation was laid in the excitement of World War I, with a modest request for a laboratory.

THE LANGLEY LABORATORY

The Committee's research laboratory got off to a shaky start. Its first decade was filled with problems that threatened at times to remove the laboratory to a different location, at times to bring all its operations to a standstill. Poor relations with the military services, especially the army, accounted for some of the trouble; difficulties with its own management and administration accounted for most of the rest.¹⁹

Problems with the military arose quickly. The NACA wanted its laboratory to be located at a site shared by the aeronautical research establishments of the army and navy, in fact with all government agencies concerned with aviation. This would have fostered cooperation, minimized duplication, and given the young Committee some much needed prestige by association. The navy, however, never went for the idea. It agreed to assist the NACA in selecting a site but never formally agreed to join the enterprise.²⁰

The NACA initially had somewhat more success with the army, but only by accepting the army's judgment as its own. In the fall of 1916, the NACA, the army, and the navy were all looking for suitable sites and exchanging information on possible selections. The NACA Subcommittee on a Site for Experimental Work and Proving Grounds for Aeronautics, appointed 9 October, participated in the search but played a less active role than the military services. On 23 November 1916, the subcommittee reported to the NACA that the site recommended by the army's selection team—1650 acres of flat land at the mouth of the Back River near Hampton, Virginia—also suited the NACA better than any other location known to the committee. Thereupon, the NACA wrote the army a letter endorsing the site for a joint experimental station and recommending purchase of the land as soon as possible, listing such favorable characteristics as climate, proximity to industry, accessibility, and local labor force. These criteria, however, seem to have been less important to the NACA than joint occupancy with the military services.²¹

The army quickly purchased the land, agreeing to set aside a corner of it for the NACA. Construction delays, however, plagued the army from the first groundbreaking in 1917, leading the chief signal officer to characterize the base as "the neck in the bottle of the aircraft program." Pressed by the demands of war, the army established an airplane-engineering department at the already functioning McCook Field near Dayton, Ohio. With that, the handwriting was literally on the wall. In August 1917, the name of the new Hampton base was changed from "Aviation Experimental Station and Proving Grounds" to Langley Field. This was both a tribute to the aviation pioneer and a hint that McCook Field was to be the real center of army experimental research.

Shortly after the armistice the army's experimental activities at Langley were transferred to McCook and Langley became a general-purpose flying field, home to a heterogeneous variety of army and later air force units. It was never to be the joint aeronautical research center the NACA had wanted. The Committee constructed its first buildings as a disappointed tenant having little in common with its landlord.²²

As a NACA staff began to form at Langley to supervise construction of the laboratory, disappointment quickly turned to friction. Abstract notions of cooperation in the advancement of aeronautics might sound well around a committee table in Washington, but to the men who actually staffed the army base at Hampton the NACA personnel were so many interlopers whose very presence complicated the business of establishing a flying field. Working conditions at the site were by themselves enough to shorten tempers and preclude harmony. One new arrival at Hampton reported: "Nature's greatest ambition was to produce in this, her cesspool, the muddiest mud, the weediest weeds, the dustiest dust and the most ferocious mosquitoes the world has ever known. Her plans were so well formulated and adhered to that she far surpassed her wildest hopes and desires. . . ."²³ For at least the first decade of its history the nascent Langley Field would exist under these adverse conditions, which affected NACA and army personnel alike. Furthermore, many in the army air service were resentful of the NACA's opposition to a separate air force and the friction at Langley Field gave them more than one opportunity to vent their hostility.

The most serious, or at least the most acrimonious, dispute was over housing.²⁴ The town of Hampton was several miles from the field and no public transportation came closer than four miles. On-base housing was almost a necessity. But the army had built what housing there was, and the army wanted to keep it for itself. These were the very years when the NACA headquarters was itself being bounced from office to office within military buildings in Washington. What the Main Committee could not wring from the army, the small staff at Langley surely could not.

Housing was not the only problem. The construction firm under contract to the army to erect the buildings at Langley Field proved so unsatisfactory that the army took over construction, using its own personnel. As the contract had included buildings for the NACA, army personnel found themselves constructing the NACA's laboratory. While this arrangement was very much to John Victory's liking, for it meant that the Committee got free labor, it caused problems of its own. For example, promoting and rating the men assigned to work for the NACA raised questions of fairness, and the NACA was finally led to request a separate detachment for its exclusive use. The tail was trying to wag the dog. Even the operation of the Committee's facilities, when

they were finally completed, created problems. The NACA plot at Langley Field was next to the officers' club; when the staff of the engine-dynamometer laboratory worked late, to take advantage of off-peak-hours electrical power, the noise considerably upset the ambiance of the club.²⁵

The dissatisfaction of both parties at Langley Field reached a crisis in 1919. That summer John H. DeKlyn, the first technical assistant hired by the NACA and the man assigned to oversee construction of the laboratory, wrote to Ames recommending that the Committee abandon Hampton in favor of another site. "Langley Field can never be an efficient or satisfactory place for the Committee to carry on research work," said DeKlyn, primarily because the NACA would continue to be dependent on the army for quarters, power, transportation, roads, lights, and so on and so forth. Furthermore, he thought the Hampton area lacked an adequate labor force and recreation facilities.²⁶

DeKlyn's recommendation was seconded by Edward P. Warner, a young aeronautical engineer recently hired away from the Massachusetts Institute of Technology to become the first chief scientist of the NACA. With the Air Service deciding not to establish its principal research center at Hampton, argued Warner, the only reason for the NACA to remain was that its facilities were already under construction. Militating against remaining were the isolated location and inadequate power. John Victory sent these memorandums on to Ames with the notation: ". . . the conclusions are obvious."

Victory visited Langley in September 1919 and reported that, before the base could become a satisfactory site for the Committee's laboratory, provision would have to be made for room and board for the staff, a new powerhouse, and regular research trips by the staff to other government laboratories. The alternative was removal of the laboratory to another site, assuming the army and the Congress could be persuaded to agree. He suggested Bolling Field, a new air base under construction on a strip of land along the Anacostia River in southeast Washington, D.C.²⁷

The Committee's *Annual Report* for 1919 echoed Victory's recommendation. The reasons for having the laboratory at Langley Field had evaporated, and Bolling Field would place the research staff nearer to Committee headquarters, visiting scientists, and adequate libraries. Furthermore, the report argued, the army was going to need all of Langley Field for its own purposes. "Much direct effort is wasted," concluded the report, "in striving to accomplish results in the face of the difficulties encountered at Langley Field."²⁸

With the formal admission that conditions at Langley were unsatisfactory, the NACA seemed resolved upon a move. However, Congress

showed no enthusiasm for abandoning the buildings already erected for the Committee, and the site at Bolling turned out on further consideration to have shortcomings of its own. There seems no clear moment when the Committee consciously abandoned its resolve to leave Langley Field, but over the next two years it became apparent that the laboratory staff would have to make the best of it.²⁹

The NACA Langley Memorial Laboratory was formally dedicated 11 June 1920. During the ceremonies, Admiral David W. Taylor prophesied that the facility would one day become an aeronautical Mecca.³⁰ Consisting of three modest buildings—a wind tunnel, an engine-dynamometer laboratory, and a research laboratory—encroaching on a none-too-friendly army base, the NACA laboratory appeared unlikely to live up to such promises.



Langley laboratory's wind tunnel #1, shown here in about 1921, was part of the very modest facilities with which the NACA began its career in aeronautical research. (LaRC)

Further darkening the laboratory's prospects as it was being dedicated was the second of its main problems in the early years: internal management. Until 1926 the NACA did not specify how its laboratory would be administered or how it would work with the headquarters. Continuing friction with the army and unsatisfactory living and working conditions only exacerbated what was really an internal problem within

the NACA. At first the Main Committee had expected that George Lewis would take up residence at the laboratory to perform as executive officer from there. But Lewis soon concluded that he could best carry out his duties in Washington. So the Committee still needed a man to run the laboratory, a man who could get along with the army, provide for the staff, and meet the demands of Victory and Lewis in Washington. This was no small order, and the NACA spent several years and considerable unpleasantness filling it.

The first head of the Langley laboratory, John H. DeKlyn, took over in 1917 with the title of engineer-in-charge of buildings and construction. He had more than his share of problems with the army, and all too soon he ran afoul of John Victory as well. Before George Lewis's appointment as executive officer, and even before DeKlyn took up the campaign to relocate the laboratory to Bolling Field, the young engineer-in-charge was involved in the kind of petty dispute with Victory that would infuriate future laboratory directors. Some routine correspondence between DeKlyn's staff and Victory's had been mismanaged, and Victory concluded that the Langley staff showed a lack of "courtesy and sympathetic cooperation" in righting the matter. So he undertook to lecture DeKlyn not only on the mechanics of submitting travel vouchers but also on the etiquette of interoffice relations. Victory was nothing if not efficient, and probably had cause for reprimanding DeKlyn, but there was always something officious and condescending in his tone when he undertook to correct those whom he considered his subordinates. Such letters from him read more like papal bulls than constructive criticism, and they never failed to rankle. DeKlyn, after all, ranked above Victory in both salary and prestige. The head of the laboratory was, in DeKlyn's mind and the minds of many of his successors at the NACA field centers, an engineer doing the Committee's real work, whereas Victory was merely a bureaucrat doing a purely administrative job. DeKlyn was not about to be scolded by a pompous place-filler in Washington; yet getting along with Victory was a *sine qua non* for running Langley. Some time in 1919, DeKlyn simply gave up.³¹

Within a year the situation was critical. After a visit to the laboratory in February 1920, just three months after George Lewis's installation as executive officer, Victory reported:

The station is operating with poor efficiency, morale is low, and effective cooperation . . . does not exist on other than routine matters requiring a minimum of interest or active effort by Mr. DeKlyn. He has subordinated the Committee's best interests and neglected his duties. He has failed to competently supervise the workmen or the administration of his own office, and is undermining the loyalty of the workmen to the Committee.

Victory recommended immediate suspension of DeKlyn and immediate acceptance of the resignation he was reportedly preparing. DeKlyn was not at the laboratory when Victory visited, "having taken leave of absence to visit Pittsburgh in quest of another position," but Victory was told that he was resigning "as a protest against . . . the Washington office."³²

At least two men at the laboratory gave Victory support in his findings and apparently some hope that the situation could be salvaged. Edward P. Warner, the chief physicist, and Leigh M. Griffith, the NACA staff engineer recently assigned to Langley, cooperated with Victory on his inspection and agreed to the remedies Victory prescribed. Soon thereafter Victory was dealing directly with Griffith in the conduct of laboratory business, and two years later Griffith was officially appointed engineer-in-charge.³³

Griffith ran a better show at Langley than his predecessor, but he had more favorable conditions to work under. Relations with the army had improved. Some quarters were at least available. Plans were afoot to build a recreational camp for the staff. The laboratory's facilities were in use, lending a sense of purpose and accomplishment to the activities of the researchers. The staff had divided into working sections set up much as they would remain for the next twenty years. The research was showing results, the staff was growing, and new facilities were being planned. Even a research policy of sorts was taking shape. In short, the future of the laboratory was brightening. Furthermore, Griffith was an old friend and colleague of George Lewis, and their close personal relationship surely eased the course of business between headquarters and staff.³⁴ Still, these improvements were not enough to keep Griffith from clashing with John Victory over administration. In 1924, for example, Victory returned a voucher to the laboratory for "re-execution in a neat and proper manner." The document was the carbon copy of a proposal or requisition that had marks and alterations on it. To Victory it presented "an improper appearance," and he directed that any such untidy document should be recopied before being sent to headquarters. "There is no excuse," he proclaimed, "for such *misdirected efforts at labor saving* [italics in original]."³⁵

In fact, there was an excuse, for the voucher had not been prepared by the laboratory, as Victory had assumed, but by a commercial supplier over whom the laboratory had no control. Since the laboratory was required to send the original copy to headquarters, it had no choice but to foul Victory's in-basket with "an improper appearance." To his credit, Griffith tried conciliation, addressing a "Dear John" letter to Victory in which he suggested that the "degree of personal contact between the Laboratory and the Washington office has been insufficient to ensure that close sympathy and understanding which will

alone prevent the development of small differences due to lack of appreciation of the difficulties and problems of the associated organizations."³⁶

This entreaty had no apparent effect. Within six months, relations between Victory and Griffith had so deteriorated that their correspondence was barely civil, Griffith was looking elsewhere for work, and Victory was recommending his removal. The final crisis was precipitated by a dispute over correspondence policy. Unwilling to argue the fine points of administrative etiquette with Griffith, Victory sought to terminate a quibbling exchange of letters by directing that "argumentative matter, unnecessary matter, and impertinent and irrelevant matter be eliminated from official correspondence," Griffith wrote back the next day, suggesting that Victory take his own advice and rewrite his letter accordingly. That did it. Victory advised Griffith that he was making the whole topic "a matter of official record in order to check a growing practice . . . destructive of discipline and efficiency in the orderly conduct of routine business relations between the Committee and its laboratory." That language foreshadows the charges on which Billy Mitchell would come before a court-martial later the same year. To Griffith it was: "Good evidence of [the] ignorance and impossible attitude of Asst. Secy."³⁷ Before the year was out, both Griffith and Warner had swelled the ranks of promising young engineers who had left the NACA laboratory. Some left because of the generally poor conditions at Langley, or the dim prospects there, or the chance of a better position with industry; but more than one of the departures could be charged to the officious John Victory.³⁸

Griffith was succeeded by Henry J.E. Reid, a young electrical engineer in whom the NACA finally found that rare and indispensable combination of talents: the ability to get along with both the laboratory staff and John Victory, to master both the technical demands of aeronautical research and the bureaucratic demands of administering a NACA field installation. Reid was only 30 when he took over as engineer-in-charge at Langley. He was 63 and in the same post when the Committee went out of business in 1958, and was second only to John Victory in length of service to the NACA.

His longevity and success can be attributed to two things, his professional interests and his disposition. Reid moved up to head the laboratory from the instrument section, where he had pioneered in designing and developing instruments for aeronautical research, most importantly a V-G (velocity-gravity) recorder to measure and record the airspeed and normal acceleration of an aircraft in flight. Because the instrument section did work for all other sections of the laboratory, Reid had come into regular contact with all of his colleagues and had developed an appreciation of their work. This, of course, served him



Henry J.E. Reid in his office in 1928, two years after taking over as engineer-in-charge of Langley Memorial Aeronautical Laboratory. (LaRC)

well when he came to administer the research program at the laboratory; though his time was increasingly given over to administration, as the years wore on, he never lost his interest or his expertise in instrumentation. He kept his hand in, and this helped him understand the problems of his staff and maintain their respect and sympathies.³⁹

Reid's ability to get along with John Victory is a tribute to his disposition. An easy-going man of manageable ego and even temper, he ran Langley with a keen intuition for when to give people a free hand, when to rein them in. Deeply ingrained in him was the engineer's propensity for order and reason. Like Victory, he wanted the NACA organization (and the Langley laboratory in particular) to run like a quiet machine; unlike Victory, he could communicate that wish to his subordinates without being imperious or heavy-handed. An ideal buffer between Victory at headquarters and the staff at Langley, he intervened more than once to the advantage of all concerned. With Reid in place, the organizational and administrative structure that dominated the NACA until World War II was established.⁴⁰

MAX MUNK: THE RESEARCH PROGRAM

But what was the NACA to do? What kind of research would the NACA undertake, and how would it be selected, conducted, and reported? Some of these questions were answered even before the laboratory was dedicated; some were worked out slowly, even painfully, as the Committee's structure and facilities evolved.

The NACA began by dividing aeronautical research among the government agencies involved: the military services, the National Bureau of Standards, and the NACA. The army and navy, it was understood, would do "technical engineering work" aimed at the de-

velopment of specific military aircraft. Most of this research would consist of developing specifications for aircraft, supervising the production and acceptance of prototypes, and testing aircraft to see if they met the standards and if they could be improved.⁴¹

This left to the National Bureau of Standards and to the NACA what both agencies liked to call scientific or fundamental work: research into the basic scientific principles applicable to all kinds of aviation, not just to a certain airplane or type of aircraft the services might be developing. They wanted to study ailerons in general or radial engines, not just the control surfaces or power plant of this or that particular military aircraft. Of course, both agencies did research on request for the services, but they tried to limit this to instances when they had unique facilities the services could not duplicate, or when the research promised some fundamental data applicable to all aeronautics.⁴²

The two most important areas for aeronautical research at the end of World War I were aerodynamics and power plants. The NACA and the NBS divided these, the NACA concentrating on aerodynamics, the NBS on engines. The NBS had been doing research on engines before the NACA was created; as many of the problems related to engines in general were applicable to aviation engines, it was natural for the NBS to continue this work. Because the NACA tried always to avoid duplication and to give a wide berth to the territory of other agencies, it limited its own work on engines and contracted out to the NBS much of what needed to be done. Samuel Stratton, director of the NBS in 1916, chaired the NACA's Power Plants Committee from its inception until he left the NACA in 1931, even though he had departed the NBS in 1922 to become president of MIT. He and his successors up to World War II saw to it that the lion's share of aircraft-engine research went to the Bureau. Of course, the NACA did not neglect engines entirely; George Lewis and Leigh Griffith both came to the Committee with backgrounds in engine research, and the engine-dynamometer laboratory was one of the first structures built at Langley. But the very first test facility built there was a wind tunnel, and what was first was foremost. In the crucial years immediately after World War I the NACA settled upon aerodynamics as its main field of interest, an orientation it never lost.⁴³

Another reason for the NACA to go slowly on engines was that industry already had its own engine-research facilities when the Committee was formed. The pivotal 1916 conference that broke the deadlock over manufacturing aircraft engines for the war had revealed the existence of a considerable engine-research capability in the private sector, independent of the government support and attention needed for aerodynamics and other more esoteric branches of aeronautics.

Unfortunately, the NACA may have relied too heavily on its first impression of the aircraft-engine industry, received when the field was dominated by automobile-engine manufacturers. Because the NACA adamantly refused to admit industry representatives to its Main Committee or main technical committees, it had no sure mechanism for staying abreast of developments. Its neglect of engine research may well have been based in part on a false sense of security.⁴⁴

Nevertheless, the Committee had succeeded in selecting an area of specialization—aerodynamics—claimed by no other government agency but still offering real opportunity to advance aeronautical science. Once its field was chosen, however, the NACA had great difficulty deciding how to proceed. The minutes and correspondence of the early years exhibit a striking lack of technical knowledge within the NACA about how to construct a research program, or what facilities would be needed, or what specific questions should be pursued. The members of the NACA were genuinely convinced of the need for aeronautical research in the United States, yet—with only one or two exceptions—none of them had very much idea about what to do, once the opportunity to prepare a program was before them.⁴⁵

The Committee might have asked its engineering staff for a program, but it did not. George Lewis, after all, had been hired as an executive officer, not as the director of aeronautical research for whom the Committee had been searching. He was an engineer, and what the Committee had in mind was a program of scientific research. Leigh Griffith's memorandum commenting on the Committee's future had contained much advice on the structure of the organization but little on the substance of a program. It was important counsel in its way, as were other early contributions of the NACA's engineers, but more was needed. For this the Committee turned to scientists, and European scientists at that.⁴⁶

First the NACA tried George de Bothezat, a Russian aeronautical engineer of auspicious reputation. After several interviews with Bothezat in the spring of 1918, Joseph Ames wrote to Stratton:

I am convinced that he can be of more use to our Committee, at the present time, than any man in America. . . . He knows more about propellers, design of wind tunnels and all that than any other man in the world, I think. . . .

I beg to urge upon you the imperative need of engaging his services instantly. . . . In my judgement, he should be engaged now as a technical advisor to assist our engineers. . . . They are eager for his help and questions are arising every minute where he can be of untold assistance. . . . His schemes are very far reaching and full of great interest. I know of no plans which are more important for the development of the airplane.⁴⁷

This breathless recommendation might stand as Joseph Ames's greatest error of judgment in a quarter century of service to the NACA, had he not suggested Bothezat be hired only conditionally by the Committee and given an opportunity to prove the assertions he had made in interviews with Ames. Stratton had interviewed Bothezat as well, shared Ames's enthusiasm, and also wanted to see some proof. Between them, Ames and Stratton had more than enough influence to get the NACA to adopt their suggestion. Bothezat was retained by the NACA, in a joint arrangement with the Army Air Service. He would advise the Committee on wind tunnels and a research program, and he would design for the Air Service a propeller suitable for the Liberty engine. If he succeeded in both, the NACA would consider hiring him full time.⁴⁸



The man in the center is probably George de Bothezat. Far left is George Lewis; far right is Joseph Ames. The other two men seem to be army air service officers. This photograph was probably taken in Washington, D.C., or at Wright Field, Ohio, around 1920. (National Archives)

Bothezat began by examining the programs suggested by the NACA's staff engineers. He found them wanting. "They consist merely in a enumeration of different problems that can be investigated," he said, "but without any systematization of those problems." What was wanted was an understanding of "the general spirit that must animate all research in general but special [sic] all aerodynamical research." He explained:

Before a general conception of a problem to investigate is stated, one must take account of all the works made before and submit them to a critical investigation. Afterwards in the problem to investigate there must be reached as far as possible a certain general theoretical standpoint and clear understanding of the connections of the studied

problem to other problems and its relation to the general principals [sic] of dynamics and hydro-dynamics. The last constitutes only the fundamental demand of the continuity of scientific evolution.⁴⁹

In his awkward English, Bothezat was suggesting that the best researches are those enlightened by a knowledge of the previous work in the field and of the theoretical issues underlying the various problems retarding aeronautical progress. A laundry list of possible investigations is no substitute for a thorough understanding of the state of the art and an appreciation of what knowledge is required to advance that state. As he said earlier in the same report, with obvious reference to the kind of research being advocated by the NACA engineers:

Experimental researches or investigations can be of two kinds: Either they simply consist in measurements of some mechanical or physical quantities; Such measurements can be considered as scientific only when they are of a high grade of exactitude; In the other cases they simply constitute routine work. Or the experiments constitute a verification of a general conception of the studied phenomenon. It is the last investigations that generally have the most importance. This kind of conceptional investigations can be undertaken only when they are guided by a deep knowledge of all the studied phenomenon in its whole and its understanding from a unique philosophical standpoint.

Discounting the muddled syntax of that pronouncement, it is possible to see through his inadequate English to the essential idea he was trying to convey. Instead of the "measurements" and "routine work" he saw in progress around him, he advocated "conceptional investigations" based on "deep knowledge" and "understanding." That idea rang true to the charter of the NACA to engage in "the scientific study of the problems of flight." Presumably it was this kind of talk that had so impressed Ames and Stratton.

But Bothezat's influence with the Committee was shortlived, for he soon revealed himself as a better talker than performer. Ames had been warned, even before Bothezat was taken on by the NACA, that while he was "a brilliant mathematical physicist, and very suggestive," he was nonetheless "wholly untrustworthy." Not only did it turn out that Bothezat promised more than he could deliver; he was soon discovered to have a temperament entirely unsuited to the Committee's needs. When an article he published was criticized by Jerome Hunsaker for claiming overmuch, Bothezat called the objections "ignorant criticism." At McCook Field to do propeller work for the army, Bothezat repeatedly modified the research program and never came to grips with the problems he had boasted of being able to solve. At the same

time, he gave overblown public lectures on the possibilities of using jet propulsion for interplanetary travel. His entire record with the Committee confirmed the hunch that he was brilliant but erratic. In the end, the NACA simply let him go as being too temperamental and poorly suited to working in American organizations. Though he seemed to have all the right ideas, he lacked the capacity to reduce them to practice.⁵⁰

Bothezat was soon forgotten at Langley and within the NACA. His successor, however, was unforgettable. Max Munk spent six years with the Committee and did more to shape the NACA's history than any other man in a comparable period of time. A protégé of Ludwig Prandtl, Munk came to the Committee in 1921 from the Zeppelin company in his native Germany, highly recommended by Jerome Hunsaker, who felt that his employment by the NACA would be the cheapest way of obtaining a great deal of unpublished aeronautical information generated in Germany during the war. Hunsaker also felt that Munk's abilities as a theoretician and generalist would allow him to draw conclusions from the work of others at the NACA—that is, from the engineers. Munk, in short, was to be the scientist providing the conceptual framework on which the NACA engineers would hang their researches.⁵¹

At first, Munk was spectacularly successful. In five years with the Committee he authored or co-authored 57 reports, more than any other writer in NACA history except Edward P. Warner. As early as 1922, Dr. Ames—himself a scientist—reported to the NACA annual meeting that “Dr. Munk's work during the past year, in the theoretical side of aerodynamics, has placed the Committee in the forefront of the world.” Two years later, Ames said that “the papers written by Dr. Munk during the past year have done more to make aerodynamics and hydrodynamics a living thing than anything that has happened during the past twenty years.” Even George Lewis, the engineer, shared this original enthusiasm for Munk's work and its value to the Committee. At Lewis's suggestion, Dr. Ames summarized six of Munk's most important reports in a form more understandable and appealing to aeronautical engineers who lacked the “very extensive training in mathematics and physics” necessary to understand them. Lewis wanted to make Munk's work more “readily appreciated by the average aeronautical engineer or designer and to further stimulate his interest so that he will undertake the reading of Doctor Munk's papers in detail.”⁵²

Munk's greatest contribution to the NACA, however, was not the papers he wrote but the wind tunnel he built. When Munk joined the NACA, only a simple atmospheric wind tunnel based on European design was in operation at Langley. Through a 5-foot-diameter test section in the tunnel, a propeller pushed air at varying speeds across a

model of an aircraft or wing section to simulate conditions of flight. The forces on the model were measured by a set of balances. One of the main questions of aerodynamical research at the time was the scale effect: Did the air act on the model in a way determinably proportional to the way it acted on the full-scale body? Even as the NACA's first atmospheric wind tunnel went into operation, it was realized that the answer was no; a scale effect compromised wind-tunnel results, and required correction in a way that could then only be guessed at.⁵³

Munk's contribution was to create a wind tunnel in which the conditions in the tunnel were directly comparable to those in flight. The key to the problem was air density. The forces acting on bodies immersed in a moving fluid (like air) depend on the Reynolds number—a dimensionless mathematical quantity that varies directly with the size of the body, the velocity of the stream, and the density of the air, and inversely with the viscosity of the air. Results from use of a small model could be made comparable to those from a full-size aircraft by increasing the speed or the density of the air, or by reducing its viscosity. The first method was impractical because a one-tenth-scale model would require air speeds in the tunnel ten times those encountered in flight. Even had such a supersonic tunnel been technologically feasible in the 1920s, which it was not, it would have produced compressibility effects even more distorting than the scale effect. The third method, reducing viscosity, was theoretically possible by reducing the temperature in the tunnel, but this too was beyond the technology of the 1920s. The only practical factor to vary was the air density. This could be done by increasing the pressure in the tunnel. If ten atmospheres of pressure could be generated in a wind tunnel, then tests of a one-tenth-scale model would produce usable results.⁵⁴

Though all this was known before Munk began his work for the NACA, no use had been made of it. It was Munk who translated the theory into a practical proposal and designed the variable-density wind tunnel, essentially a tunnel in a bottle. A conventional annular-return wind tunnel with a five-foot test section was entirely enclosed in a steel tank 10.5m long and 4.5m in diameter. The tank could withstand pressures of 21 atmospheres, so that almost any model of reasonable size could be tested under conditions comparable to those encountered by a full-scale aircraft in flight.

Though greeted with some skepticism at home and abroad, the variable-density tunnel worked, and it began a revolution in aeronautical research. By the end of the decade, other countries began building similar tunnels. The NACA became famous for innovative research techniques and tools, and used this fame to win more funds from Congress for equally innovative facilities and equipment in the years to come.⁵⁵ Munk's fame also increased, not only for the tunnel but also



Max Munk in front of the variable-density wind tunnel that made his reputation, and the NACA's. (LaRC)

for the research he conducted with it. Early in the tunnel's life, Munk used it to test his new theory of airfoils. From this work flowed the achievement for which the NACA is perhaps best known among aircraft designers: the NACA family of airfoil shapes. By designing, modeling, and testing whole series of airfoils in which such characteristics as camber, maximum thickness, and chordwise thickness distribution were varied slightly and systematically in each successive model, the NACA was able to provide designers with a wing section for every purpose: that is, a family of sections in which the characteristics of each were so well defined that a designer could simply select off the shelf the one best suited to the aircraft he was designing.⁵⁶

All of this began with Max Munk, but he was not around to share in the harvest. However popular he may have been with Joseph Ames and other members of the NACA, he was not well liked at the Langley laboratory, where he headed the aerodynamic research section. Like Bothezat before him, Munk was arrogant and eccentric, and the English language would never quite do what he wanted. Like many geniuses, he had a mind filled with as many crackpot schemes as flashes of bril-

liance; his utterances supplied ample evidence that he was simultaneously an aerodynamical wizard and an unstable charlatan. No one, it seems, was neutral about Munk, and he was forever at the center of controversies characterized by extremely strong opinions on all sides.⁵⁷

The NACA tolerated him for a while because so few had his experience or his credentials. But, as the Committee staff grew and matured, Munk's position became more precarious. Engineers were taking over the Committee staff, in part because of their sheer numbers, in part because of the positions they held. In 1924 George Lewis was made director of aeronautical research. The Committee thus abandoned its effort to find a scientist for the post and settled instead on the engineer who had used his position as executive officer to take over technical direction of the NACA. The head position at Langley was now designated engineer-in-charge. In 1923 there were only two positions for scientists at Langley; one of these was vacant, one was filled by an engineer.⁵⁸ In these circles, Max Munk was increasingly out of place. Late in 1923, Leigh Griffith revealed the extent of the friction when he wrote to Lewis about staff comments on a technical report:

With reference to Dr. Munk's criticisms in the present case, it is rather unfortunate that he is not more familiar with current standard American nomenclature and is therefore inclined to criticize terminology not in agreement with his own peculiar ideas. . . . As a general rule, it would seem highly desirable that criticisms of research reports dealing with actual research laboratory results should not be undertaken by theoreticians since the viewpoint of the theoretician is usually so radically different from that of the laboratory research man.⁵⁹

The snobbery underlying that argument is the same one that fuels most role disputes between scientists and engineers. The scientist sees things purely, and speaks with the condescension of the purist; the engineer labors in the field and deals every day with the practical exceptions to the scientist's theories. Seldom does either have the sympathy and experience needed to appreciate fully the strengths of the other's work. The scientist disdains the engineer as a pedestrian tinkerer, with dirty fingernails and blinkered eyes. The engineer resents the scientist as an impractical dreamer designing castles in the air and proving that bumblebees can't fly.⁶⁰

Such men can work together, but it takes a competent referee. Neither George Lewis nor H.J.E. Reid was equal to the task. When Reid took over as engineer-in-charge at Langley, he promptly locked horns with Munk over the latter's habit of communicating directly with headquarters.⁶¹ Reid viewed Munk as just another staff member of the laboratory; Munk saw himself as an eminence of sorts, with special



A handful of men were capable of both science and engineering. One such was Theodore von Kármán (the dramatic figure in the center), shown at Langley laboratory during a visit to the United States in 1926. Like Max Munk (front row, third from left), von Kármán was a protégé of Ludwig Prandtl, who immigrated to the United States and influenced the course of the NACA's history. (LaRC)

privileges. Still, things might have been smoothed over had Munk not run afoul of George Lewis. The NACA records do not reveal exactly what the dispute was about, but they do show that it was intense, personal, and bitter. Munk later called Lewis a “liar and a slanderer,” accusations that appear entirely at odds with Lewis’s reputation.⁶² Lewis for his part could barely bring himself to deal with Munk even years after the dispute. Whatever it was that brought the two men to such a pass ended Munk’s career with the NACA forever, and it ended as well the role of the brilliant, eccentric, independent scientist on the Committee staff. There would be other scientists in the NACA, even brilliant ones who would make substantial theoretical contributions to the field of aeronautics, but never again would there be a prima donna working independently of the engineering team. Lewis’s fight with Munk was personal, but it climaxed a running dispute that was essentially professional and philosophical. The engineers won.

The departure of Munk was a watershed in the history of the National Advisory Committee for Aeronautics. Lewis now reigned at the top of a hierarchy that would direct the course of NACA research for the next twenty years. Munk and Bothezat had given the young committee theoretical guidance in its formative years, but now Lewis meant to replace their volatile genius with a *research process*, a well-oiled machine that would make aeronautical progress routine. As the *Annual Report* declared in 1926, the year of Munk's departure:

Reviewers of the progress in aerodynamics in the past have usually found that the theory had advanced at a greater rate than its practical application. This is a natural phase in the development of a new science. However, it is apparent that the time has now arrived when the main theoretical foundation has been laid and we may expect in the future to find extensions of and additions to existing theory rather than new fundamental conceptions. We are therefore entering into a phase of refined and applied theory, as shown by the developments during the past year. This phase demands that theory be developed in detail to fit peculiar requirements or to explain unusual phenomena.

The annual report of the previous year had set the tone: "There is nothing in sight at this time to indicate the probability of the discovery of a revolutionary principle contributing any great or sudden improvement in aircraft," it said,⁶³ blind to the fact that discoveries are by definition out of sight. Gone with Munk and Bothezat were the vision and conceptualization with which they hoped to guide and inform NACA research. They were always looking for revolutionary principles; with helicopters, jet propulsion, swept wings, and countless other discoveries yet to be made, their belief in creative imagination would seem to have as much merit as the conservatism of the NACA.

Not to George Lewis, however. To him, the "scientific study of the problems of flight" was a means, not an end. The end was "their practical solution," and upon that goal he focused. He set himself and his staff on the road to refining flight as it then existed. The process he established by 1926 was based on the belief that a smoothly running research organization holds the greatest promise of technological progress. In 1926 he sent to H.J.E. Reid a long quotation that captured his notion of how the NACA should work:

A research organization is a body of scientists that are combined through system and regulation into a coordinated whole. Every successful research-laboratory director is an organizationist, a believer in the smoothly operating machine of management. All of his research men work together for a common end.

MODEL RESEARCH

The value of direct cooperation, or concerted teamwork, among the members of a research laboratory cannot be overemphasized. There should be no tendency toward purely individualistic work; an appreciation of the importance of mass action in achieving results should be firmly established from the start. . . .

No research man is a complete unit of himself. He requires the contact, the stimulus, and the driving power that are generated by his association with other research men, in his own organization, as well as at meetings of professional societies.⁶⁴

No room there for a Max Munk. For better or for worse, the NACA by 1926 was committed to a research philosophy that valued process over prescience, the team over the individual, experiment over theory, engineering over science, incremental refinement of the existing paradigm over revolutionary creation of new paradigms. On this commitment the NACA built its success and prepared its downfall.⁶⁵

5

Working With Industry, 1926-1930

The years 1926 and 1927 witnessed dramatic changes in both American aviation and the National Advisory Committee for Aeronautics. The Air Commerce Act established for the first time official government control and support of civilian aviation. The navy and army aircraft-building programs ensured strong aviation arms in both services and produced "the only time during [the first half century of American aviation] when the United States had a consistent, planned policy in peacetime for maintaining a healthy level of aircraft production." The American aircraft industry emerged from its postwar slump and enjoyed a period of sustained growth and prosperity.¹

By far the most dramatic catalyst to the advancement of American aviation in the second half of the 1920s was Charles A. Lindbergh. His solo flight from New York to Paris in the summer of 1927 caught the imagination and the hearts of the American people as had no other event in the twentieth century. Overnight, he became a hero and aviation gained a popularity and respectability that the Wright brothers, Eddie Rickenbacker, and Billy Mitchell had been unable to bestow upon it. "More than any other single factor," historian John B. Rae has observed, "his flight sold the American people on commercial aviation." Even the NACA felt the immediate popular impact. Lewis wrote to John J. Ide in September of 1927 that "since the Lindbergh flight the business of our Intelligence Office has increased practically 100 per cent."² There was a fever in the land to know about aviation, perhaps even to give it a try.

THE NACA STYLE

As these events were changing American aviation, the NACA was also changing. At the Langley Memorial Aeronautical Laboratory, Max Munk was out and Henry J.E. Reid was in. The triumph of engineering over science did not entirely please the Committee, but there seemed

no alternative. Reid made things work, Munk made trouble. The only remedy was to replace Munk with someone more congenial to the staff.

At headquarters, Walcott died in 1927 after having reluctantly accepted election the previous fall to an eighth consecutive term as chairman of the Main Committee. In his place the NACA elected Joseph S. Ames, who had been chairman of the Executive Committee (the real locus of power) during the same eight years. With Walcott's passing, the formative years of the NACA came to an end. His genius had been political and organizational, consummating in the give and take of Washington politics the dream of establishing for the United States an aeronautical research organization rivaling those of Europe. He, more than any other individual, had guided the campaign through the frustrating years of failed commissions and stalled legislation, and had ensured for the nascent committee an acceptable status within the



Joseph Sweetman Ames, chairman of the NACA 1927-1939. (LaRC)

government hierarchy and the American aviation scene. Although he never mastered the technology of aviation, as a bureau-builder he was without peer.³

With Ames installed as Walcott's successor, the triumvirate that would rule the NACA until World War II was in place. Ames's eleva-

tion to chairmanship of the Main Committee gave him the title and prestige to match the power he continued to hold as chairman of the Executive Committee. From nearby Baltimore, where he rose from professor to president of Johns Hopkins in 1929, Ames commuted one day a week to Washington to conduct the Committee's business; he held himself available by telephone at other times. George Lewis and John Victory ran the agency day-by-day, Lewis the technical aspects, Victory the administrative. Both were sincere admirers of Ames and did their best to carry out his wishes. In Ames's absence, they enjoyed considerable authority but tried always to conform to what Dr. Ames would want.⁴

The professional training and temperament of these three men determined the public image of the NACA: Ames the scientist, Lewis the engineer, Victory the bureaucrat. Nominally, the arrangement was hierarchical and triangular with science at the top, engineering and administration at the base angles. But very often over the years it was difficult to tell where one left off and the others began, let alone which one was on top. One thing remained clear: the show would be run from Washington. All three men realized that the aeronautical research to which the NACA was dedicated was conducted at Langley, but they also realized that Langley could not survive by itself. The headquarters was needed to secure funds, mend political fences, prevent duplication, and keep the Langley program in line with the needs of the NACA's customers, especially the military services and the aircraft industry. The laboratory that came into the hands of Henry Reid in 1926 was an undeniably versatile and powerful tool for executing the Committee's program, but it was no more than that. Its purposes must always serve those of the Committee, not the other way round. In a Freudian slip of startling clarity, Ames wrote to Lewis in 1924: "I was very glad to get your letters, & to hear of your visit to the Laboratories. We are the real people." Of course he meant to write "They are the real people." This was part of the catechism of the headquarters. But Ames and Lewis knew where the real hope for the NACA lay: it lay with the leaders in Washington and their ability to steer the agency through hazardous political waters into safe harbor.⁵

While Ames, Lewis, and Victory took charge in the late 1920s, other events were influencing the course of the Committee's history. In a move that had been under way since the passage of the Air Commerce Act in 1926, Congress in 1929 increased the membership of the Main Committee from 12 to 15. Originally this idea had been suggested to make room for the assistant secretaries of the army, navy, and Department of Commerce, whose posts had been created by the 1926 legislation. As passed, however, the 1929 bill required only that the three additional members have the same qualifications as the origi-

nal members from private life: i.e., that they be "acquainted with the needs of aeronautical science, either civil or military, or skilled in aeronautical engineering or its allied sciences." In theory, private members now could outnumber government members eight to seven. However, one of the new positions was reserved exclusively for the assistant secretary of commerce, and the tradition of majority government representation on the NACA was never violated.⁶

In 1927 the "Rules and Regulations for the Conduct of the Work of the Committee" were amended to provide that the members of the Main Committee would elect from their number a vice chairman instead of a secretary. Retired Admiral David W. Taylor, a member of the Committee since 1917 first as a navy representative and then as an at-large member from private life, was elected vice chairman in 1927 and annually thereafter until he retired from the Committee in 1938. He came into the offices every day, serving ably as executive officer to the absent Dr. Ames. John Victory was elevated to the position of appointed secretary, and two years later his chief aide received the title of assistant secretary.⁷

Also in 1927, Congress amended a provision of the Army Five Year Aircraft Program that had assigned to the NACA review responsibilities for aeronautical patents submitted to the government. The new procedure strengthened the Committee's role and led to creation of a Committee on Aeronautical Inventions and Designs, which sat until the beginning of World War II.⁸

Other new committees appeared as well, corresponding to the branches of aeronautics that the NACA considered worthy of special attention. Main technical committees on Aircraft Accidents (1928-1941) and Problems of Air Navigation (1928-1935) reflected increased concern with the problems of aircraft operation and the safety of commercial aviation, as did the new subcommittees on Instruments (1928-1935), Meteorological Problems (1928-1958), and Problems of Communication (1928-1930). Some subcommittees were merely signs of the times, like Aeronautical Research in Universities (1928-1930), which existed while the Daniel Guggenheim Fund for the Promotion of Aeronautics was actively establishing aeronautical laboratories at selected colleges and universities around the country, and the subcommittee on Airships (1927-1940), which sat while these dinosaurs of the air were in their heyday. At least one committee—Aircraft Structures (1927-1958)—marked the beginning of a long-term NACA commitment to a new line of research.⁹

None of these organizational adjustments proved as significant as the solidification of the NACA leadership at headquarters and at Langley Field, for in the absence of a Max Munk or a technically knowledgeable Main Committee it was Ames, Lewis, Victory, and Reid who would

determine the Committee's course in aeronautical research. Or rather they would manage the system through which the research program evolved. By 1926, the main function of the NACA had been clearly defined as fundamental research, with heavy emphasis on aerodynamics. The question that remained was: What would be the specifics of the program? How would the NACA determine what project to undertake next, what fields to enter, what subjects to ignore or leave to others? Munk, with his broad knowledge and intuitive grasp of theory, had always seemed to know.¹⁰ Without him, the NACA had to rely on a process of screening and consultation to determine by consensus what seemed best.

As it evolved in the 1920s the process worked like this: The Committee received suggestions for research projects from three primary sources—other government agencies, most often the military services; the NACA staff, especially the staff at Langley; and outside sources, most often aircraft manufacturers. Requests from the services or other government agencies went directly to the Executive Committee and were approved without question, so long as they did not duplicate work already under way at Langley or elsewhere. Proposals from other sources went to an appropriate subcommittee for evaluation on their technical merits and, if approved there, were sent to the Executive Committee. After 1926, George Lewis insisted that all recommendations from the Langley staff be routed to him before going to the technical subcommittee, an attempt on his part to prevent zealous staffers from selling their pet ideas to one of the subcommittees and foisting on Lewis a project he did not want. In all these proposals, the NACA looked for investigations that promised to reveal some fundamental aeronautical knowledge applicable to all flight, not just to the prototype or assembly or instrument that was causing a problem or raising a question. For the military services, however, the NACA met all requests, whether for fundamental research or not.¹¹

When a project was approved, a research authorization was signed by Ames and forwarded to the Langley laboratory for execution. All research at LMAL was conducted under a research authorization, at least in the early years, and each RA was expected to lead to the publication of a NACA report. After 1920, the NACA began to publish preliminary results as "technical notes," a less formal typescript document used by the Committee to disseminate information not yet ready for final publication.¹² Minor amendments could be made to research authorizations in the course of the investigation, but large changes usually resulted in a new RA and ultimately a different report. Regular review of active research authorizations led to cancellation or consolidation of those that proved less productive.¹³

One feature of the research authorizations, especially those initiated by the staff at Langley, differentiated Ames and Lewis somewhat. Like Bothezat and Munk and other scientists, Ames believed that the researcher must be granted the maximum amount of freedom in determining how to conduct his research; for Ames, serendipity and inspiration were as important in research as the rational structuring of a program. George Lewis, the engineer, agreed up to a point, or at least paid lip service to the notion. For example, he told the staff at Langley in 1924 that "research authorizations . . . are intended to be rather broad in scope so as to permit the technical staff to use their own initiative in pursuing the problems."¹⁴

Ames, however, seems to have meant something else when he spoke of initiative. He would have the researcher play an active role in selecting and formulating the investigations he was to conduct. For Ames, asking the right questions was a necessary precondition of getting the right answers. In 1922 he criticized the National Physical Laboratory of England for failing to embrace this principle.

Their method is this: There are subcommittees of the Advisory Board dealing with the various subjects. They decide what problems are to be investigated. Suggestions are made to these subcommittees by the actual laboratory workers themselves in the shape of research programs. The Advisory Committee passes upon the programs. The N.P.L. is not free to undertake investigations without this approval; they have no initiative in regard to investigations until authorized.¹⁵

What is most remarkable about this comment is that Ames was describing the very process that the NACA would adopt as soon as Munk departed. As late as 1925, Ames was still leveling the same criticism at the British. He told the Morrow Board:

England, in my judgement, has the best men working on it [aeronautics]. I think their men, man for man are better than the men we have. But they lack a workable organization and facilities. . . . They lack opportunity for initiative. Their men are not allowed to undertake problems that they think of themselves. They undertake problems handed down by the Air Ministry.¹⁶

To the extent that the Air Ministry was a body separate from the N.P.L. and thus not a part of the research process, Ames's argument had some merit. But he either did not know or deliberately ignored the extent to which George Lewis was attempting to funnel all internal initiative through his own office. Lewis did not object to the fact that the ideas surfaced at Langley: in fact, he seems to have agreed with Ames that this was a normal part of the research process. He differed with Ames over the amount of autonomy the researcher should have in

pursuing these ideas. Ames would have given the researcher his head, whereas Lewis wanted such initiative pursued only with the approval of headquarters.¹⁷

This difference in perspective is apparent in the different ways they dealt with Max Munk. Ames was genuinely proud of Munk and his contributions to the Committee. He spoke of the Committee's irreparable loss when Munk left. Lewis was not unmindful of Munk's contributions, but he had to deal with the man every day, and when they parted company it was with bitterness and hard words. Ames could contemplate the advance of aeronautics from his study in Baltimore, but Lewis had to make the NACA organization function, and for that he needed discipline, order, and team players. In 1931 Lewis sent to Langley laboratory the following quotation from a recent speech by Herbert Hoover in praise of Thomas Edison:

I may emphasize that both scientific discovery and its practical application are the products of long and arduous research. Discovery and invention do not spring full-grown from the brains of men. The labor of a host of men, great laboratories, long, patient, scientific experiment build up the structure of knowledge, not stone by stone, but particle by particle. This adding of fact to fact some day brings forth a revolutionary discovery, an illuminating hypothesis, a great generalization or practical invention.¹⁸

To Lewis, this summary "so aptly cover[ed] the aims and purposes of the Committee" that he directed it be framed at Langley and hung in the office of the engineer-in-charge or the corridor of the administration building.

Lewis and Ames viewed the work of the Committee from different vantage points, Lewis from the engineer's, Ames from the scientist's. In large measure they agreed, but clearly disagreed in subtle ways difficult to document. Understanding these slightly different perspectives makes the following extract from the *Annual Report* of 1930 more revealing.

Previous summaries of the progress in aerodynamic development called attention to the fact that the main theoretical foundations of this new science have been firmly laid and that the present work is necessarily restricted to extensions of or additions to existing theory. This does not mean that no important theoretical work is being done; it means that practically all of the present work is along lines previously laid out and that no new outstanding general problems are in sight. With this explanation it may be stated with confidence that problems of a basic or fundamental nature are now receiving far more attention than at any time in the past . . .¹⁹

In other words, Munk was no longer needed. Nor did the researcher need much guidance in staying on course. The NACA (read George Lewis) knew where it was going, and decisions on how to get there would be more political than theoretical: how to avoid duplication, how to answer the needs of industry and the services, how to stay off the toes of others in the field. There was a hazard in this attitude. It contains a serious logical inconsistency, but it was one that both George Lewis and Joseph Ames could live with. Anyone who approaches scientific research with the assumption that the existing theoretical framework is both correct and adequate is unlikely to discover evidence at odds with that framework. The essence of scientific research is skepticism and unbiased evaluation of evidence. The excerpt from the 1930 *Report* implies condemnation of Munk's style of research, the pursuit of original ideas that might be brilliant or crazy. Lewis could not tolerate such a pursuit in his day-to-day running of the laboratory; Ames, more inclined by nature and experience to indulge it, had to guard against antagonizing the Committee's clients and supporters. Lewis and Victory drafted the report out of their concern for engineering and administration; Ames signed it presumably out of his concern for politics. If the report fell short of his ideal of a research ethic, it nevertheless addressed itself to fundamental research and claimed as much as was possible for a government agency.²⁰

The research process worked out by Ames and Lewis in the early 1920s and instituted in full after Munk's departure was a compromise of sorts, but one that worked exceedingly well. It allowed for review of all NACA research when first proposed and at various intervals thereafter. Because the technical subcommittees evaluating and monitoring the research contained experts in the various branches of aeronautics, there was some guarantee that the subjects chosen for research were the best and most promising ones. Because the Executive Committee contained representatives of all the parties interested in aeronautical development (except industry), there was some guarantee that duplication was being avoided and that the NACA was not straying into someone else's territory. In practice, Lewis and Ames often gave their approval—individually or jointly—to some research project without consulting either the technical subcommittee or the Executive Committee.²¹ When there was any doubt, however, they fell back on the process, for there lay consensus and caution. The system may have lacked brilliance and inspiration, but it provided a rational and defensible system of research selection.

The Committee did retain some of the daring and originality of Max Munk in its development of research equipment. The success of the variable-density wind tunnel enhanced the reputation of the Committee and emboldened Lewis to propose a new departure. When it

was suggested to Lewis that propeller research had reached an impasse because the scaling corrections required for the small tunnels then available yielded unsatisfactory results for the high tip-speeds then of interest, he took the problem to Munk. With the latter's concurrence, Lewis initiated a request for funds to build a propeller-research tunnel with an unprecedented 6-meter throat that would allow full-scale testing of propellers and would obtain results comparable to those achieved in the variable-density tunnel for airfoil and airplane models. The power required to run air through such a tunnel at an acceptable speed was enormous, but that bothered neither Munk nor Lewis. They saw the request through Congress and had construction under way in less than a year.²²



An aircraft fuselage with a NACA cowling is installed in the propeller-research tunnel at Langley laboratory, 1929. (LaRC)

The propeller-research tunnel, which went into service in 1927, proved as revolutionary and effective as the variable-density tunnel. By the time another dramatically new tunnel was proposed, Munk was no longer with the Committee, but Lewis went ahead on his own. In 1928 he recommended construction of a full-scale wind tunnel that could accommodate actual aircraft. At the time, the propeller-research tunnel had the largest throat of any in the world (6 meters) and most tunnels

were in the class of the other two at Langley, 1.5 meters at the test section. Lewis was proposing nothing less than a tunnel with a test section 9 by 18 meters. Because the other tunnels had been so successful and so productive, the Bureau of the Budget and Congress approved even this huge request, and the fiscal 1930 budget included \$525,000 in construction funds to begin the work. This single tunnel would finally cost almost three times as much as all the other buildings constructed at Langley in the laboratory's first 12 years, including 3 laboratory buildings, the atmospheric tunnel, the variable-density tunnel, hangars, and the propeller-research tunnel.²³

In the same year that this money was appropriated, Congress also allotted to the NACA \$208,000 to construct a towing tank to study seaplanes. This project also was recommended by Lewis, this time on the basis of a trip to Europe to examine the laboratories of the competition.²⁴ With the NACA's reputation and boldness growing, the Committee was now trying to secure its newly won position as the best equipped and most productive aeronautical-research establishment in the world.

The building program of the late 1920s was heady stuff, but—like all intoxicants—it had its dangers. In this case the hazard was that the tools of research would become more important than the research itself. The new wind tunnels were magnificent engineering specimens, the kind of machine with which an engineer could easily become enamored. A researcher forced, for lack of equipment, to stand at his blackboard or look out the window is not likely to lose sight of the big picture. Too often, that is all he sees, for he lacks the wherewithal to test or pursue his ideas. On the other hand, if an engineer has a wind tunnel he will use it—and it will use him. The NACA engineers at Langley Field, possessed of the best research equipment in the world, climbed into their tunnels and promptly lost sight of events outside those narrow chambers. They produced magnificent results in applied aerodynamics, but, as time went by, other fields would need—and fail to receive—equal attention.

INDUSTRY AS CLIENT

The danger was not apparent in the late 1920s, years of growth and promise and excitement. The events of 1926 and 1927 had created a boom in American aviation, and the NACA was riding high on a crest that carried along other elements of the field as well. Not least of these was the aircraft-manufacturing industry, recovering at last from the collapse that followed World War I. Orders for new and improved aircraft were pouring in from the military and from private carriers,

and industry turned to the NACA for answers to the problems posed by these requests. The NACA, for its part, took the industry's demands seriously, believing that both civil and military aviation were worthy of experimental research. The Committee went so far as to state in 1927 that "civil aviation must in itself be regarded as one of the most important factors of civilization."²⁵

Industry's need for NACA research and the Committee's determination to help industry raised the question of how the parties should communicate. How should the industry make its needs known to the NACA? How should the Committee report its results to industry? The simplest and most direct solution was membership on the Main Committee and the main technical committees for industry representatives. Suggestions of this sort had been made as early as 1919 but had always been rejected. Industry representation had been limited mostly to the technical subcommittees. In the years between the world wars, industry maintained about the same relative strength in numbers while making some positional gains. The Aerodynamics Committee never had industry representatives. Power Plants for Aircraft did briefly, but these were purged soon after World War I. Materials for Aircraft always had representatives from industry, largely because there was no other source of expertise in fields such as metallurgy for aircraft. Industry representatives also appeared in the 1920s on subcommittees of Materials for Aircraft, such as the subcommittees on Metals and Aircraft Structures. When the Committee on Problems of Air Navigation was formed in 1928, it contained industry representatives, including one who was chairman of the Subcommittee on Problems of Communication.²⁶

From the industry's point of view, however, it seemed that the technical committees proposed and the Main Committee disposed. The Main Committee made the final decisions on the course of NACA research, at least nominally, and it was there that the industry looked for representation. The strongest voice in support of such a move in the 1920s was Edward P. Warner, the former chief scientist at LMAL in 1919 and 1920. Warner spoke with authority, for his remarkable career in aeronautics was already well launched. From LMAL, he had returned to MIT to teach aeronautics. In 1926, at the age of 31, he was appointed the first Assistant Secretary of the Navy for Aeronautics. Three years later, after moving from the navy to the editorship of *Aviation*, Warner was appointed a member of the NACA.²⁷

Since 1920 Warner had been a member of the Committee on Materials, and with that experience in mind he wrote to Ames in 1927 recommending more "liberal representation to industrial and other non-governmental . . . interests" on the main technical committees,



The only NACA staff member ever to serve on the Main Committee, Edward P. Warner was chief physicist at the Langley laboratory in that facility's early days before returning to the NACA as a member from 1929 to 1954. (LaRC)

i.e., Aerodynamics and Power Plants. He felt "three or four representatives of the aircraft industry" could broaden the effectiveness of the committee, and his service on the Materials committee revealed no "instance during the last five years when subjects [were] discussed which could not properly have been gone into before, and with, the representatives of the industry or when their presence would have been otherwise than beneficial."²⁸

Ames brought Warner's suggestion to the attention of the Executive Committee, which promptly referred it to the Committee on Personnel, Buildings, and Equipment. There, the objections of George Lewis carried the day. Lewis feared that the committees would become unwieldy if members from industry were added, and he doubted that a satisfactory scheme could be formulated for equalizing representation of the various industry interests. He recommended that industry membership be limited to the technical subcommittees. The Committee on Personnel, Buildings, and Equipment concurred, as did the Executive Committee in its turn. The time for a major industry voice in NACA policy was not yet, in spite of the growing power and importance of the industry.²⁹

Although it denied full representation to industry in the late 1920s, the NACA took several lesser steps to promote communication and cooperation. It increased industry membership on technical subcommittees and ad hoc committees. It began systematic visits to factories of major aircraft manufacturers, publicizing the NACA's work and asking about industry's problems. It also paid more attention to civil aviation. As the NACA stated in its *Annual Report* for 1928:

The development of aviation in America during the past year has been amazing, and emphasizes the necessity for the continued study on a large scale of the basic problems of increase in safety and reduction in cost of construction, maintenance, and operation of aircraft. The research programs of the Committee have been enlarged during the past year to serve increasing needs of a growing industry.³⁰

This interest in civilian aviation reflected the lessening demands of the military services in the halcyon years of the late twenties, the growing influence of the aviation industry (both manufacture and operation), and the Committee's longstanding belief in the importance to the United States of commercial aviation and the Committee's responsibility for helping it develop. Through these years the NACA stressed research in noise reduction, safety, and economy—features of aviation not of primary importance to the military.

The Committee's most important concession to industry in the late 1920s was to institute the annual industry conference at Langley laboratory. Beginning in 1926, the NACA invited the leading figures in the field of aviation from industry, academia, and government to Langley for a one-day tour of the laboratory and a briefing on the Committee's work. These trips soon developed into a ritual as important as the tour itself. Attendees would gather in Washington the day before the conference and board a Chesapeake Bay steamer for an overnight trip to the southern end of the bay. After docking at Old Point Comfort in the morning and having breakfast at the Hotel Chamberlain, the attendees would be driven to the field by Langley employees. The morning was given over to a tour of the laboratory. After lunch at the airbase officers' club, the guests would hear the Langley staff report on its current work in carefully rehearsed and choreographed formal presentations. Questions and suggestions were invited throughout. As evening came, the visitors were returned to Old Point Comfort, where they boarded the steamer for dinner and another overnight trip. They were deposited in Washington the following morning.³¹



Those attending the fourth annual industry conference at Langley laboratory in 1929 pose behind George Lewis and the members of the Main Committee (seated). (LaRC)

These conferences flowed like syrup in a tube—smooth, slow, and controlled. Lewis insisted on clear presentations by the Langley staff, free of jargon and technical details, understandable to even the least informed of the guests. Though not unmindful of the useful information that would be exchanged at the conferences, Lewis viewed them primarily as public-relations events, opportunities for the NACA to impress its customers and friends and to keep channels of communication open. Victory, for his part, was the social director. He personally cherished the evenings on board the steamer when great names of aviation met in pleasant surroundings and easy exchange of smalltalk and great ideas. There was opportunity for such as he to rub elbows with the leading lights in the field, who in their turn could hear the NACA story in the most salutary setting. When one distinguished aeronautical engineer at New York University elected to proceed directly to Langley and not waste the time required for the boat trip, Victory waxed indignant. Unable to understand why anyone would pass up the outing he cherished so much, Victory cajoled and badgered relentlessly. Driven to exasperation, the engineer finally asked, “Don’t you think that there is a serious danger of your becoming a complete bureaucrat? In one so young this is a dreadful fate!” The warning was

lost on Victory. He went on orchestrating these excursions with the zeal and singlemindedness of a true believer.³²

In one respect, the annual conferences were enormously successful, for they brought together the leading figures in American aviation for an exchange of information and at the same time cast the NACA in the best possible light, both as cordial host and as exhibitor of an impressive research establishment.³³ The arrangement was not, however, entirely free of problems. Those companies profited most that could afford to send representatives, a condition that favored the larger concerns and widened the gap, at least in the minds of some, between the establishment companies (with whom the NACA already seemed too cozy) and smaller organizations struggling to make it in what was still an intensely competitive field. In the same vein, a real danger existed that results reported by the NACA at these conferences—results still months from publication—could be exploited by one of the attendees at the expense of his competitors. Finally, the industry used this podium to make requests of the NACA, and the Committee felt some obligation to deal with each of these. Doing so, however, could draw the Committee further into short-term practical research and away from the long-range fundamental research to which it was philosophically committed. Industry, after all, had to worry about selling the next prototype and needed answers to questions about that particular plane. The future of aeronautics would matter little to a company angling for a government contract if it were no longer in business when that future arrived.³⁴

This last problem, of course, was not created by the annual conferences, only made more apparent by them. Many problems in the Committee's relationship with the aircraft industry remained to be solved at the end of the 1920s: the conferences only made them more difficult to avoid. Should the NACA do research on industry prototypes? If so, should the results be published, or furnished only to the manufacturer? What proprietary interests did a manufacturer forfeit when he handed the Committee a design or an idea for testing? What fees should the NACA charge industry for research on prototypes, or for other problem-solving? Most of these questions would not be resolved until the 1930s, but they were being asked in the 1920s because the industry by then had a voice strong enough to make itself heard.³⁵

THE USES OF THE COWLING

The most instructive example of how the NACA turned its matured research organization to the service of the aircraft industry in the late 1920s is the famous NACA cowling. The story is familiar to aeronautical circles. At one of the annual conferences at Langley, industry

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representatives asked the NACA to investigate the cowling and cooling of radial engines, then the most popular powerplant for military and civilian aircraft. Within months of beginning work, the Langley staff had developed a new cowling that covered almost the entire engine, greatly reducing aerodynamic drag with no significant decrease in cooling. Dramatic improvement in flight efficiency resulted and the NACA won its first Collier trophy, the prestigious award presented annually "for the greatest achievement in aviation in America, the value of which has been thoroughly demonstrated by use during the preceding year." ³⁶



NACA pilots and mechanics who installed these NACA cowlings on an Army aircraft pose in front of their handiwork in 1929. (LaRC)

What is less well known is that the military services had been the first to ask the NACA to investigate cowling of radial engines. At the first industry research conference, both military and civilian representatives had suggested the cowling of air-cooled engines as a project worthy of the NACA's attention, but it was the military that had submitted the first formal request and it was the military for whom the

first research authorization on the subject was approved. The chief of the navy's Bureau of Aeronautics wrote to Lewis just a week after the 1926 conference to ask for help with the cowling of one of the navy's fighter planes. He noted that considerable work on cowling had been done abroad but none of the results were available in the United States. Like all requests from the military, this one was assigned a research authorization and work began on the prototype mentioned in the letter.³⁷ But this was not the work that produced the NACA cowling.

At the second conference the following year, cowling again attracted considerable attention. In fact, the vice chairman of the Aerodynamics committee judged it to be the "outstanding problem presented to the subcommittees" and recommended on behalf of his committee "a research authorization covering the investigation of cowling and streamlining an aircooled engine, both as a fundamental study and as applied to special types of commercial aircraft." The Committee saw this investigation as an ideal opportunity to serve industry directly and to pursue at the same time a line of research basic to all aviation.³⁸

What the Aerodynamics committee failed to state was that the time was now ripe for this investigation. The industry request was tabled the previous year because the propeller-research tunnel had not yet been completed. This would be the ideal facility for conducting such an investigation. It was large enough to enclose a full-scale engine, precluding the need to correct for scale effects and thus surpassing even the variable-density wind tunnel for verisimilitude. The NACA had gone along with the military request the previous year because it always honored such suggestions, but the real breakthrough on cowling would be made under the industry authorization using the propeller-research tunnel. Shortly after the industry request received a research authorization, Lewis decided to keep the two authorizations for the same investigation entirely separate, on the curious ground that the more recent request applied to commercial planes.³⁹

From the industry investigation came quick and dramatic results. Wind-tunnel tests began in July 1927. By the end of the year the NACA was circulating blueprints and plans for a proposed cowling to industry representatives and soliciting their comments and suggestions. Results were available and ready for publication by the summer of 1928. That November, the Committee published a Technical Note and sponsored an article in *Aviation*, the latter so that "there may be no question in the minds of aircraft people and the public in general as to the fact that the cowling is a N.A.C.A. development." The following year two separate technical reports made public the detailed results of the investigation.⁴⁰

By then, however, the results were already well known. The 60-percent reduction in drag and 14-percent increase in speed predicted by the NACA were demonstrated in February 1929 when a Lockheed Air Express equipped with the NACA cowling established a new trans-continental speed of 18 hours and 13 minutes. The company wired the NACA: "RECORD IMPOSSIBLE WITHOUT NEW COWLING ALL CREDIT DUE N A C A FOR PAINSTAKING AND ACCURATE RESEARCH AND GENEROUS POLICY." Industry representatives and other aeronautical experts on the Collier trophy committee echoed that praise later in the same year. And manufacturers around the world gave the ultimate vote of confidence by adopting the NACA cowling almost universally in the 1930s and later, making this one of the most significant aeronautical advances of the 1920s.⁴¹

The NACA began exploiting this success with the Bureau of the Budget and Congress even before its full dimensions were known, and the hyperbole was breathtaking. Describing to the director of the BoB the NACA cowling's part in the record-breaking flight of the Lockheed plane, George Lewis reported that "the Committee feels that this development is the greatest single advance that has been made in commercial aviation." Somewhat less sweeping (though no less calculated) was the Committee's claim in its *Annual Report* for 1928 that "never before in the committee's history or in the history of the development of aeronautics has the value of a new piece of scientific equipment been so well demonstrated."⁴² The NACA got as much mileage out of the cowling in the halls of Congress as any plane ever got out of it in the air.

Like all successes, the NACA cowling had its share of criticism. Historian of technology John B. Rae has reported Lockheed's claim that the cowling on its Vega aircraft, first marketed in 1927, had been the basis of the NACA design; however, the enthusiastic telegram sent to the NACA by Lockheed after the record-breaking flight of 1929 suggests that this was not the official position of the company. More likely, some engineers at Lockheed took exception to the claims made for the NACA cowling and wanted to suggest that the Committee's work was not entirely original. Chance Vought also provided the NACA with blueprints for one of its planes and an aircraft of similar fuselage and landing gear was used in the NACA experiments. But the correspondence on this transaction contains no evidence that the manufacturer saw any duplication of the kind of cowling it had been using before the NACA experiments.⁴³

The most serious criticism of the NACA cowling was the claim that it was preceded by (and inferior to) the Townend ring, another type of cowling for radial engines developed in England's National Physical Laboratory at about the same time. Townend published his results

before the NACA and thus claimed precedence. The NACA retorted that its investigation had begun before Townend's and proceeded independently of it and, in any event, the cowling it had developed was categorically different from Townend's; while his provided only a ring about the bank of engine cylinders, the NACA cowling enclosed practically the entire engine and incorporated special ducting to pass cooling air over the cylinders. Both cowlings had their merits and both saw wide use, thus feeding the dispute over which was more important or more original. That dispute ended in court, in a series of patent suits that dragged on into the 1930s.⁴⁴

Many of the disputes over the NACA cowling arose from a misperception of what the Committee had claimed for it. The NACA had professed neither conceptual originality nor revolutionary development. In fact, it had decided against taking out a patent on the cowling, leaving that tactic to its competitors and detractors. The NACA did claim that it had done more comprehensive work—original in its way—that had improved on an existing idea. The NACA cowling, said the Committee, was admittedly an innovation of an idea as old as World War I. What was different about the NACA version was that the Committee's better facilities (i.e., the propeller-research tunnel) had yielded better results and a superior configuration.

The last two claims, better facilities and better results, went hand in hand and helped to intensify the controversy. What the NACA wanted most from the cowling was more appreciation and support in Congress. It wanted to make the case that the research facilities of the Committee had helped determine the quality of the product. As the NACA had the best tunnel, so it got the best cowling. The Committee made the latter claim not so much to blow its own horn as to make a case for more tunnels. Nonetheless, the claims sounded like bragging, especially to those informed about the background of the cowling. Furthermore, singing one's own praises—for whatever good and practical purposes—can become a habit.⁴⁵

If the Committee hardened some of its critics with the public display over the cowling, it achieved important results as well. When it had requested an unprecedented full-scale wind tunnel in 1928 at a projected cost of almost \$1 million, Congress demurred. The following year, however, after the success of the NACA cowling became known, Congress authorized the building of not only the 30- by 60-foot wind tunnel but also a new maintenance building and a towing tank for testing seaplane models. These were the first construction authorizations since the propeller-research tunnel had been approved more than four years previously. The message was clear. Demonstrated results from equipment already funded could be parlayed into more new equipment, even to making the Langley Memorial Aeronautical Labora-

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tory the best equipped in the world. It became just that with the construction approved in 1929, if it had not been so before.



The primitiveness of early NACA research is shown in these two 1921 photographs. Above, a model helicopter rotor is tested in Langley's wind tunnel #1, an exception to the NACA pattern of ignoring helicopter research before World War II. Below, a cockpit is equipped with a new airspeed indicator (next to the empty space on the right side of the panel) to aid flight research. (LaRC)



PLEASING EVERYONE

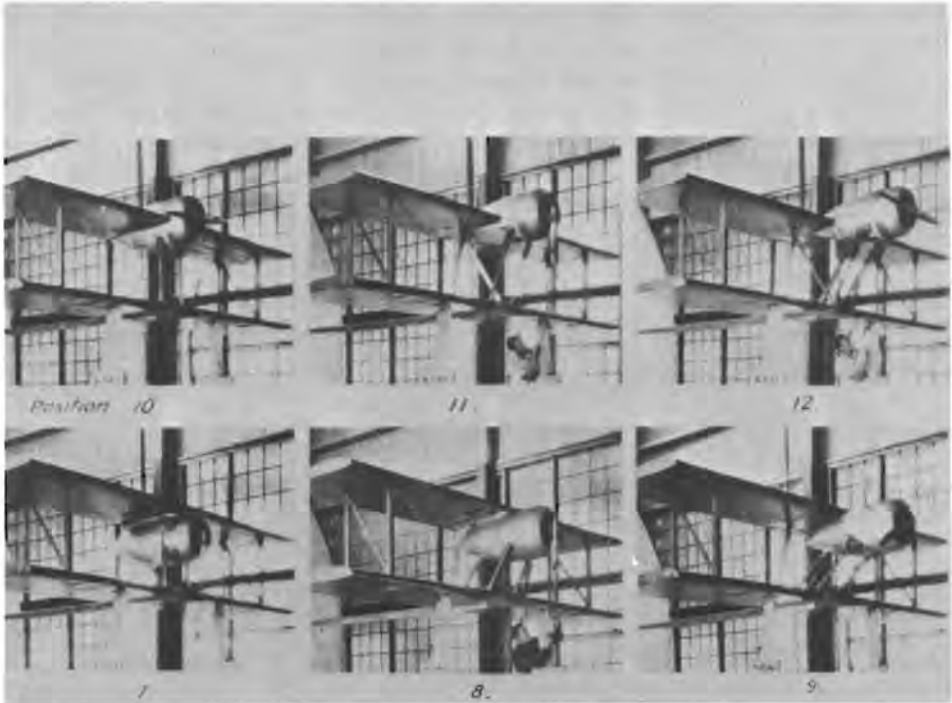
Not all the work done with this equipment was for industry. The NACA continued to work during the late 1920s for its principal customer, the military services. All military requests for research were honored with a research authorization. The Committee on Aeronautical Inventions and Designs continued to be primarily a service for the military as its previous incarnations had been since World War I. Some NACA research applied only to military aircraft: development of accelerometers for aircraft being catapulted from a carrier, improvement of the range of pilot vision in pursuit aircraft, or analysis of stresses on pursuit aircraft in combat maneuvers.⁴⁶

However, most of the NACA's research—whether requested by the military or by industry or by the NACA staff—applied to all flight, commercial or military. As early as 1922, when trying to identify research applicable to commercial aviation, George Lewis confessed an inability to draw any line between the various uses to which aircraft could be put. As he had written to the chief physicist at Langley: "I have been thinking for sometime [sic] of problems which we could properly undertake at Langley Field that would apply directly to the development of commercial aviation but so far have not been able to think of a single problem that does not apply to aviation as a whole."⁴⁷ Devoted as it was to the fundamental problems of flight, the NACA by definition directed its efforts toward problems of wide applicability. For an agency continually called upon to answer the question, "Yes, but what have you done for me lately?", this was not only good programming, it was also good politics.

The advance of civil aviation and military aviation carried about equal weight in Washington in the late 1920s, to judge by the claims made by the NACA. Describing for the director of the Bureau of the Budget in 1928 "Some Accomplishments of the National Advisory Committee for Aeronautics," George Lewis divided his comments almost equally between civil and military aviation. In the military category he cited the development of instruments to measure aerodynamic loads on aircraft and on airships and to measure controllability and maneuverability of high-performance aircraft, determination of airplane-design characteristics that would control spinning, measurement of loads and stresses on seaplane bodies and floats, and improvements in propeller design and construction. For commercial aeronautics, Lewis listed cooling and cowling of aircooled engines (overlooking the fact that this work had first been requested by the military, and was equally applicable to military aircraft), reduction of interference effects created by the junctures of wing and fuselage, and development of standard sets of wing sections and of a diesel engine for aircraft. Lewis

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also mentioned the Roots supercharger, though he left it unclear whether this was a military or a commercial development. In fact, almost all the work he cited was equally applicable to all kinds of aviation, and Lewis's division into military or commercial categories seems to have been arbitrary. His real message was that the NACA's work had meant rich returns on the dollars invested by the government.⁴⁸



Among NACA researches applicable to both military and civilian aviation were these 1933 tests to determine the best location for engine nacelles with respect to wings. (LaRC)

The NACA clearly intended to please its entire constituency, not only in the substance of its work but also in the style of its operations. Here again the Americans had found in the British copybook another example of what to do and what not to do. The Royal Aircraft Factory—roughly an English counterpart of LMAL—had reportedly “got into very considerable disrepute” within military and manufacturing circles in Britain in World War I, causing a decrease in support of aeronautical research. The British engineer brought in to remedy the situation reported to Joseph Ames in 1919 that he had turned things

around by exploiting his "personal acquaintances" with manufacturers and army officers "and inviting everyone I met to come down quite freely and welcoming them in every possible way."⁴⁹ The NACA had formalized this type of contact by means of its annual industry conferences, but it kept up an informal liaison as well. After the Committee got its own airplane in the 1920s, Lewis flew to the Langley laboratory once a week and was more than happy to take influential people with him.⁵⁰ Victory was constantly inviting congressmen and important executives from government and industry to tour the laboratory and see the NACA at work.

The Committee's courtship of influential friends reached its most blatant and controversial heights at the "N.A.C.A. Shore Camp," known more familiarly as just "the camp." Located on the Back River about two miles from the laboratory, the camp was openly and explicitly created, as John Victory said, "first, to provide an inducement for government officials to visit the laboratories of the Committee and become familiar with the work of the Committee; second, to promote the morale of our own employees at Langley Field." Laboratory members—using time and materials they claimed were their own—built a small lodge on a piece of waterfront property apparently owned by Lewis, Victory, and three laboratory officials. The NACA launch *Retriever* provided passage to and from the camp. Annual rental came out of the Laboratory Camp and Entertainment Fund.⁵¹

In the humdrum environs of Hampton the camp was a real boon to the morale of the Langley staff, but that was not its chief value to the NACA. The most frequent non-NACA visitor to the camp was Congressman Clifton A. Woodrum of Roanoke, Virginia. "Judge" Woodrum championed the interests of his state—and of the Langley laboratory in particular—from his powerful position as chairman of the independent offices subcommittee of the House Appropriations Committee, where the NACA received annual increases in operating expenses throughout the 1920s. In 1930 for the first time the total NACA budget passed \$1 million, a far cry from the \$5000 with which the Committee had begun only fifteen years before. True, the 1930 budget was swelled by the first installment of construction funds for the full-scale wind tunnel, but that tunnel was itself a testimony to the ability of the Committee to convince Judge Woodrum and the rest of Congress that its work was worth the nation's while.⁵²

If there were any clouds on the NACA's horizon in the late 1920s, they warned of personnel problems. These were of two kinds. First was the problem of obtaining qualified engineers. From the earliest days of recruiting Edward Warner from MIT, the Committee had made it an unwritten policy to bring in promising young engineers and train them to the NACA style. Formal credentials in aeronautics mattered less than

a fundamental grasp of engineering and an ability to learn and adjust. Many felt that the NACA offered a better education than graduate school, especially after the Committee began to establish a reputation and acquire its unparalleled research facilities. One bright young MIT graduate who joined the NACA in 1929 turned down a full scholarship for postgraduate work at Göttingen and fifty firm employment offers from industry to take the lowest-paid alternative because of the opportunities he perceived at Langley. "I was going down there," he said, "strictly for what amounted to a post-graduate course in aeronautical research because I figured that was the best place in the world to get it."⁵³

Not everyone was as pure, however; by the end of the 1920s, industry was buying up many of the young engineers who in earlier times would have gone to the NACA. The industry's recovery after 1926, which the NACA had so promoted and desired, now boomeranged on the Committee and created a major problem. As Ames explained to the House Appropriations Subcommittee in 1927:

We used to be able to get young men from the universities, but now they can go to work in commercial aviation as soon as they are out of school. If they were to come to us, they would have to take a civil service exam and there would be quite a delay before they got in. That is one of our difficulties which the prosperity of the aircraft business has brought about.⁵⁴

The Daniel Guggenheim Fund for the Promotion of Aeronautics eased this problem somewhat, but it also created problems of its own. Formed in 1926, the multimillion-dollar fund was intended to promote aeronautical education throughout the United States, to advance aeronautical science, and to further the development of commercial aviation. Universities receiving grants from the fund did in fact institute or expand programs in aeronautical engineering, and these in turn increased the supply of trained aeronautical engineers. However, some of the best of these engineers went on to pursue graduate work and later to teach in these same schools; others were drawn off by the industry that the Guggenheim Fund was also helping to expand. Furthermore, the fund was liquidated in 1930 and its impact attenuated over the years. While the net effect of the fund was surely to help the NACA deal with its personnel shortage, it never sufficed to fill the Committee's continuing needs. George Lewis put the issue clearly and directly in 1927: ". . . the industry and the educational institutions are too much for us in the way of offering high salaries."⁵⁵

Nor was the shortage of engineers the only personnel problem faced by the Committee. Max Munk was gone, and the prospect of

finding another like him dimmed with each passing year. It was not that Munk was smarter or more creative than others who succeeded him at Langley. Rather, he had brought to the Committee a rare synthesis of theory and experiment, a seemingly intuitive sense of what were the most important problems in aeronautics and how they might be solved in the laboratory. Munk took giant steps, bold and heavy, and if occasionally he leaped to false conclusions, still he made enough right guesses to outweigh the wrong ones.

In his wake came a succession of scientists who may properly be called theorists, but none of them had as much impact on the Committee or on the course of aeronautical research as Munk had had in his five years with the NACA.⁵⁶ What they contributed instead—what they had that he lacked—was the ability to work as part of a team, to subordinate their own intuition to the needs of the NACA, to confine serendipity within the limits of a rational program. This made for harmony and teamwork, but it deprived the NACA of the genius and vision that had established the Committee's reputation in the first half of the 1920s. The NACA had to learn to sustain that reputation by other means.



6

The Uses of Adversity, 1931–1936

The NACA had more reason than most to view the economic bubble of the late 1920s through rose-colored glasses. The wave of prosperity and optimism that swept the country toward overexpansion carried the aviation industry on its crest. From 1926 to 1929, the dollar value of American aircraft production increased fivefold, while the stock in certain companies jumped tenfold in even shorter periods. Aircraft manufacturing—of both airframes and engines—achieved the growth and vitality that the members of the NACA had espoused and had all along considered essential to American aeronautical supremacy. And in the wake of Lindbergh's flight to Paris, passenger aviation showed signs of becoming a popular and self-sustaining industry in its own right.¹

The NACA rode the same wave. In 1929 it won its first Collier trophy; its laboratory was widely conceded to be the best and most productive in the world; and Congress had recently approved even more new equipment. Everything grew at a great rate, and the horizon looked limitless. In June 1929, just four months before the stock-market crash that burst the bubble, John Victory wrote to a friend:

Things have been so dull in the stock market . . . I think things will get even a little lower toward the end of the fiscal year and that after the middle of July they will definitely be on the up-trend. Moral, buy early in July—most anything.

Nor was Victory the only one in the NACA convinced that things had nowhere to go but up. In the fall of 1929 the Committee took delivery of a new staff car, a \$4000 Pierce-Arrow to replace the Franklin that had served since the comparatively lean days of 1924.²

REORGANIZATION

The Great Depression, of course, turned on questions of business and economics, and the NACA was nominally a government agency at least one remove from the vagaries of the marketplace. Still, the NACA was always very much alive to the condition of the aircraft industry and the national environment in general, so the Depression was bound to affect the Committee's behavior. Like most institutions, the NACA at first responded somewhat ambiguously, discounting the gravity of the crisis and conducting business as usual. But as the Depression deepened, as the Committee encountered financial problems of its own, and as charges of corruption and profiteering were leveled at the aircraft industry, the NACA sought to put some distance between its own skirts and the crumbling and discredited world of commercial enterprise. While continuing to assist the aircraft industry and allowing a high proportion of industry representatives on its technical subcommittees, the NACA retreated from the organizational commitment it had made to commercial aviation in the heyday of the late 1920s.³ This retreat appears most clearly in the shifting committee structure of the early 1930s.

In 1930, the Committee on Problems of Air Navigation and its three subcommittees constituted a group second only to the Committee on Materials for Aircraft in the proportion of industry representatives. These committees suffered heavily in the Depression. In 1931 the subcommittee on Problems of Communication—the only NACA committee before World War II to have an industry representative as chairman—was discharged, ostensibly because its functions overlapped those of the Liaison Committee on Aeronautic Radio Research of the Aeronautics Branch of the Department of Commerce. In 1935, the entire Air Navigation Committee was discharged, as was its Subcommittee on Instruments. The only survivor was the Subcommittee on Meteorological Problems, which was transferred to the Committee on Aerodynamics.⁴

The Committee on Materials for Aircraft, another bastion of industry representation, underwent similar changes, though here technological forces were also at work. In 1931 a new Subcommittee on Miscellaneous Materials absorbed the dated and moribund subcommittees on Woods and Glues and on Coverings, Dopes, and Protective Coatings. This move away from wood and cloth aircraft bodies of the 1920s into all-metal, stressed-skin aircraft also was reflected in the creation of the Subcommittee on Research Program on Monocoque Design, which sat from 1931 to 1936. The industry lost no representation in this shuffle, but the NACA achieved a committee structure at once more workable and more justifiable on the basis of where the NACA sought industry representation.⁵

The blurring of industry visibility within the NACA was prompted in part by the Committee staff's growing preference for government members on committees. The NACA got along well with other government agencies; by 1930 it felt free for the first time to disband its charter Committee on Government Relations. Government representatives were readily available in Washington to attend meetings of technical committees and there was little suspicion or tension among them over confidentiality and the advancement of special interests in the meeting room.⁶

During the Depression the NACA emphasized research of primary interest to the military services, in the belief that the results would eventually trickle down to commercial aviation. Of the Committee's investigations on airships, for example, "the major portion [were] made at the request of the military services." But, as the NACA made clear in a resumé of that research, the Committee "endeavored to arrange the work so as to obtain data of general application and thereby acquire for public use knowledge essential to the development of airships."⁷

NACA research on airships, which began in 1922, peaked in the 1930s, after the creation of the Subcommittee on Airships in 1927, chaired first by Edward P. Warner and then by Jerome Hunsaker. The United States enjoyed a virtual monopoly of the world's supply of helium, a safer though less efficient gas than volatile hydrogen; to many enthusiasts, including some within the NACA, this suggested a bright future for lighter-than-air craft in America, in spite of the accidents that continually plagued airships. After the crash of the *Roma* in 1922, George Lewis predicted that "one, two, or three such accidents can not definitely stop the development of lighter-than-air craft." But by the time this strange era in aviation history was over, more than a third of the world's 161 airships had been destroyed in accidents, the most dramatic being the *Hindenburg* crash of 1937. That disaster virtually eliminated airships from American skies, though it did not end military interest in the craft nor diminish NACA enthusiasm for their potential, including their usefulness in fundamental research on bodies-of-revolution in a fluid stream. The Subcommittee on Airships survived until World War II, and as late as 1948, John Victory was still advising the Bureau of the Budget that airships had great promise and were still far from the "zenith" of their development.⁸ So long as the military services continued to believe in a project, the NACA was not reluctant to make public its own support.

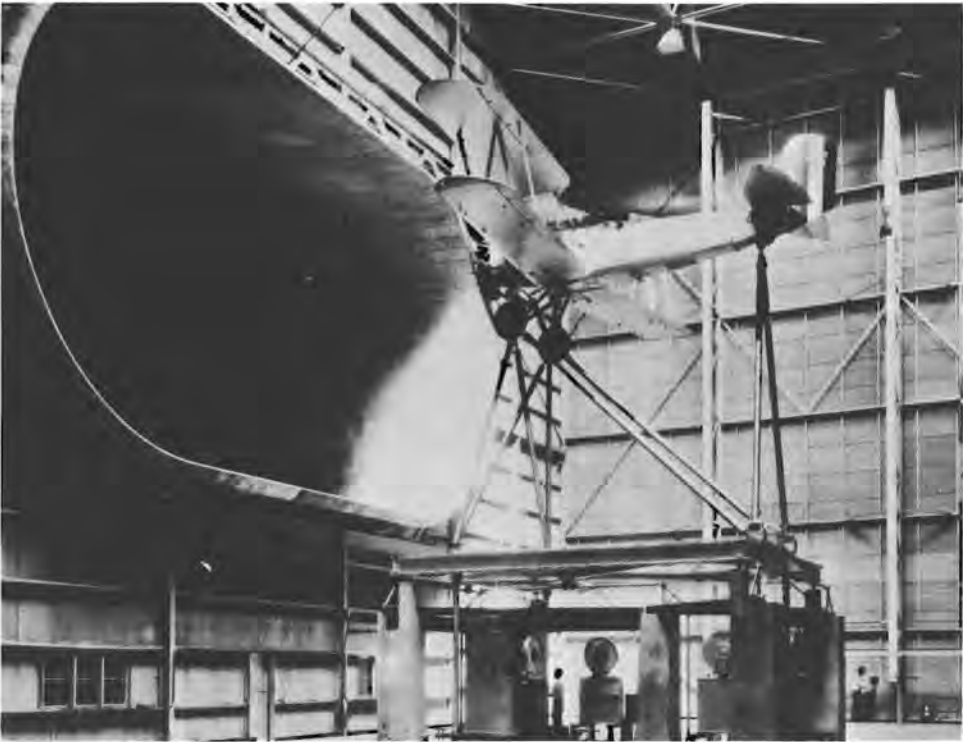
Seaplanes presented a similar case. Though the NACA recognized the commercial potential of seaplanes and noted this advantage when creating its Subcommittee on Seaplanes in 1935, still it populated that committee entirely with government members under the chairmanship

of a naval officer. Some new NACA committees (like Aircraft Fuels, also formed in 1935) had interests equally applicable to commercial and military aviation, but the drift of committee structure was away from obvious ties to the industry and toward more apparent service to the military.⁹

Behind the scenes, the NACA was more accommodating to industry. Most importantly, the Committee worked out procedures in these years to conduct research for industry on a reimbursable basis. During the 1920s, the NACA had generally refused to test industry models in its wind tunnels on the grounds that the NACA was in the business of conducting fundamental research applicable to all flight, not isolated research on specific prototypes. Furthermore, argued the Committee, an inordinate amount of time was required to clear a wind tunnel, set up an industry model, and run the tests—time that could be more advantageously spent on basic research. Finally, the results of NACA investigations were by definition public property that the Committee could not in good conscience promise to keep secret for the benefit of private interests. Thus it had advised the industry to use private wind tunnels or those at educational institutions.¹⁰ This last argument, of course, lost its force after the NACA became the only agency in the country with such specialized tools as the variable-density wind tunnel or the propeller-research tunnel.

Sometime in the first half of the 1930s, the NACA position changed. Prodded by the Bureau of the Budget while preparing its fiscal-year 1932 appropriation request, the Committee began to consider how and under what circumstances it might conduct research for industry. Rejecting a BoB suggestion that it seek legislative approval for such action as the National Bureau of Standards had done, the Committee established a policy on conducting investigations for private industry and developed a table of fees. The policy, first approved in 1931 and amended in 1936, restricted the Committee to answering specific requests from American sources for research that only the NACA was equipped to perform. The requestor had to make a deposit equal to the estimated cost plus a 100-percent fee, supply the model and any other special apparatus needed, and make a deposit covering additional costs before any additional work would begin. The NACA agreed to forward to the manufacturer the results of the investigation but retained the right to use them for the benefit of the government, and most importantly to release them to the public at its own discretion. The manufacturer thus gave up absolute proprietary rights to the results on the understanding that the NACA would not release the information unless it was deemed to be in the national interest.¹¹ By establishing this costly fee system and by failing to guarantee the confidentiality of new ideas, the NACA once more created a policy that,

however unconsciously, favored the large manufacturers at the expense of the small, and widened the gap between those hoping to enter the aircraft business and those already established. More than one Langley staff member felt that Martin Aircraft Company and Boeing Aircraft Corporation, for example, abused the privilege of access to the Committee's facilities and in fact used the laboratory for research and development work neither covered by the regulations nor constituting a proper function of the Committee.¹²



Tests for the military, like this one on a Navy O3U-1 Corsair in 1931, took priority over industry research. This, incidentally, was the first test conducted in the Langley full-scale wind tunnel. (LaRC)

Such criticisms, however, were kept within the NACA family, as were other observations on the growing role of the industry in the affairs of the NACA. In 1931, for example, when the death of Samuel W. Stratton created a vacancy on the Main Committee, Joseph Ames wrote candidly to Victory about the advisability of choosing a replacement from among three industry men who seemed the most qualified

for membership. Allowing that "the President may prefer to appoint some university professor rather than a man identified with the aircraft industry," Ames argued that there was then no qualified professor of aeronautics on the east coast, making it "necessary to look elsewhere than to universities at this time." Ames's memorandum is clearly sincere and well intentioned, free of the slightest taint of cronyism or conflict of interest.¹³ But Ames, in Baltimore, was more detached from the realities of Washington politics than were Lewis and Victory and the staff at the White House. Ames's recommendation, which sought to bring the greatest possible expertise to the Main Committee, was rejected, and Charles A. Lindbergh was chosen to succeed Stratton. Not only was Lindbergh free of public ties to industry, but his enormous prestige and popularity also lent weight to the NACA letterhead.

THE CRITICS ATTACK

Some of the committee shuffling during the Depression was done in response to criticisms of the NACA, or in attempts to head off further criticism. Throughout its history, the NACA faced opposition from two classes of critics. First were those, generally outside the government, who felt that the NACA did its work badly and should be abolished. Second were those, generally within the government, who felt that the NACA did its work well but would be more effective or efficient if absorbed by another agency. The politics of the Depression made bedfellows of these otherwise incompatible factions.

The first group campaigned through the 1930s in league with the critics of American aviation in general. Its litany ranged from Billy-Mitchell-style advocacy of a unified air force to Max-Munk-like protests about retarding aviation progress by failing to appreciate genius. The chorus sang "aviation trust"—the familiar plaint about a small group of conspirators' gaining monopolistic control of the aviation industry, aided and abetted by government officials who were either inept or corrupt. This trust, chanted the critics, blocked the real progress of aviation by excluding new ideas and new people and by putting its own narrow self-interests before the interests of the country and the human race. This campaign was a holdover from the 1920s; it continued on and off through the 1930s.¹⁴

In the opening year of the latter decade, the critics focused their wrath upon the NACA (not that they had ignored the NACA earlier, for ever since the cross-licensing agreement the Committee had been a target of those who believed in an aviation trust.)¹⁵ In 1930, however, the NACA was singled out for a particularly scathing attack.

In an *Aero Digest* editorial entitled "Why the NACA?", Frank Tichenor surveyed the record of a decade of NACA research and found

the Committee wanting.¹⁶ With "the largest, the most splendidly equipped and the most modern laboratories, and facilities for aeronautic research" in the world, the NACA had failed to give "an adequate return of the money spent." Tichenor doubted that the Committee's engine research had improved a single engine.

The free-flight tests of the Committee were more fruitful, but they failed the NACA's own measure of success, for "no free flight test [had] been a scientific test nor dealt with investigation of fundamental phenomena of nature." Wind-tunnel research, which Tichenor thought should have been the NACA's most productive, was instead its most disappointing effort. The results produced were obvious or trivial or beside the point. The NACA had ignored "the research having most of the scientific element in it, that dealing with the rotating cylinder," a method of increasing lift by boundary-layer control. The autogyro, a forerunner of the helicopter, was to Tichenor "the most painful subject of all," for the Committee had passed up an early opportunity to advance this important new field of flight. "The only line in which the N.A.C.A. [had] contributed to aeronautics by way of its own experimental research" was the development of the NACA family of wing sections, but even this research, "so admirably begun, [had] never been continued." Even the NACA cowling failed Tichenor's scrutiny because it "was a development rather than an original work," it could not be "regarded as scientific work" for it did not "involve the study of new and fundamental phenomena of nature," and in any event the Townend ring was "definitely superior to the N.A.C.A. cowling." Tichenor concluded: "There is hardly one research project of scientific value, and only a few of technical value. There is an enormous gap between the principles of research laid down and those applied."

According to Tichenor, there was a "keen feeling of disappointment throughout the industry about the outcome of the N.A.C.A. research," and he undertook to explain why the act had fallen so far short of the promise. First, he surmised, "scientific knowledge cannot be amassed by a committee any more than an opera can be written by a committee." Members of the NACA committees had neither the time nor the motive to do more than rubber-stamp the program suggested by the staff. The real blame lay there, particularly with George Lewis, whose most important roles were "diplomacy" and "organizing." "Only secondarily need he exhibit any scientific spirit." Likewise, the leading officials at Langley were "not research engineers at all" but "mere routine engineers, and hardly that; . . . mere bureaucrats, signing letters and unwrapping red tape." "Nearly all good research engineers [had] left the N.A.C.A.," said Tichenor, "and the few older men who [had] stayed with the organization [were] for the greatest part less capable than those who left." The NACA had, in fact, run upon

the shoals that threaten all bureaucracies, the pursuit of survival at the expense of the mission. Said Tichenor:

If the results of the N.A.C.A. could be computed according to their worth in dollars and cents, the Committee would long ago have been bankrupt. But it is not a money-making organization; it is a money-spending organization. That leaves much energy free, and unfortunately the conditions in such a case are favorable to the survival of those most unsuitable for carrying on scientific research.

Tichenor's final judgment of the Committee was a strongly worded call for "radical changes in the management":

The activity of the N.A.C.A. has become a mere building of new laboratories without distinct ideas of what to do with them after they are built, and it has become a mere weighing and measuring of less value than the weighing of a grocery clerk. No concerted efforts are made to advance science; no efforts are made to apply the results of the tests to any logical system, to digest them, and to interpret their significance in the sum of general knowledge. The truth is that the tests cannot be interpreted that way because the program has not been guided by scientific reasoning. Weighing for weighing's sake is not scientific research, but at best a kind of indoor golf.

George Lewis and other members of the NACA staff saw Max Munk's hand in this article. They were probably right. Since leaving the Committee, Munk had spent three years "in industrial employ," but had failed to match the brilliant record he had achieved when the resources of the Committee and its staff were available to him. In 1928 and 1929 he had petitioned the NACA to publish an article he had written, and he had come away angry when the piece was rejected. In 1930 he was reduced to rather pathetic letters soliciting subsidies for his work, letters in which he styled himself "the foremost aerodynamic expert of the world" and asserted that it was "generally conceded throughout the civilized world that all special scientific methods by which aircraft is computed [sic] nowadays, most experimental methods, and types of equipment for such experiments have been originated by me." In spite of the hyperbole, made worse by his ineptitude with the English language, there was some truth to these assertions; but the presence of these letters in the NACA files suggests that he was making his pleas to friends of the Committee who were not likely to be sympathetic to one who had fallen from grace with George Lewis. By the time the Tichenor editorial appeared in late 1930, Munk was listed on the masthead of *Aero Digest* as a consulting editor. He had joined the

opposition, and the tone and syntax of the Tichenor piece suggests he was providing ammunition as well.¹⁷

Many of the assertions made by Munk and Tichenor were simply not true, or at least so exaggerated as to be misleading and unfair. These the NACA had little trouble dismissing. The basic premise, however, was less easy to dispel. Was the Committee doing fundamental scientific research as it professed, or was it simply doing unimaginative pedestrian engineering that produced some technical progress without advancing basic knowledge and understanding in proportion to the excellence of the research facilities available to the NACA staff? Here were Munk and Lewis squared off again, the scientist calling for genius, theory, and abstraction while the engineer defended teamwork, practicality, and steadiness.

Ames and Lewis refused to enter the debate, but members of the staff and at least one member of the Committee took up the gauntlet. Their responses were both predictable and enlightening. The only staff member to address the basic question at length was Elton W. Miller, head of the Aerodynamics Division. While conceding that "very little of our work could be classified as fundamental, according to general acceptance of the term," Miller insisted that the research was scientific nonetheless. Science, he suggested, could be defined as "accumulated and accepted knowledge, systematized and formulated with reference to the discovery of general truths on the operation of general laws," and research as "careful or critical examination in seeking principles or facts." Just because their research had a practical object, he said, did not disqualify it as scientific; after all, "research need not necessarily be aimless to be scientific."¹⁸

Miller's response was meant for internal consumption in the NACA; Edward P. Warner's was not. As editor of *Aviation*, he replied in kind to Tichenor. Unfortunately, Warner uncharacteristically contributed more heat than light to this debate and thereby played into the hands of Tichenor. Unlike Miller, he skirted the definition of "scientific research" and devoted himself instead to the comparatively easy task of refuting some of Munk's more exaggerated criticisms of the NACA. This no doubt provided considerable comfort to the Committee's friends, but it did little to blunt the main thrust of the Tichenor piece. Warner mentioned scientific research only to say that it was properly the province of the universities. The NACA, consciously or not, subscribed to this belief throughout its history, as did most other aeronautical institutions in the United States throughout the age of flight. The NACA profitably employed theorists like Theodore Theodorsen, H. Julian Allen, and R.T. Jones, but it avoided duplicating the role of the universities. Warner and others of the NACA considered this a reason-

able division of labor, especially after the Committee's unpleasant experience with Max Munk.¹⁹

Tichenor retorted that Warner was ignoring "the keynote of the N.A.C.A.'s shortcomings." In fact, Tichenor concluded from Warner's editorial that "our [presumably Tichenor's and Munk's] principal criticism, the absence of scientific research, is tacitly admitted" in the Warner piece. In an extravagant prophecy that bears the imprint of Max Munk and speaks to a central issue of the NACA's history, Tichenor concluded:

Aeronautics has not yet reached its goal. The final shape of airplanes will eventually be quite different from what we have now. We want that development hastened. We want a critical and scientific survey, an exploration of all known possibilities. It may be possible (it probably is possible) to increase the specific lift to ten times what we have now, and we want a central institution of research to give us light on that. It may be possible to reduce the specific drag to one-tenth what we have now; the theory of air motion producing drag is still entirely in the dark. Friction of air, as such, does not account for more than one-twentieth of actual drag. We want to have some light on that too. We want knowledge concerning boundary layer control, concerning the effect of rotating cylinders, of vibrating surfaces, of lubrication, of autogiros, of Flettner cylinder, of jet action, of shooting action, of sound wave action, and of chemical action. Indeed the possibilities are without limit. We want a national agency to explore these unexplored regions, and to do so with scientific spirit, systematic thought and honest endeavor. We are not satisfied with useless pressure measurements and with the building of wind tunnels which will never be really usefully employed. Build small laboratories and do big things in them: not the other way. Only then will the nation attain high rank in world aviation.²⁰

Words by Frank Tichenor; music by Max Munk. This chorus of criticism rang so stridently and abused the facts so recklessly that it deafened the NACA to the overtone of truth imbedded within it. Munk and Tichenor were demonstrably wrong in their overall conclusion, for the United States did "attain high rank in world aviation" without adhering to their advice. Furthermore, they showed themselves ignorant of NACA activities which in fact included a general research program in boundary-layer control incorporating many of the specific techniques they advocated. But the main thrust of the criticism—that the NACA had embraced what historian of science Thomas S. Kuhn calls the "normal science" of "problem solving" at the expense of radical and imaginative conceptualization—had some merit.²¹ The problem always was how to draw on the good ideas of people like Munk without letting them run away with the program and indulge in

crackpot hunches that could be politically embarrassing and institutionally suicidal. Never having had a clear mandate laying out exactly what it was to do, the NACA had always tended to do what was safe, what would please its customers and satisfy the public and Congress. Relying on the universities for theory while claiming to be doing fundamental scientific research placed the NACA in the potentially awkward position of being responsible for a phase of aeronautical research which it had in large measure left to others. If the Committee did not relish this position, it embraced it nonetheless.

Had this debate over the Committee's mission and method confined itself to the pages of the aeronautical journals, it might have done the NACA no immediate harm. Though both sides claimed support from most knowledgeable people in the aeronautics field, there seems little doubt that a majority sided with the NACA. And of course the NACA's committees included men from the most important segments of the aeronautical community. Such men, many representing companies and organizations that relied on the NACA for work and information, naturally sided with the Committee.²²

When the debate spilled into the public arena, however, as it did in 1932, the NACA found itself vulnerable. As the Depression deepened and political incumbents sought to demonstrate in an election year that they were doing something about it, economy and efficiency became watchwords of Washington life. *Aero Digest* found a ready audience, then, when it proposed the "elimination of the National Advisory Committee for Aeronautics." In a February 1932 editorial addressed to the chairman of the House Appropriations Committee, the journal suggested that merging the NACA with the National Bureau of Standards "would save non-productive millions and give 100 per cent more in scientific investigations." Labeling Lewis and Victory "politicians" exploiting the prestige of the prominent men on the Main Committee in order to "hold their excellent berths—snug and warm, safe and secure," *Aero Digest* said the NACA was engaging in too much politics and not enough engineering. The following month, in a longer editorial, Tichenor repeated many of his criticisms of the previous year, calling on President Hoover to overhaul the NACA.²³

Victory later recalled that in this period "Congress lent itself to the disgrace of the country to listening to the snipers"—that is, to the critics of the Committee. It is unclear how far Congress acted in response to Tichenor and his adherents or to the Depression, but one thing is certain. In the spring and summer of 1932, the NACA was in its most serious trouble to date with the Congress. In the same month as Tichenor's call for merger of the NACA, Congressman Carl E. Mapes introduced a bill to reorganize the Department of Commerce, including a provision that it absorb the NACA. Two days later, the

chairman of the House Appropriations Committee, acting in his new role as chairman of the recently formed ad hoc House Economy Committee, asked Ames to suggest "where consolidations may be made and duplications eliminated in the interest of economy and efficiency." Ominously he reported: "The Committee feels that there can be a very substantial saving effected in this way in the activities of your office." By April Victory found himself writing to a friend: "As you can imagine from what you see by the papers, I have been more than up to my neck, for we have not only had . . . 'Congress on our hands', but we have had Congress literally at our throats."²⁴

The worst was yet to come. In April 1932, the NACA appropriation for fiscal 1933 encountered opposition in the House though Congressman Woodrum was able to get it passed relatively intact. In June, however, when it came up in the Senate, it met stronger opposition and fewer friends. The Senate was then attempting to reduce all appropriations by 10 percent; when the NACA bill reached the floor, three senators backed an amendment to apply the same cuts. It was Saturday, and only the bill's sponsor was present to head off the attack. The arguments of the attackers were those heard most often when Congress took to criticizing the NACA: duplication and special interests. Said one senator:

There has been an enormous waste in the aeronautical activities of the Government. . . . Instead of consolidating all of the aeronautical activities of the Army and the Navy and other departments of the Government, we are diffusing them, and we are trying to take over some of the duties and some of the experimentation and scientific work which are being done by private manufacturers of airplanes, who have technical staffs that are infinitely more competent than the technical staffs which the Government of the United States provides. This whole organization ought to be abolished; and, if it is not abolished, the appropriation ought to be reduced one-half.

In a curious reversal of the complaint by Tichenor and others who felt that the NACA was not doing enough for the industry, the same senator suggested "that while this organization may have done some good, it is a sort of an appendage to the Army and to the Navy, and is doing work—what little is being done—for the private manufacturers of America." When the appropriation-bill sponsor suggested that, under proposed cuts, the NACA "would go to pieces," the critic replied, "That would be a blessing rather than a calamity."²⁵

The amendment to reduce the NACA appropriation was approved, as was a motion to reconsider on Monday all the items in the NACA budget. Over the weekend the friends of the Committee rallied enough support to hold the line on the budget, and on Monday they were able

to fight off any further reductions. The most telling point in that debate was the charge that the campaign to save the NACA budget was another instance of the business interests of the country lobbying to save the government agencies that favored them. The NACA's main defender countered that any benefit the industry derived from NACA research was a second-order consequence, an inevitable trickle-down of the advances made primarily for the military services:

As always happens when we build up a science for the sake of getting the national defense perfected, we benefit incidentally commercial activities along the same lines; but the Senator must not have the idea that the chief activities of this committee are to benefit commercial aeronautics, because that is not true.

Incongruously, the effect of this oration was a motion to reconsider the entire NACA appropriation; fortunately for the NACA the bill ended up in a conference committee, where Congressman Woodrum succeeded in restoring almost the entire amount cut by the Senate.²⁶

The NACA, however, was not yet out of the woods. The same session of Congress passed and sent to the president an economy bill which empowered him to propose drastic reorganization of the executive branch of government in the interests of economy and efficiency. President Hoover—who had as secretary of commerce approved a plan to transfer the NACA to his department—was of course a confirmed cynic with regard to government agencies. “No one with a day’s experience in government,” he once said, “fails to realize that in all bureaucracies there are three implacable spirits—self-perpetuation, expansion, and an incessant demand for more power.” It is little wonder then that his reorganization plan—revealed in December, after he had already failed of reelection—included transfer of the NACA to the Department of Commerce. What did seem to surprise at least some within the NACA was that this particular phase of the plan was created on Hoover’s personal initiative. Apparently the Committee had not been as successful as many had believed when it prevailed upon him in 1925 to reconsider the Department of Commerce proposal.²⁷

Once more the members of the NACA manned the barricades. Victory began at once to line up congressional support to defeat the measure, and the Main Committee met within the week to decide on a course of action. At the request of a friendly senator, the Main Committee forthwith resolved itself into a Special Committee on Proposed Consolidation of the National Advisory Committee for Aeronautics with the Bureau of Standards and unanimously adopted a draft report (prepared in advance, no doubt by Victory). The report contained testimonials by Presidents Harding, Coolidge, and even Hoover; pre-

sented figures on the economic value of the Committee's work; and argued that the proposed transfer would not effect the economies that were claimed for it.²⁸

As it turned out, this report was unnecessary, for the Democrats in the House voted almost unanimously to defeat not just the NACA transfer, but the entire Hoover reorganization plan. Any reorganization, they argued, should be left to President Roosevelt, who would, after all, have to live with it. Years before, when he was assistant secretary of the navy, Roosevelt had provided a key endorsement of the plan to create the NACA in the first place. No evidence from the intervening years suggests that he had become any less favorably disposed to the NACA. If anything, he seemed to have grown more friendly to it and to its supporters, at least more friendly than Hoover. As it turned out, Roosevelt and his administration made no effort to abolish or transfer the Committee. The NACA experienced other attacks during the Depression but, once Roosevelt was in the White House, the most serious episode was over.²⁹

THE NACA DEFENSE

In its struggle for survival during the Depression, the NACA employed and refined the same defenses that it was to use through all of its remaining years. It collected and circulated endorsements from its friends and clients. It presented evidence of the efficiency of its operation and a complete lack of duplication of effort. It waved the banner of military necessity. And it courted key congressmen and executive branch officials, most often during trips to the Langley laboratory.

John Victory took upon himself the task of collecting endorsements. For example, when the chief engineer of Boeing wrote to Lewis in December 1930 deploring the Tichenor attack in *Aero Digest* and offering a statement backing the NACA, Victory wrote in the margin, "Get it." Lewis in turn requested the endorsement, noting that "letters of this type are of great value to the Committee, especially if the matter is brought up by a congressman, in which case the letter can be shown and not made public." Friends of the Committee were thus assured that they could endorse the NACA without having to do so publicly.³⁰

With other endorsements, Victory was less circumspect. Any incoming correspondence complimentary to the NACA he flagged for inclusion in his "bouquet file." He would mark the appropriate passage, often lifting it entirely out of context, and direct a secretary to "card" it. From these excerpts Victory compiled over the years a 3- by 5-inch card file more than 2 feet high. In it were compliments for all occasions that could be selected and quoted for any purpose, especially to justify the continued existence of the Committee. The more notable

the correspondent or the more glowing the praise, the more likely that the quote would come to the attention of the appropriate authorities.³¹

Reading the letters of praise received by the NACA over the years, one senses that the approval was genuine and that the correspondents sincerely appreciated what the NACA did.³² The impression given by Victory's card file, however, is something entirely different. Selecting his material with care and quoting it out of context, Victory compiled a set of endorsements more in keeping with his views of the Committee than with those of his correspondents. What he failed to mention in presenting the endorsements was that some had appeared in bread-and-butter letters written after the correspondent had been a guest of the Committee at the annual research conference. Some came after the correspondent had received a free set of Committee reports or some similar favor. They were naturally generous and complimentary. Victory failed to note that some of the compliments had been written by him and merely signed by the endorser—for example, the president's letter transmitting the Committee's annual report to Congress. He was especially fond of quoting these. Nor did he mention that some of the endorsements were written by members of the NACA, that some came from industry and military personnel dependent on the Committee for assistance and information, and that some had been solicited by the Committee.³³

Endorsements may well have been necessary for the survival of the NACA. Without them, Congress and the Bureau of the Budget would have been hard pressed to evaluate the Committee's work—partly because the Committee's job was arcane to the layman and beyond his capacity to judge, partly because the Committee's job was never entirely clear in the first place. But collecting endorsements entailed serious dangers. First, the process became self-serving and biased, for the Committee chose what to reveal and what to conceal. Second, the Committee and some of its friends spent too much time reading and believing their own clippings; often it became unclear whether Victory and others could distinguish between the statements in the bouquet file and the actual happenings within the NACA.

The second defense the Committee used against detractors was the efficiency argument. This took two forms. First and oldest was to refute the charge of duplication. Congress always wanted to know (especially during the Depression) if the NACA was duplicating the work of any other federal agency. With the military services and the Bureau of Standards conducting aeronautical research, it appeared that the NACA might be redundant and might profitably be merged with one of these other agencies.

To this complaint the Committee always replied that—far from duplicating the work of other government agencies—the NACA actually

prevented duplication. It did fundamental research categorically different from that done at the Bureau of Standards or in the services; by providing a forum where representatives of all aeronautical research establishments could meet regularly to survey the entire field, the NACA ensured that no agency would inadvertently stray into the territory of another. It was conceivable, for example, that the Bureau of Standards and the NACA could both decide to pursue similar investigations on boundary-layer control, but because the NBS was represented on the NACA Committee on Aerodynamics (which would have to approve any such program within the NACA) there existed a sure check against such duplication.

Very often congressmen failed to comprehend the difference between the fundamental research conducted by the NACA and the engineering research or testing conducted by other government agencies, but in such cases Victory always had a pile of endorsements ready to demonstrate that those who understood such matters believed there was no duplication.³⁴

The other form of the NACA's efficiency defense was that the Committee's research resulted in savings for aviation that made the dollars invested in the NACA a profitable use of the taxpayers' money. Frank Tichenor set off this line of argument when he accused the Committee of giving a poor return on the money appropriated to it. Even though there was no precise and objective way to measure the worth of the Committee's work, the NACA demonstrated in 1933 that it could match statistics with Tichenor. In a paper entitled "Economic Value of the National Advisory Committee for Aeronautics," the Langley staff undertook to prove that just "six researches completed within the last few years . . . [resulted in] savings in money . . . in excess annually of the total appropriations for the Committee for the eighteen years of its existence." The proofs seem to fit John Victory's aphorism that a statistician is "a man who draws a mathematically precise line from an unwarranted assumption to a foregone conclusion," but this caveat does not negate the premise: the government did get, especially in the early years, a sizable return on the dollars it invested in aeronautical research. The federal government was still, after all, the major institution in the country concerned with aviation, and flying was still a young enough enterprise to need all the refinement it could get. So the NACA used the argument unabashedly, and Ames (perhaps relying on the authority of his position as a scientist and university president) went the Langley staff one better. Writing to a friendly senator in 1933, he claimed that \$10 in aviation costs were saved annually for every dollar invested in NACA research.³⁵

The third NACA argument against proposals to abolish was that old reliable—military necessity. Congress might question the need for

aeronautical research or the advisability of nurturing a growing bureaucracy in Washington, but never the need for adequate national defense. To the extent that the NACA could ally itself with the military services and demonstrate that its work was essential to national defense, it could assure itself of continued existence and appropriations. The Committee was created in World War I largely in response to that conflict. Its organic legislation appeared in a naval appropriations bill. It was quartered for years in offices provided by the military services. Two representatives from each service sat on the Committee. Military requests for research were always honored. And military endorsements were among the first sought when moves were afoot to abolish or transfer the Committee. "If the NACA ever sets itself aside from the Army and Navy," Lewis often remarked, "it is a 'dead duck.'" ³⁶

During the aviation boom of the 1920s, when war and the threat of war seemed most remote, the NACA had strayed as far as it ever did from under the military umbrella. Publicly and privately it increased its attention to the problems of the aircraft industry and commercial aviation. When the Depression struck, however, and attacks on the NACA began, the Committee retreated to the high ground of military necessity. When scandal shook the aviation industry in 1934, the NACA put greater distance between itself and industry while closing ranks with the armed services. Through President Roosevelt's dramatic cancellation of the airmail contracts flowing from the so-called "spoils conference" of 1930, the Nye Committee hearings into the "merchants of death," and the round of allegations about startling and excessive profits within the aircraft industry, the NACA gathered in its skirts. While never abandoning the industry nor reneging on its commitment to foster commercial aviation, the Committee kept a more discreet distance than it had in the past. ³⁷

Lastly, the Committee refined during the Depression one other mechanism for combating movements to abolish or transfer it. John Victory courted a select number of congressmen and executive department officials with trips to the Langley laboratory, especially in sessions at the camp. Inviting a congressman to visit Langley in 1931, Victory said: "Frankly, we are somewhat proud of what we have accomplished and are anxious to make a personal report of our stewardship to those few members of Congress that we feel are genuinely interested." ³⁸ That sentence has the ring of sincerity to it, and rightly so. The Committee was indeed proud of its work, and visitors came away from Langley impressed not only with the monumental array of wind tunnels and laboratories and airplanes and machine shops, but also with the spirit of enthusiasm and devotion that pervaded the laboratory. To visit Langley was to become enamored of it.



George Lewis, H.J.E. Reid, and John Victory stand behind eight members of the NACA at the ninth annual Aircraft Engineering Research Conference at the Langley laboratory, 23 May 1934. Committee members, left to right, are Charles A. Lindbergh, Arthur B. Cook, Charles G. Abbot, Joseph S. Ames, Orville Wright, Edward P. Warner, Ernest J. King, and Eugene L. Vidal. (LaRC)

The perfect complement to such a visit was a stay at the NACA camp, where men could relax in comfort and contemplate by the quiet waters of Back River the advances in aeronautics being made at Langley. In 1939 Victory reported to the chairman of the NACA:

Friday night I accompanied nine members of Congress on a boat trip to Old Point Comfort and a visit to the Committee's laboratories on Saturday, after which they stayed over at the Oak Point Club for some fishing. They developed a unanimous sentiment for additional research facilities in aeronautics.³⁹

DECLINE AND RECOVERY

In spite of these defenses, the attacks sustained by the NACA in the early years of the Depression took their toll. In 1933 and 1934 the Committee's budget for general purposes declined for the first time in the Committee's history. It fell by more than \$100,000 in 1933, by more than \$200,000 in 1934, a total drop of one-third from the 1932 level. Only in the year following World War II and the year following the Korean War would the Committee again suffer a decrease in its appropriation for general purposes, and neither would be as precipitous as in these early Depression years.⁴⁰

Of course, times were bad for everyone, and all federal agencies were experiencing budget reductions. In 1932 the Senate was applying its 10-percent reduction formula across the board. The furlough of government employees affected almost all government agencies, as did the accompanying salary cuts. Federal revenue fell by 50 percent between 1930 and 1932 and did not reach the 1930 level again until 1935. Federal expenditures stagnated from 1931 through 1933.⁴¹

The NACA suffered more than most agencies, for two reasons. First, as a scientific agency, it became associated by the public with the policies responsible for the Depression. Historian A. Hunter Dupree has said that, in the campaign of 1932, Hoover "seemed to equate scientific research with the prosperity of the 1920's, the economic system then reigning, and the voluntary program he had developed as secretary of commerce. . . . Thus basic research became linked in the American mind with overproduction and the Depression, with long-term goals pursued at the expense of present needs, with intellectual projections blinded to practical realities." The result, according to Dupree, was something like a backlash, and even though the new administration was more sympathetic to the NACA than its predecessor had been, "the large sums of money that the government began to spend during the first hundred days of the New Deal were designed to care for the unemployed and revive the economy, not to aid the hard-pressed scientific bureaus of the government nor to attack the depression by a long-range research program."⁴²

Sad irony for the NACA, then, that the other reason for the disproportionate reduction in its budget in early Depression years was the strange alliance formed by the Committee's enemies: outside critics on one hand, and government efficiency experts on the other. Thus Hoover damaged the Committee twice, once by aiding those who would eliminate or transfer the Committee and again by contributing to a general sentiment against large expenditures for scientific research. That the Committee weathered these lean years as well as it did is more remarkable in light of the forces aligned against it in the early 1930s.

More serious in the long run than the decline in general-purpose funds in 1933 and 1934 was the refusal of Congress to appropriate a penny of construction funds to the Committee from 1931 until 1937. Since receiving its first appropriation for a laboratory in 1917, the NACA had grown by following up construction with more people and more work: get Congress to approve a new research facility, and once it was in place argue that the money would be wasted unless operating funds were increased. Expansion of the Committee's budget over the years had followed this push-pull pattern, until (by 1932) the budget for general expenses topped the million-dollar mark, approaching the

record \$1,200,000 appropriated for construction in the heyday before the Depression. Now the Committee had to look elsewhere for hope of continued growth.

The answer, of course, was the New Deal. Congress might balk at direct appropriation to the NACA for construction, but it went along with the pump-priming philosophy that lay behind the Public Works Administration. Money that the NACA could not get from Congress directly, it got in the name of economic recovery. In 1933 the Committee won approval of a \$200,000 allotment for miscellaneous construction, later augmented by almost \$48,000 to repair damage from a hurricane that had flooded Langley Field. The following year the Public Works Administration granted the Committee almost half a million dollars to construct a new wind tunnel capable of speeds up to 500 miles an hour, the range in which the aircraft of the 1940s would fly.⁴³

With the impetus of these construction funds, the NACA general-purpose budget began to rise again. In 1935 it increased 10 percent. The following year it jumped more than 50 percent, carrying it over the \$1,000,000 level it had achieved so briefly in 1932. Never thereafter did it fall below this mark. The trick that had rescued the NACA from the doldrums of the Depression was not lost on at least one congressman. When the 1936 NACA budget was on the floor of the House, Congressman Otha D. Wearin charged that congressional intent had been circumvented by the PWA funding and the consequent NACA demand for increased salaries and expenses. Wearin, a believer in what he called the "air trust," expressed serious doubts about the independent functioning of the NACA, which he preferred to see consolidated with other government agencies dealing with aeronautics. But that was not his specific complaint. At this juncture he wanted only to delete any increase in the NACA appropriation

to operate equipment purchased with P.W.A. funds that this Congress has never had an opportunity to authorize for that particular purpose. I object to the policy of the P.W.A. purchasing materials of that kind and then coming to the Congress with an apparent club over our heads and asking funds to use in the operation of the equipment that we did not authorize.⁴⁴

Once more, Congressman Woodrum stepped into the breach and saved the NACA appropriation, but it was apparent that the method used by the Committee to increase its budget was not going entirely unnoticed in Congress and was not without its critics—critics still nursing old grievances over the "aircraft trust" and its roots in the cross-licensing agreement.

But by this time the critics were growing less vocal and less numerous, and things were looking up for the NACA. As early as mid-1934, Victory could report, with obvious relief, that "for the immediate present we are not confronted with any threat of abolition." The budget was on the rise again. New construction was under way, and the personnel cuts of the early Depression years were being restored. The Federal Aviation Commission, as part of a general study of American aviation following the scandals in 1934, recommended that the NACA step up its program, an idea echoed by the NACA's own Special Committee on Research Policy. Reporting in March 1935, the special committee recommended supplemental appropriations of \$338,050 to make up for the work deferred during the lean years of the early 1930s. Both the Bureau of the Budget and Congress approved this sum. For the NACA, at least, the Depression was over by the middle of 1935.⁴⁵

It was not without cost, however, that the NACA survived the Depression. The costs were of two sorts. The first, and ultimately more important, was not immediately apparent. The Committee had lost objectivity, impartiality, self-confidence, and equanimity. It became further removed from the business of aeronautics, closer to the business of survival that Hoover said was the main interest of all Washington bureaucracies. If the Langley staff kept an eye on the ball, it was in spite of continual distractions from Washington. One day they would be escorting congressmen and other VIPs around the lab and attending to their needs at the camp. The next day they would be estimating the cost per hour of running a wind tunnel so that the Washington office could present yet a new set of efficiency statistics. The day after that they would be refuting arguments of Max Munk and Frank Tichenor. The annual budget cycle of preparing estimates and composing justifications that laymen could understand was quickly turning into a year-round enterprise.

The NACA's organic legislation was cast in vague terms that did not—at least in the minds of many congressmen—fully justify the existence of the Committee or explain how it differed from other aeronautical research facilities or why it had to remain independent; thus, the NACA was under constant pressure to justify its existence. Compounding this disadvantage, only the haziest of boundaries divided the various categories of aeronautical research: the fundamental research that the Committee claimed to be doing; the scientific study of the problems of flight, which was in its charter; the theoretical research conducted at universities; the engineering research conducted by the military services; and the design and development done by manufacturers. The NACA, weak and vulnerable in its early years, was forced to choose a territory that infringed on no one else's; the ground it called its own was really a no-man's-land carved out of dead space between

larger and more powerful institutions. No wonder, then, that the Committee was hard pressed to answer Tichenor when he pointed out the basic contradiction between what the Committee said it was doing and what it was doing in fact. Although the NACA fought off that attack in the Depression years, it never really resolved the contradiction, and this did not enhance the staff's ability to perceive reality and understand just what the NACA's place was in the order of things. Because the criticisms of Munk and Tichenor were closer to the mark than the NACA cared or dared to admit, the Committee embraced a shrill and rigid denial. Repeated often enough, this denial took on the aura of truth to the very people who should have recognized it—at least in their own circle—as an expedient for public consumption.

The leaders of the NACA thus sowed in the Depression the seeds of a self-deception that would bear a bitter harvest in later years. More immediately, the Committee faced another loss incurred in the hard years of the early 1930s. Though the NACA had recovered from the Depression by 1935, earlier than most other agencies and institutions in the United States, it had lost valuable time in the international race for aeronautical supremacy. The years of budget reductions and the years during which Congress appropriated no funds for construction had taken their toll. The NACA still claimed in mid-1935 to be the leading aeronautical research laboratory in the world, but that claim would soon be challenged.

Girding for War, 1936-1941

The NACA was the first to realize that it no longer led the world in aeronautical research. Not for nothing had it labored in the 1920s and 1930s to become a clearinghouse of aeronautical information. The problem was not the awareness of danger, but the national will to act upon it. For two years after learning of the frantic pace of aeronautical research in Europe, especially in Germany, the NACA was unable to convince the Congress or the Bureau of the Budget that a crisis was in the making, a crisis requiring a crash program in aeronautical research. Instead, these years were dominated by the same constraints of domestic politics that had robbed the NACA of its world preeminence over the course of the 1930s.¹

DOMESTIC DISTRACTIONS

Throughout 1936, news of what was happening in Europe reached NACA headquarters with ever clearer portent. In March, the Executive Committee heard a report from John J. Ide, describing greatly expanded aeronautical research in England, France, Italy, and Germany. In May, Charles Lindbergh—a member but infrequent attender of NACA meetings—reported from his home in England on the aviation developments there and their possible effect on the United States. In August, George Lewis accepted an invitation to cross the Atlantic on the airship *Hindenburg* as guest of the Deutsche Zeppelin-Reederei. Ames approved this trip explicitly so that Lewis could become better informed on aeronautical research in Germany and Russia. When Lewis reported back in the fall, he brought grave if not dire news.²

In the company of Dr. Adolf Baeumker, head of government aeronautical research in Germany, he had toured the vast facilities initiated or expanded under Hitler and had come to appreciate the unparalleled German commitment to aeronautical supremacy. Baeumker worked directly for General Goering, whom he described as “intensely interested in research and development.” Goering in turn reflected the policies of



On 17 December 1936, the NACA Executive Committee met at the home of Orville Wright, after which it posed out front with the host in the front row, center. NACA's technical assistant in Europe, John J. Ide, an infrequent attendee of NACA meetings, is in the center of the back row between John Victory and George Lewis. (National Archives)

“Chancellor Hitler,” who reportedly had removed aeronautics from the Ministry of Transportation and made available for its development practically unlimited funds. “The cost is not considered,” reported Lewis, describing the unprecedented facilities then in place or under construction. Much of the research equipment had been modeled on the NACA’s; when Baeumker first visited Goering, he had taken with him as a conversation piece a photograph of the NACA full-scale wind tunnel, and Goering decided on the spot to build one for Germany. Since then, reported Lewis, the growth of aeronautical research facilities had been explosive. The old facilities at Aldershof and Göttingen had been greatly expanded—the former, said Lewis, “looks like a construction camp”—and two entirely new laboratories were being built. Yet it was not the facilities that concerned him most, for in 1936 he

still believed "that the equipment at Langley Field is equal to or better than the equipment in the German research laboratories." "But," he continued, "the personnel of the German research laboratories is [sic] larger in number, and the engineers have had an opportunity of having special training, which has not been afforded to many of our own engineers." Here, of course, he referred to the NACA practice of taking young engineering graduates right out of college and training them on the job. The quality of America's aeronautical engineers, at least in comparison with Europeans, had bothered Joseph Ames as far back as 1925, and apparently neither the Guggenheim Fund nor the growth of aeronautical-engineering education in the intervening years had closed the gap. Lewis estimated that Aldershof alone employed 1600 to 2000 persons compared with the 350 then at Langley. If the engineers among these were better trained than their American counterparts, then the prospects were grim indeed.³

Faced with this crisis, the NACA did what it had done in the past—it created a committee. In fact, it created two committees. The Special Committee on Aeronautical Research Facilities was formed in March 1936 in response to the warnings from Ide. It quickly recommended a deficiency appropriation for 1936 and an increased budget request for 1938. Government expenditures for research were just then turning sharply upward in response to the later New Deal and the sabre-rattling in Europe, so the NACA requests carried.⁴ The Special Committee on Relation of NACA to National Defense in Time of War, formed in October after Lewis's report on his trip to Germany, acted less quickly, unable or unwilling to formulate any recommendations until the summer of 1938. In spite of the worsening situation in Europe and the growing concern of the NACA, domestic politics continued through 1937 and most of 1938 to retard the expansion of aeronautical research that was deemed necessary to keep the United States in pace.

The most damaging and troublesome event of these years, from the NACA perspective, was the 1937 report by the Brookings Institution on government activities in the field of transportation. Commissioned by the Senate to suggest possible economies through elimination of duplicating or overlapping agencies, the Brookings report recommended abolition of the NACA and transfer of its research functions to a proposed department of transportation. As with many critics before and after, the Brookings staff found no great fault with the way the NACA executed its responsibilities. Rather, it criticized the NACA as an irrational anomaly, an independent establishment of unique composition running counter to the conventional wisdom about government structure and chains of command. At Brookings, as later at the Bureau of the Budget, the critics of the NACA preferred a traditional

bureaucracy, hierarchically organized as a pyramid of officials capped by a single officer, answerable to an immediate superior who could evaluate an agency's performance and correlate it with all similar work being conducted by the federal government.⁵

The response of the NACA was swift and predictable. First it published a detailed rebuttal of the Brookings report, objecting to the methodology of the investigation and concluding that the Brookings staff had not gained sufficient knowledge of how aeronautical research was conducted in the United States to make an informed recommendation. In this, as in a subsequent attempt to negotiate a retraction, the NACA staffers talked past the Brookings staff and vice versa. The Brookings people were talking structure while the NACA talked function. To the Brookings people, who no doubt were unqualified to evaluate the technicalities of aeronautical research, the structure of an organization determined how efficiently it would function. To the NACA staff, how the agency functioned was the sole criterion of success. Since the agency functioned to their own satisfaction (and purportedly the satisfaction of all who were concerned with their work—that is, their clients) the structure should not be tampered with. As was their custom in such disputes, the NACA spokesmen claimed broadly that their independence and their committee system of organization were essential to their success, but they never made it entirely clear why. Their assertion that aeronautical research would fall under the sway of politics if they were absorbed by another agency always rang a little vague, and was contradicted in any event by the influence the armed services already exerted in the NACA meeting room.⁶

The Committee's second response to the Brookings report was equally familiar and in the long run probably more effective. It mustered political support to fight the recommendation on Capitol Hill. Specifically, Harry Guggenheim was selected to take up the matter with his old friend Harry Byrd, chairman of the Senate committee that had commissioned the Brookings report. Congress, as it turned out, was not about to buy the Brookings recommendation for a department of transportation; failing that, it had no enthusiasm for recasting the NACA.⁷

This did not mean that the Brookings report was without effect on the Hill. The Senate cut \$100,000 from the fiscal 1939 appropriation, apparently in response to the Brookings report, and only the heroics of the Committee's old friend Congressman Woodrum got the funds restored in conference. The Brookings report merely intensified the conviction of those in Congress who were suspicious of the NACA and anxious to see its power reduced, regardless of the growing menace in Europe.⁸

Other domestic concerns were also distracting the NACA and delaying its response to the German challenge. The Civil Aeronautics Act of 1938 divided the old Bureau of Air Commerce into a Civil Aeronautics Board and a Civil Aeronautics Administration, altering the composition of the NACA in the process. The bureaucratic rearrangement was in many ways a change without a difference, "dictated more by political than substantive consideration," but the alteration of the NACA was real and significant. First, it legislated that the NACA include two members of the CAA on its Main Committee. This placed civil aviation on an equal footing with the army and navy, and reestablished by law the traditional majority of government membership on the Committee. Since 1929, a representative of the Bureau of Air Commerce had consistently held one of the at-large positions on the Committee, but the NACA had not been legally bound by this custom. Furthermore, the Civil Aeronautics Act of 1938 limited the term of office of nongovernment NACA members to five years, bringing NACA practice in line with that of other regulatory and advisory bodies in Washington.⁹

The act's main effect on the NACA was to increase the influence of commercial aviation. Like the Air Commerce Act of 1926, the Civil Aeronautics Act was specifically designed to foster commercial aviation, which now had two of its highest officials on the NACA, giving it a stronger voice in Committee decisions than it had ever enjoyed. Still the NACA guarded itself against the machinations of politics and against CAA encroachment on its own domain. It refused to be drawn into development work on commercial aircraft like that which the services sponsored for military aircraft, and it won inclusion of a provision that "nothing contained in this act shall be construed to authorize the duplication of the laboratory research activities of any existing governmental agency." The NACA was pleased to see commercial aviation win increased support and representation, but it would not allow that to upset the delicate balance of research roles that had been worked out over the years with the services and the industry.¹⁰

Some domestic pressures the NACA could not resist. The aircraft manufacturers, recovering from the scandals of 1934 and the subsequent reorganization of the industry, were again becoming strong and vocal, with the aid of lucrative new military contracts prompted by the worsening situation in Europe. As before, the industry hoped for better response from the NACA to its requests for research, and it sought to channel the Committee's programs along lines of interest to the industry. The Committee's most dramatic reaction to this pressure was its elevation of the Subcommittee on Structural Loads and Methods of Structural Analysis to a full Committee on Aircraft Structures. Airframe manufacturers had long desired more attention to the problems of

structure, and as the military also increased the pressure to produce more and better planes, the NACA found itself compelled to respond.¹¹

So too was the NACA compelled to increase its aid to aeronautical research in universities. In its first years, the NACA had contracted with universities for specific research projects and had published the results of this work and other university research in its technical publications. As its own research capability grew in the 1920s, however, the percentage of university work sponsored and published by the NACA declined dramatically. In 1928, at the urging of Harry Guggenheim, the NACA created a Subcommittee on Aeronautical Research in Universities to continue the work begun by the Guggenheim Fund for the Promotion of Aeronautics. This subcommittee, composed of NACA representatives and professors at Guggenheim-sponsored university laboratories around the country, met in 1929 and 1930 to exchange views and to foster closer cooperation between the NACA and the universities. It did not, however, provide NACA funding for university research, nor did it represent a major commitment on the part of the Committee. The Guggenheim Fund made its last university grant in 1930, and the NACA Subcommittee on Aeronautical Research in Universities was discharged the following year.¹²

In 1935 the NACA once again reviewed its relationship with universities, this time at the prompting of the Federal Aviation Commission. Appointed by President Roosevelt in compliance with the provisions of the Air Mail Act of 1934, the five-man commission, which included Jerome Hunsaker and Edward Warner, had reported its findings and recommendations early in 1935. The commission had voiced unstinting praise for NACA research, but recommended expanding ties with academia to take full advantage of talent and resources available there. The NACA thereupon appointed a Special Committee on Aeronautical Research in Educational Institutions, which concluded that the NACA should continue its pattern of cooperation and should supplement it with an appropriation request of \$25,000 for fiscal year 1936. With this money the NACA was to support specific investigations in universities "upon a showing of their probable usefulness and value to aeronautics." It went on to recommend, however, that "no allotments be made for the specific purpose of supporting aeronautical activities in universities." The special committee was discharged with thanks, and the \$25,000 was requested and approved later the same year. While this sum was far short of what some university professors recommended, it nearly doubled the entire amount invested by the NACA in university research in its first 20 years, and it opened a channel for still larger appropriations in succeeding years.¹³

In its internal deliberations, the NACA revealed its reasons for keeping the universities at arm's length. Alexander Klemin, head of the Guggenheim School of Aeronautics at New York University, had prepared a brief for the Federal Aviation Commission on "Cooperation between the Universities and the N.A.C.A." When a copy came into the hands of the NACA, Ames and Victory noted their objections in the margin. The most telling comments came from Ames. Next to Klemin's assertion that aeronautical research, "if it is to be original and progressive, [should] be decentralized so as to bring entirely independent minds into service," Ames wrote "this means to undo good." Where Klemin observed that, while "in other industries, companies encourage University research," the aeronautical industry "naturally leans on the NACA, since problems may be solved at Langley Field at public expense, and turns to the University laboratories for routine testing if at all," Ames noted "Right!"—a surprising remark from a university president. Where Klemin asserted that "research at the Universities is infinitely less expensive than work done by governmental agencies," Ames wrote "not true." NACA personnel believed that the universities were suited for teaching and testing, perhaps for some theoretical work, but the NACA system of centralized fundamental research was too efficient and productive to be compromised by a shift of power and funds to academia.¹⁴

In the midst of these political struggles at home and the looming conflict in Europe, Dr. Ames succumbed to time and fatigue. In 1936 he suffered a stroke that deprived him of the use of his right side and confined him to his home in Baltimore. Immediately he resigned as chairman of the Executive Committee, the real working body of the NACA, though he retained the largely ceremonial post of chairman of the Main Committee. Dr. Willis R. Gregg, chief of the Weather Bureau, succeeded Ames as chairman of the Executive Committee in 1937. When Gregg died the following year, he was succeeded by committee freshman Vannevar Bush, soon to be dean of the "scientists against time" who came to Washington to win World War II. The old guard was changing even before the crisis broke.¹⁵

THE SUNNYVALE LABORATORY

The NACA finally rode into active preparation for war on the coattails of military preparations. The Special Committee on Relation of NACA to National Defense in Time of War, formed by the NACA in 1936 after hearing Lewis's report on German aeronautical research, had taken second place to domestic events through most of 1936, 1937, and 1938. In August the committee at last submitted its report. Included in it was what came to be known as the Mobilization Plan of

the Aeronautical Board, approved by President Roosevelt in June 1939, which formalized the NACA's status in national emergency. Of more moment for the NACA—and unexpected until shortly before the Committee submitted the report—was the recommendation that the NACA establish another laboratory. Maj. Gen. Oscar Westover, chief of the Army Air Corps and chairman of the special committee, told the NACA that aeronautical research was being hampered by “the congested bottleneck of Langley Field”; another laboratory was needed both to relieve the workload at Langley and to disperse the Committee's research facilities so that they would not be vulnerable to a single attack. He suggested a second laboratory in the central United States or on the west coast. He envisioned that this second laboratory would replace Langley, which would be allowed to sink into obsolescence.¹⁶

General Westover did not live to see his suggestions acted upon. His Special Committee was charged with making a long-range study of the best location for a second laboratory, but he and Willis R. Gregg, then chairman of the Executive Committee, both died in September, leaving only the third member of the Special Committee, Rear Adm. Arthur B. Cook, to carry on the work. In October Admiral Cook was appointed chairman of a new Committee on Future Research Facilities, charged with examining the need for additional facilities for both military and commercial aviation, establishing more effective coordination of existing research functions, and recommending a suitable location for a new laboratory.

By the time the Cook committee reported in December, the world had become a different place. Any optimism remaining after the Munich compromise of September was quickly dissipated in the ensuing weeks. Charles Lindbergh visited Germany in October and confessed himself incapable of conveying in a letter the extent of German aeronautical development. *National Aeronautics* in October called for “awakening our legislators and government leaders to a consciousness of the dire need for increased appropriations for aeronautic research and experimentation.” The *NACA Annual Report* for 1938 played upon the theme of the “crisis in Europe in the fall of 1938.” It came as no surprise to the NACA when the Cook committee recommended on 30 December the expansion of Langley Field and the establishment of a new station at Sunnyvale, California.¹⁷

Gone was the Westover notion that this second laboratory replace Langley; for the foreseeable future, the United States would need all the research facilities it could muster. Gone too was the notion of locating the laboratory in the central United States where it would be comparatively immune to attack by sea or air. Although Lewis reported in November “a strong feeling among a number of the members that a second station of the Committee should be established somewhere

inland," the NACA finally settled on a location just as vulnerable to Japanese attack as Langley was to German. Even in 1938, such thoughts were very much on the minds of men in Washington concerned with national defense.¹⁸

Why then did the Committee choose Moffett Field in Sunnyvale, California, just 20 miles from the coast? In a word, industry. In 1939, 80 percent of America's aircraft manufacturing industry was located within 200 miles of either coast. Almost half of it was on the west coast, principally in southern California. The NACA was being drawn into working more closely with the aircraft manufacturers as part of the military buildup that had been under way since 1936. The military asked the NACA what was possible, then drew up specifications to match. The industry, left with the task of building to these specifications, naturally wanted NACA advice and assistance. It brought to the NACA problems for solution, prototypes for testing, ideas for evaluation. Each trip from a southern California factory to the Langley lab, each trip from the Langley lab to southern California, was expensive in money and time.¹⁹

Industry, therefore, was turning to other sources, and the most important of those sources now posed a real threat to the NACA's position in American aeronautical research. Since 1927, when Daniel Guggenheim had endowed an aeronautical laboratory at the California Institute of Technology in Pasadena, GALCIT (as it came to be called, for Guggenheim Aeronautical Laboratory of the California Institute of Technology) had grown in size and importance, along with the aircraft-manufacturing industry of southern California. The increasing military requirements of the late 1930s taxed GALCIT beyond its capacity and prompted the chairman of the Caltech Executive Council, Robert A. Millikan, to ask Washington for help in expanding. Alive to the sensibilities of the NACA, and reluctant to intrude on the Committee's territory, Millikan cast his request in terms of a research function complementary to that of the NACA. In so doing, he set off a debate about the NACA's role that was to have a major impact on the Committee's history.²⁰

Millikan differentiated between basic and applied research. Conceding basic research to the NACA, he claimed that there was a great and growing need for applied research. Whereas basic research was "concerned with fundamental problems not associated with any specific aircraft design (a definition the NACA could love), applied research, he argued, "deals with questions arising in the development and design of a particular machine." It was into this field that he wanted to expand the GALCIT facilities, to serve the manufacturers in southern California who were overloading his laboratory with test requirements and asking questions that his old Guggenheim-funded tunnel could not

answer. Would the government (he asked General Hap Arnold, chief of the Air Corps) fund a new wind tunnel at GALCIT to supplement the research being done at Langley and at Wright Field?

Arnold, in passing the request to NACA, went Millikan one better by suggesting that there were really three kinds of aeronautical research. Like Millikan, he envisioned basic research on fundamentals, in which the NACA would be preeminent if not entirely alone. Applied research, which he described as the "application of new aerodynamic theories, principles, and discoveries to the particular problems of military aircraft," would be divided between military laboratories and the manufacturers. Production research, which he considered the responsibility of the manufacturers, should "be conducted in the facilities available at Universities or other private or civilian institutions in the vicinity of the manufacturer concerned." NACA was the obvious organization to coordinate this tripartite division of responsibilities, so Arnold forwarded Millikan's proposal to the Committee for action.²¹

Not to be outdone, John Victory prepared an internal memorandum covering Arnold's formulation of aeronautical research activities with one of his own. Leading his list was "scientific laboratory research," which he ascribed entirely to NACA. "Military experimental engineering"—obviously a lower order of activity—was the responsibility of the army and the navy. It entailed the "immediate application of the results of scientific laboratory research conducted by or under the cognizance of the N.A.C.A." Finally, "industrial experimentation and development" was to be performed by the "engineering staffs of the various aircraft and engine factories" using the "enlarged facilities of the NACA . . . whenever adequate facilities are existent or available at the wind tunnels of educational institutions."²²

Victory, and indeed the rest of the NACA staff, were walking a narrow path here. Their own request for expansion at Langley and for another laboratory was working its way through the executive branch and Congress. They wanted to do nothing to endanger that. On the other hand, the military seemed favorably disposed to the GALCIT request, and the industry on the west coast was beginning to flex considerable muscle in support of the proposition. Some congressmen already felt that the NACA was trying to preempt the field of aeronautical research, and NACA opposition to the GALCIT tunnel could arouse suspicion of mere obstructionism.²³

The real threat from Caltech, however, was territorial and functional, and it ran to the very heart of the NACA's justification for continued existence. Understanding it requires a perspective not only on the specific issue of developmental wind tunnels for Caltech but also on the division of research roles in the United States, not just in aeronautics, but in all branches of science and technology. A. Hunter

Dupree has described the situation in the 20th century in the same terms used by Millikan:

In 1900 the universities, grown in one generation from colleges with narrow courses of studies, seemed to have become the natural homes of disinterested, pure science. The broadening of the curriculum, the introduction of the German seminar and its ideal of research, the creation of graduate schools, and the rapid accumulation of endowment either created new centers of learning or remade old ones. With Johns Hopkins setting the pace, such universities as Harvard, Cornell, Chicago, Columbia, and Michigan became the headquarters of fundamental research in the country.

The result was a division of labor which gave rise to the assumption that basic research belonged to the universities, leaving only applied research to the government. The difference heightened between the disinterested, cloistered seeker for pure knowledge and the grubby civil servant chained to the mundane, grinding routine investigation. Although the split between basic research and the common concerns of society was noticeable fairly early in the nineteenth century, after 1900 it became institutionalized in the division of functions between government and the universities.²⁴

As can be seen in Victory's memorandum on research roles, the NACA generally shied away from the dichotomy of basic versus applied research. The Committee, in agreement with General Arnold, saw a spectrum of research in which the NACA could play a variety of roles, concentrating whenever possible on fundamental research. A concept might originate in a theoretical investigation, very often at a university. The NACA would test the theory for soundness and practical application. The military services would use the results to draw specifications for advanced aircraft; industry, to design and develop prototypes meeting those specifications. In postulating a research spectrum, the NACA was interested more in dividing the ground with its clients, the military services and the industry, than in contesting roles with the universities, which before 1930 had contributed little besides engineers to American aeronautical development. Witness the lukewarm liaison with academia as late as 1935.²⁵

Now Millikan, by raising the dichotomy again, was endangering the NACA position in two ways. First, by ascribing basic research to the NACA, he was associating the Committee with the universities at one end of the research spectrum, separating the NACA more clearly than it wanted from the applied research that he left to the services and industry. Second, Millikan was proposing that the government help Caltech move into applied research to assist the west coast manufacturers. If that were done, what part of the research spectrum could the

NACA call its own? It had always been willing, at least after Munk's departure, to concede to the universities an edge in theoretical work, retaining for itself the incomparable wind tunnels needed to convert that theory into fundamental data useful to the military and industry. If the universities started building similar tunnels with government funds, Congress would soon cry duplication.

To make matters worse, GALCIT was then run by Theodore von Kármán, who revealed another chink in the NACA armor. Von Kármán was a brilliant aerodynamicist whose career bore striking similarities to and sad contrasts with that of Max Munk. Both had been students and protégés of Ludwig Prandtl, and both possessed the rare ability to comprehend aerodynamics in the abstract and to apply that insight in fruitful experiments and techniques. Though both had been trained in engineering, their real strength lay in theoretical insight that informed and directed their research. It was for these research gifts that both were brought to the United States, Munk to the NACA in 1921 and von Kármán to GALCIT in 1930. While Munk's prestige deteriorated after he left the NACA, von Kármán's grew through years of productive teaching and research at GALCIT, culminating in election to the National Academy of Sciences and undisputed recognition as dean of American aerodynamics. Of course, all good aeronautical research—whether done in the laboratories of GALCIT, the NACA, the military services, or the industry—required ad hoc mixing of theory, experimentation, testing, and ingenuity, and no institution had a monopoly on any of these ingredients. Still, for the NACA to agree to place government-funded research tools in von Kármán's hands was to arm a rival and loose him in a field the NACA meant to command.²⁶

How could the NACA get out of this bind? The answer was to build its new laboratory in Sunnyvale, California, forestalling a Caltech monopoly in aeronautical research on the west coast. The danger of Japanese attack was more remote than the danger of GALCIT's preempting NACA's role. General Arnold apparently felt that locating a NACA laboratory in southern California would answer the needs of the industry there, for he elected to build a new military wind tunnel at Wright Field in Ohio instead of supporting the Millikan-Caltech proposal. For the time being, at least, the ties between the NACA and the army were proof against pressure from industry and the educational community.²⁷

There were signs, however, of changes to come. When the Millikan proposal failed to win army support, Congressman Carl Hinshaw (whose district included Caltech) introduced a bill to fund a Caltech wind tunnel. Commenting on this proposal, Jerome Hunsaker reported that Caltech was appealing to the government only because the manufacturers in southern California were unwilling to support the tunnel

themselves, even though they were to be the main beneficiaries. They were happy to endorse proposals to build tunnels at government expense but—unlike manufacturers in other parts of the country—less willing to use their own funds. When forced to it, however, they later began to build their own wind tunnels rather than share university facilities and staffs with competitors. In time, both government and industry would contribute to university wind tunnels, but the failure of the CalTech proposal left the NACA position undisturbed for the time being.²⁸

Meanwhile, the NACA's request for a new laboratory at Sunnyvale had cleared what seemed the major hurdle (the Bureau of the Budget) and had been forwarded to Congress by President Roosevelt on 3 February 1939. Then came the unexpected. The traditionally friendly House Appropriations Committee approved the expansion at Langley, but reported adversely on the Sunnyvale item. This surprising reversal—the first congressional rejection of a major NACA proposal—seems not to have been the result of any rancor or lack of confidence. When Congressman John Z. Anderson of California asked subcommittee chairman Woodrum on the floor about the rejection, he was met with sweetness and obfuscation. Said Woodrum:

It may well be that under mature consideration it will be advisable to build a plant at Sunnyvale, and perhaps others; but the Deficiency Committee felt there was not any emergency about it; there was no reason for any great rush about it; and that before embarking upon so comprehensive a program there should be more leisurely and more orderly consideration given to the project. There was no hostility to it. The National Advisory Committee for Aeronautics, in my judgment, is one of the best groups we have in the Government service, and the committee thinks a great deal of that agency and is disposed to lean upon its judgment.²⁹

What the NACA was up against here was the pork barrel. Woodrum was not opposed to seeing funds for the expansion of the NACA pour into Langley Field, within his own state, but he was a little more circumspect about the advisability of sending such funds all the way across the country (especially if he knew of General Westover's original plan to replace Langley entirely with the new laboratory). Other members of his committee—none of them from California—apparently shared his reluctance.³⁰

Here was a new challenge for the NACA, one to which it was entirely unaccustomed. Its modest budgets in the past had gone to the Washington headquarters or the Langley laboratory, and Judge Woodrum had greased the way. Now the Committee was contemplating a huge new investment that could only result in continued growth and

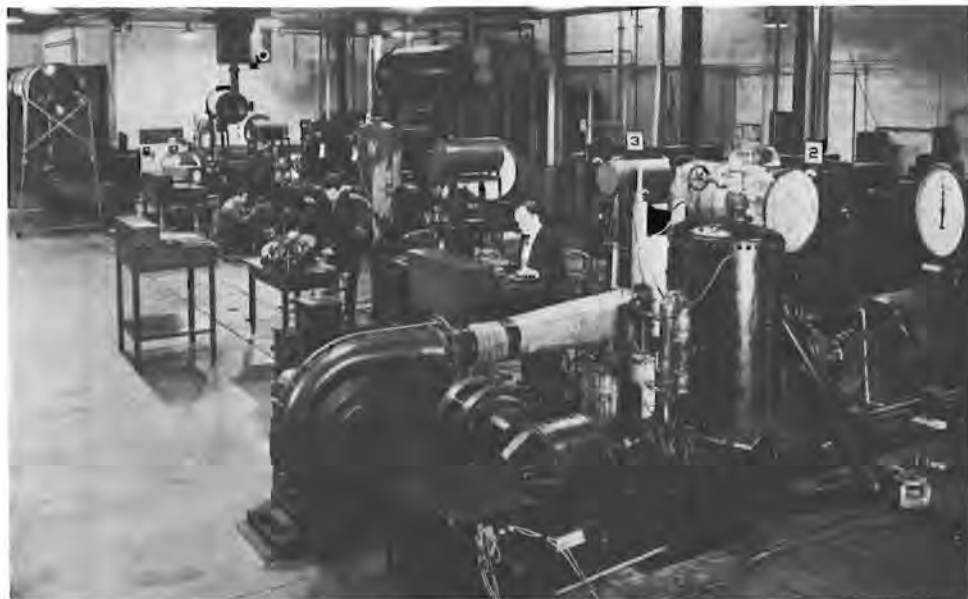
expansion. Dealing with Congress on those terms required an entirely different approach. Nothing daunted, John Victory set about a new brand of politicking. On the day Woodrum's committee turned down the Sunnyvale request, Victory wired to Smith J. DeFrance, a Langley staffer doing advance work in California: "Entire project disapproved. . . . You proceed quietly and alone and learn what you can for we still have hope." ³¹

The NACA strategy for surmounting this new obstacle included collecting endorsements, appointing a new committee under a prestigious chairman, and generally skirting the issue. The day after the Appropriations Committee vote, General Arnold and Admiral Cook signed a joint statement declaring that "the Sunnyvale research project is emergency in character and of vital importance to the success of our whole program for strengthening the air defense of the United States." Ames sent this to the president and tried unsuccessfully to have the Senate reintroduce the Sunnyvale proposal. ³²

Failing that, the Executive Committee met in June and appointed a Special Survey Committee on Aeronautical Research Facilities, chaired by Charles Lindbergh and composed of General Arnold, Admiral John Towers, and Robert H. Hinckley, chairman of the Civil Aeronautics Authority. During the subsequent congressional rehearing of the Sunnyvale proposal, a neat compromise was achieved, facilitated by the prestige of Lindbergh and the power of the other members of the Special Committee. The NACA proposal for another laboratory was approved, but the provision establishing it at Sunnyvale was deleted. Instead, the NACA was to choose a site within 30 days after the bill passed. The bill passed on 3 August. Lindbergh's committee then evaluated all the site proposals made since the original Sunnyvale plan was unveiled and settled (not surprisingly) on Sunnyvale. The Committee got the laboratory it wanted at the site it wanted, but not without some fancy footwork. ³³

THE ENGINE RESEARCH LABORATORY

True to its title, Lindbergh's Special Committee on Aeronautical Research Facilities went beyond mere endorsement of the Sunnyvale site; it also addressed the question of engine-research facilities. On 19 October 1939, after the Sunnyvale scheme was approved, the Special Committee "urgently recommend[ed] that an engine research laboratory be constructed at the earliest possible date, in a location easily accessible to the aircraft-engine industry." This recommendation, already current in NACA circles, received immediate endorsement by the Executive Committee. As was its wont, the NACA appointed a Special



Langley's power-plants engine laboratory in 1938, just as the Main Committee was about to decide that its program and facilities in engine research were inadequate. From that decision flowed the Aircraft Engine Research Laboratory in Cleveland. (LaRC)

Committee on New Engine Research Facilities within a week of Lindbergh's recommendation.³⁴

Lindbergh's report said that "the reason for foreign leadership in certain important types of military aircraft is due in part to the superiority of foreign liquid-cooled engines," and that this in turn was partially attributable to the "serious lack of engine research facilities in the United States" which could not "be compared with the facilities for research in other major fields of aviation." Two historical currents had led the United States to this dangerous situation. First, the choice between liquid and air-cooled engines remained difficult throughout the late 1920s and 1930s. Each type of engine had strengths and weaknesses that suited it for some applications and disqualified it for others. The Europeans, especially the British and the Germans, had divided their research more or less equally between the two types. The United States, however, had concentrated on the air-cooled engine because during much of this period it provided more efficient propulsion at low altitudes, where the navy and commercial airliners did most of their flying. Some research on liquid-cooled engines had been done in the United States, sponsored largely by the Army and the manufacturers themselves, but by 1939 the Europeans were far ahead.³⁵

The second major reason for the dearth of aviation-engine research facilities in the United States dated from the aviation-engine manufacturers' conference sponsored by the NACA in 1916. The participants then agreed that the automobile industry and the new engine manufacturers had sufficient expertise and resources to conduct their own research and development, given some funding and research assistance from the military services. Over the next two decades the NACA and the National Bureau of Standards did some engine research, but never did this branch of aeronautics receive in the United States the kind of interest and support given to aerodynamics. During most of this time the NACA Power Plants Committee had been chaired by the director of the National Bureau of Standards, and most of the NACA funds earmarked for engine research went as transfers to the Bureau, where aeronautical-engine research was conducted in connection with other engine research. Beyond that the NACA had seen little need for fundamental research in aircraft engines.³⁶

As late as 1937, Joseph Ames could write to an administrative assistant at the Bureau of the Budget:

The technical personnel best qualified to plan and to supervise [engine] development are in the Army Air Corps and in the Bureau of Aeronautics, of the War and Navy Departments, respectively. The problem is primarily and almost solely one of development, which can best be attacked by the aircraft engine industry under experimental contracts with the War and Navy Departments. For the immediate practical development of higher powered engines it is believed that no additional expenditures for scientific research by this Committee are required.

The thinking behind that formulation differs little from the consensus reached at the 1916 conference. When a member of the House Appropriations Committee asked George Lewis in 1933 why the United States was spending its money on air-cooled engines while the British were producing the more powerful liquid-cooled Rolls-Royce engine, Lewis lamented to Ames that here was one more misguided soul with "the big engine complex."³⁷

In 1939, Lewis and Ames were deriding this complex no more. At the urging of Hunsaker, Lindbergh, and others, the NACA had come late to the conclusion that engines were retarding the development of faster military aircraft. Speed was the key to military success in the air, and improvements in power were likely to produce greater advances in speed than were the refinements of aerodynamic design.³⁸

Resolved to make up for lost time by devoting a substantial effort to engine research, the NACA faced the harvest of its own neglect. It had neither the staff nor the experience to plan, design, and run an

engine-research laboratory. Research in this field had been left largely to the industry since 1916, and it was to industry that the NACA turned in 1939. Eight days before the Lindbergh committee recommended an engine-research laboratory for the NACA, George J. Mead, recently retired as vice president for engineering of United Aircraft Corporation, was appointed a member of the Main Committee. Six days later he took the oath of office. Two days after that he was appointed vice-chairman of the NACA. One week later he became chairman of the new Special Committee on New Engine Research Facilities. Before the year was out he succeeded Vannevar Bush as chairman of the Power Plants Committee. Never before had anyone moved into such powerful positions within the NACA in so short a time. Part of the explanation lies in the urgency of the international situation in 1939. Most of it, however, reflects how completely the NACA was dependent on industry expertise to launch its engine-research program.³⁹

Mead was as close as the NACA had yet come to placing an industry representative on the Main Committee or in the chair of one of the main technical committees. Jerome Hunsaker had been a member of the Main Committee even while serving as a consultant to firms directly involved in American aviation (including Mead's United Aircraft Corporation); but always his major tie had been to the Massachusetts Institute of Technology, where he headed the Department of Aeronautical Engineering from 1936 through 1951. Edward P. Warner had been a member of the Main Committee while he was editor of *Aviation*, and had even retained his membership after becoming a fulltime consultant to United Airlines. Presumably his work at *Aviation* was considered nonpartisan as far as competition among aircraft firms was concerned, whereas his work at United was in the operation of aircraft, with which the NACA was not directly concerned. Clearly, the NACA had dallied with the idea of industry representation on the Main Committee, but it was not yet ready to make that plunge in 1939. Retired Brigadier General Walter G. Kilner was appointed to the Main Committee from private life on 19 December 1939. When he notified Chairman Bush the following February that he had accepted a post as consultant with Curtiss-Wright, his resignation was duly accepted. The distinction between his affiliations and those of Hunsaker and Warner was a fine one; but presumably a private citizen whose principal employer was an aircraft manufacturer represented too close a link with industry.⁴⁰

George Mead was immune to such charges because he had retired from United Aircraft the previous June. Still, his background and ties were almost entirely with the aircraft manufacturing industry, and his appointment led to major changes in the composition of the NACA.

Counting Mead, half the members of the Special Committee on New Engine Research Facilities came from industry, including Mead's successor at United Aircraft. The Committee on Power Plants, of which Mead was also chairman, was soon reorganized "to include members from outside the governmental agencies for the purpose of strengthening the Committee and to make it national rather than federal in character." Again, counting Mead, half the members of the committee were now drawn from outside the government. Mead had been a critic of the NACA for some years, and his staff at United Aircraft did not cooperate as closely with the Langley laboratory as did those of some other manufacturers. Judging by his actions after coming to power in the Committee, he shared the familiar objection that the NACA was less responsive to the needs of industry than it should be and in fact was dominated by government interests in Washington.⁴¹

Had Mead restructured only the engine-research component of the NACA, his influence would have been great enough. But the change did not stop there. Taking his cue from Mead, Edward P. Warner, chairman of the powerful and prestigious Aerodynamics Committee and himself a sometime critic (though friendly and supportive), asked if the standards of industry and university representation being adopted for the Power Plants Committee would apply to Aerodynamics as well. The sense of the Main Committee was that they would. At the next meeting of the Executive Committee, the same question arose regarding membership on the Committee on Aircraft Structures. Bush stated that the NACA had not adopted a general policy applicable to all committees, but expected to hear separate proposals from each committee. With the barriers crumbling, however, there was little doubt about the course of events. From that time on, industry representation on NACA committees increased dramatically, from 9 percent of the total memberships in 1938 (before the change in policy) to 40 percent in 1948 and 44 percent in 1958. Adding to these the other members drawn from private life raises the representation from outside the government to more than half the committee memberships from World War II on. Nothing less than a revolution had occurred, almost overnight, in the composition of the technical committees of the NACA. Only the Main Committee remained free of industry members, and even there the barrier was soon to collapse.⁴²

The broadened membership of the NACA technical committees raised many ethical and legal questions, but in the fervor of preparation for war, most of these were trusted to patriotism and good will. In 1940 the possibility that a particular industry or company would exploit its privileged position on NACA committees seemed less important than getting the best people from every field and enlisting their sup-

port for the NACA program. Surely that was the case with Mead's Committee on Power Plants, which started the avalanche.⁴³

A year had passed since the proposal for a new laboratory at Sunnyvale had gone to Congress, a year that saw the invasion of Poland and the increased likelihood that the United States would be drawn into the war. The proposal for an engine-research laboratory met much less resistance than had the Sunnyvale proposal. The plan was more thoroughly thought out when it went to the White House, and the president quickly approved it. Though the Bureau of the Budget trimmed the funding somewhat, the basic NACA plan went to Congress in May of 1940 with the firm backing of the administration. One suggestion arose on the floor of the House that instead of funding a new laboratory for the NACA the Congress ought simply to allocate funds to the manufacturers for them to conduct their own research. This proposal was quickly defeated and the engine-research laboratory approved. The NACA was then in a position to win almost any request it made of the Congress, partly because of the war situation, partly because of the Committee's reputation for efficiency and economy.⁴⁴

Getting approval to build the laboratory proved to be less troublesome than selecting a site. As Victory wrote to William F. Durand shortly after the appropriation was passed:

I thought the competition for the location of our second research station which went to Moffett Field was severe, but it seems only to have whetted the appetites and interest of every one who lost out then and many others in trying to get the proposed aircraft engine-research laboratory. We even have a request from one of the largest state delegations in the Congress for a hearing before the N.A.C.A. Congressmen are calling daily with the Chamber of Commerce presidents and others, and the volume of correspondence has reached the flood stage.⁴⁵

More than a whiff of politics had hung over the selection of the Sunnyvale site. Now the whole process was about to begin again, this time with far more players. Before the selection was made, proposals had been received from 62 cities covering 72 different sites. The Committee realized at the outset that its selection procedure would have to be objective, fair, and above reproach, for it had 61 congressmen to disappoint and only one to please.⁴⁶

A Special Committee on Site was appointed under the chairmanship of Vannevar Bush. The Special Committee in turn appointed a Special Subcommittee on Site Inspection, chaired by Victory. The Special Subcommittee drew up a set of requirements for the proposed site and established a rating system. Both were circulated to the interested parties in advance of any inspections to ensure that all agreed at the

outset that the rules of the game were fair and objective. All concurred that the system might be subject to error, but it had no built-in bias.⁴⁷

Between 12 August and 4 October 1940, Victory and his committee visited 37 cities, spoke with local officials, inspected proposed sites for the laboratory and completed evaluation sheets on each site. Three times the Victory subcommittee presented its findings to the Bush Special Committee and three times the ratings were juggled. The day before the first reshuffling, Victory had written to Bush that throughout his investigations he had kept records that could "be disclosed with credit to the Committee, should the procedure ever be investigated." Eight days after the last reshuffling, Victory sealed the rating summaries in an envelope labeled "Confidential. Do not open without authority of J. F. Victory."⁴⁸

As with the selection of the Sunnyvale site, the juggling surrounding the engine-research site seems to have been done for political reasons. As with Sunnyvale, the NACA ended up with the site that it had chosen in the first place, Cleveland. Between the time when Cleveland was first selected on 10 September and finally selected on 16 October, Victory's committee visited some other sites and made adjustments to the ratings it had awarded certain cities. The effect of the first two adjustments was to elevate Glenview, Ohio, to first place, reducing Cleveland to second. In the final shuffle Glenview came in second, with Dayton (for which Orville Wright had argued) a close third. The records do not make clear why the shuffling was done, nor do they suggest any dark motive or unethical conduct on the part of the committee members. Any of the top five sites would apparently have been about as acceptable, and Cleveland seems to have been merely the first among equals. In only two criteria out of the nine used to rate the various sites did Cleveland rank decisively above all the rest; the more important of those two was accessibility to engine manufacturers. If anything made Cleveland the most desirable site for the engine-research laboratory, it was the same factor that made Sunnyvale the most desirable site for the new aerodynamics laboratory: industry.⁴⁹

The Committee's decision was accepted gracefully by most of the cities not selected. For, whatever juggling might have been done behind closed doors, the public impression was that the NACA had chosen well and impartially. As soon as the evaluation of the Victory subcommittee was substantiated and the legal arrangements made, work began on the NACA's third laboratory.⁵⁰

THE NACA'S ROLE IN WAR

While the NACA was fighting for the new facilities it needed to answer the growing aeronautical superiority of Germany, it was prepar-

ing in more somber ways for the apparently inevitable conflict ahead. Most important, it reached an agreement with the armed services on its role in the event of war. The Westover Committee on Relation of the National Advisory Committee for Aeronautics to National Defense in Time of War (whose comments on the bottleneck at Langley Field had precipitated the NACA campaign for additional research facilities) had submitted in August 1938 its report on the status of the NACA in a national emergency. It recommended that the NACA become an adjunct of the Aeronautical Board, a joint army-navy board for coordination of all military aeronautics. Although this arrangement would deprive the NACA of the independence it enjoyed in peacetime, this was felt necessary "in the interests of National Defense." The Aeronautical Board in turn drew up a plan embodying these recommendations. It was approved by President Roosevelt on 29 June 1939.⁵¹

The Westover report also addressed the increasingly critical question of the role of NACA personnel in war. The boom in aircraft manufacture in the late 1930s had already drained the NACA of key personnel, unable to resist the higher salaries offered by the now flush industry. Were this drain to be compounded by enlistment or drafting of NACA personnel in a national emergency, the Committee's ability to perform its mission would be seriously impaired. Since the Westover report had declared that mission "essential," it could not escape the conclusion that NACA personnel would have to be exempted from military service in the event of war. Although it did not call for "blanket deferment" of NACA personnel, the report declared the Committee an "Essential Industry" whose personnel would be exempted on a case-by-case basis. The Aeronautical Board accepted this recommendation also, and embodied it in the plan approved by Roosevelt.⁵²

Everyone realized that the wartime role envisioned for the NACA entailed far less fundamental research than the Committee was wont to conduct. The NACA would be drawn instead into testing, cleanup, and refinement of military prototypes of immediate use in the war. Long-range research leading to improved aircraft in the future would have to be abandoned for the duration. Of course, the fund of basic knowledge and data could be exhausted if it were not constantly replenished, but there seemed no real alternative. With some concern (and a faint hope that some of its work might still address fundamental questions, even in the crush of war), the NACA resigned itself to an inevitable lowering of its sights.⁵³

The increased pace of aircraft manufacture in the late 1930s and the planning for a national emergency also altered the relationship of universities to the national program of aeronautical research. The Caltech campaign for government funding of a wind tunnel in which to conduct research for the aircraft industry of southern California had

demonstrated that industry was being driven to new sources of aeronautical research as its production increased and the tunnels of the NACA and the military services became glutted with projects of their own. The NACA was able to coordinate the research projects of the government but, because it largely excluded industry from Committee membership (at least until late 1939) and because universities were only randomly represented in NACA councils, it had no way to ensure that their programs were not duplicating those of the government. The NACA had always looked to the universities for theoretical aeronautics, and after 1920 had assigned itself the vague task of coordinating university research in aeronautics. Since 1930, when the Guggenheim endowment had expired, the NACA had been taking an increased interest in university work and had been trying with mixed success to increase its own funding of that research as one mechanism for encouraging and controlling it. By 1939, however, these informal methods appeared inadequate to the existing and projected scope of aeronautical research in universities. What was needed, the NACA concluded, was a coordinator of research, one staff man within the NACA who would make it his business to stay apprised of the research capabilities, programs, and needs of industry and academia and to advise the NACA on how best to coordinate these with the activities of the federal government.⁵⁴

The NACA appointed the usual special committee to select a coordinator of research and work out a program for his office. Hunsaker was chairman, Lewis a member. Between them they hammered out a program representing a compromise between their very different views on how such a coordinator should operate. Hunsaker, critical of the NACA, wanted a powerful coordinator who would give the industry and the universities the attention that they had long warranted. Lewis, in contrast, did not want to weaken his own position at the heart of the research-authorization process by introducing a new locus of power, especially one that could deal directly and influentially with the powerful (and manipulatable) Main Committee. Bush openly admitted that he placed Hunsaker and Lewis in juxtaposition on this issue in hopes that out of their conflicting views "something worthwhile would . . . evolve."⁵⁵

What evolved was worked out between Hunsaker and Lewis by correspondence during August 1939. They agreed that the coordinator of research should be "primarily our field man." He would inform himself of activities in industry and the universities and coordinate these with the appropriate technical subcommittees of the NACA, ensuring that the programs complemented each other and avoided duplication. Their great point of difference was the relationship between the director of research and the new coordinator. Hunsaker saw Lewis as

the *executive* officer of the Main Committee, whose function was to "arrange or negotiate or otherwise get the projects carried out." He should not, felt Hunsaker, "*stand between*" the coordinator and the subcommittees, and he "ought not to take over part of the staff function of filtering advice." In line with this implied criticism, Hunsaker stated that the committees themselves needed to have greater industry representation and to become more active in the formulation of the research program, instead of passively accepting what Lewis fed them. "The subcommittees need to do some work," he said, "not just sit back and be informed."⁵⁶

In September Hunsaker's special committee agreed upon the "Duties and Responsibilities of Coordinator of Research" without really resolving the issues in dispute between Hunsaker and Lewis. Only in practice, it seemed, could the varying interpretations of the role of Lewis and the coordinator be worked out. In the ensuing months, the NACA sought a candidate for coordinator who would be both diplomatic and competent to deal with the technical side of aeronautics, a sort of John J. Ide for the homefront. When their first choice (a retired naval officer) declined, Lewis suggested S. Paul Johnston, Ed Warner's successor as editor of *Aviation*. Johnston accepted the appointment on 6 January 1940 and reported for duty three days later, perhaps unaware that the post he assumed was the center of a continuing controversy between Hunsaker and Lewis. The United States would be at war before that controversy was settled.⁵⁷

Meanwhile, still other personnel changes were taking place, changes that were to have a far greater effect on the course of NACA history. On 7 October 1939, Joseph Ames resigned as chairman of the Main Committee, to be succeeded by Vannevar Bush, who had already taken over his duties as chairman of the Executive Committee. Virtually incapacitated for most committee business since his stroke in 1936, Ames had nonetheless been retained as chairman against his will, partly because the NACA profited by his stature and partly because the Committee was truly grateful for his years of service. Since his appointment as a charter member of the NACA almost a quarter-century earlier, Ames had influenced the course of NACA history as have few other men. Much of his influence was masked by Lewis and Victory, through whom he worked. Very often he dealt with them orally, leaving no written record now to show how much of their activity was a reflection of his wishes. Still, the esteem they felt for him and the frequency and deference of their consultations with him leave little doubt that his was the power behind the scenes. The quiet, conservative, methodical style of the Committee can be attributed in large measure to this gentle man. The NACA named the new research



NACA annual meeting of 19 October 1939, the first at which all members were present. Joseph Ames's resignation was announced at this meeting; his successor as chairman, Vannevar Bush, is at the head of the table. (National Archives)

station at Sunnyvale the Ames Aeronautical Laboratory in 1940, just three years before its former chairman's death.

The term of Ames's immediate successor was short. In 1941 President Roosevelt called on Vannevar Bush to head the new National Defense Research Committee, soon to be absorbed in the Office of Scientific Research and Development. Replacing him as chairman of both the Executive Committee and the Main Committee was Jerome C. Hunsaker. Like Bush and other scientists and engineers taking up posts in Washington, Hunsaker brought with him new perspectives, new blood, and not a little criticism of the way things had run in Washington between the wars. In appointing Hunsaker chairman of the committee to establish an office of coordinator of research, Bush had said to Lewis: "Jerry, as you know, has been critical, and the best way to handle this is to give him a chance to get at things." Now Hunsaker would have his chance to get at everything.⁵⁸

Lewis probably greeted this appointment with some misgivings, not only because of his 1939 encounter with Hunsaker on the issue of a coordinator of research but also because outsiders like Mead and Hunsaker who were coming to power within the Committee appeared to be bent on reforms not entirely to Lewis's liking. He mistrusted the increased representation of industry and academia on the technical committees. He doubted that the expanded NACA facilities could be managed as efficiently as the Langley laboratory had been. He resented intrusions on the power base he had established at the very heart of the NACA. But he was a good trouper and the written record suggests that he kept his misgivings to himself. The war effort, after all, was now



This group outside the Langley 19-foot pressure tunnel in 1943 includes two NACA chairmen and the Committee's only two directors of aeronautical research. Chairman Vannevar Bush is fourth from the left in row two, three places to the left of his successor, Jerome C. Hunsaker; Director George Lewis is at the far right of the first row, opposite his successor, Hugh L. Dryden, farthest left of the second row. (LaRC)

the greatest concern, and in that cause he would sacrifice and subordinate his own judgment with the best of men.

Preparations for war in the late 1930s had brought three major changes to the Committee. In the event of war the NACA was committed on paper to applied research, foregoing if need be its basic mission of fundamental research. Second, it had set afoot an expansion of facilities that would soon triple the Committee's physical plant and staff, changing irrevocably the style and procedures of Committee operations. Finally, the old order was passing, and a new generation of leadership was coming into positions of power. Lewis and Victory still held the center, as they had for twenty years. But the Committee charter clearly gave power to the committees; if these had failed to exercise that power in the preceding two decades, or rather had delegated much of it to Lewis and Victory, there was no guarantee that the new leaders were so disposed. On the contrary, they plainly meant to institute reforms that had been on their minds for years past. War would be the crucible in which to begin those changes.

8

What Price Victory, 1941-1945

For the NACA, World War II began in 1937 with the discovery of the aeronautical research being conducted in Germany. The Committee then realized that it had fallen behind in aeronautical development and that the danger for the United States was increasing as war approached. By the time Germany invaded Poland in 1939, the NACA was on a self-imposed war footing. The attack on Pearl Harbor and the U.S. entry into the war merely formalized what the NACA had been doing for several years.

BEFORE PEARL HARBOR

The NACA's most important preparation for the impending war was its construction of two new research laboratories. These projects consumed vast amounts of time and material, distracted and in some cases completely occupied key members of the staffs at both headquarters and the Langley laboratory, and led to a radical change in the way the NACA operated. Recruitment of new staff became more difficult as young men who might otherwise have been attracted to the NACA were considering, or being considered for, military service. Introduction of industry representatives into NACA committees and subcommittees—precipitated by the enlistment of George Mead and others needed to plan the new engine-research facilities—altered the very composition of the agency. It was hard to tell if the changed order of things was due more to the scale of operations the NACA was undertaking, the infusion of new blood, or the sense of urgency that accompanied the approaching war.

Establishment of the new Ames Aeronautical Laboratory (AAL) at Moffett Field in Sunnyvale, California, went as smoothly as could be expected, thanks largely to the cool competence of Smith J. DeFrance, the first and only director the laboratory was to have while it belonged to the NACA. After interrupting his college career to fly in World War I, first for Canada and then for the United States, DeFrance completed

his training in aeronautical engineering at the University of Michigan in 1922 and joined the Langley staff the same year. During the 1930s, he worked on the design and construction of research tunnels and test equipment at Langley and directed research in four of the large tunnels there, thus becoming a natural choice to head the team that would build a new and better LMAL on the west coast. Even before the California laboratory was formally approved by Congress, DeFrance and his team were at work on the preferred site at Sunnyvale, making preparations to construct the laboratory they had designed at Langley.¹



Smith J. DeFrance, first and only director of the NACA's Ames Aeronautical Laboratory. (LaRC)

As soon as Congress approved the laboratory (in August 1939) the reality began to take shape. Construction of the flight-research building began the following February, the first of the service buildings two months later. In May, work began on a 16-foot high-speed tunnel, fastest of its size in the NACA, and on the first of two 7- by 10-foot workhorse tunnels. When DeFrance took over officially as engineer-in-charge in July 1940, construction was under way on a second 7- by 10-foot tunnel, and the first test piles were driven for a 40- by 80-foot full-scale tunnel, larger by a third than its predecessor at Langley. In October 1940 the first research began at Ames; by the time of Pearl

Harbor, the new laboratory had published its first technical report and begun wind-tunnel research.²

In contrast to this rapid progress at Sunnyvale, the Aircraft Engine Research Laboratory (AERL) at Cleveland experienced delays and setbacks that upset the early construction schedule and interfered with the successful completion of the first researches. There were several reasons for this weaker start at Cleveland. Congressional approval for this laboratory came later than that for Ames and brought the project into greater competition with other war-related activities for increasingly scarce resources of men and materials. The NACA lacked the expertise to plan and execute such a facility and had to rely on outside experts unaccustomed to its methods. The logical man from the Langley engine-research staff to head the new laboratory proved unacceptable to George Mead and others and was bypassed in favor of Edward Ray Sharp, who was recalled from Ames in 1941. A self-made man without benefit of a college degree, Sharp had joined the Langley laboratory in 1922 as an airplane rigger. Three years later he was administrative officer of the laboratory, a post he held until 1940 when he was sent to administer the building program at Sunnyvale. He was chosen for the Cleveland job because of his common sense and administrative ability, but he lacked the technical expertise that Smith DeFrance could call upon in establishing the Ames laboratory.³

When Sharp took over the Langley team working on the Cleveland laboratory in August 1941, more than a year after Congress approved funds for the project, not a single building had been completed. Caught up in the outbreak of war, the project soon fell even further behind. Drastic measures were required to get it back on schedule. The Langley team drafting plans for the laboratory was transferred to temporary quarters in Cleveland. Experts from the aircraft engine industry were brought in as consultants. Permission was sought and received to let new contracts for the laboratory on a cost-plus-fixed-fee basis rather than the lump-sum basis previously used. Pressure was put on contractors to meet their deadlines, and the Committee threatened them and their bonding companies with penalties if they failed to comply. The Army-Navy Munitions Board assigned the highest possible priority rating to the project, as did the Aircraft Division of the War Production Board, facilitating the purchase of critical supplies. And Congress granted additional funds to meet the escalating expenses incurred by these actions and by upward revision of the original estimates of what the laboratory should comprise and how much that would cost.⁴

Because of these actions, the laboratory was able to begin research in June 1942 and formally opened in April 1943, nine months ahead of the originally predicted completion date. But the cost was more than twice the original estimate, and the results were not as sterling as many



Edward Ray Sharp, first and only director of the NACA's Aircraft Engine Research Laboratory. (LaRC)

had hoped. In September 1943 an informed army source reported that "the Army is very much discouraged by the lack of results at AERL," contrasting this with the "excellent results put out by AAL."⁵ In general he felt that AERL was not providing timely information, not providing the right information, and apparently not working quickly enough. No doubt many shortcomings could be attributed to the circumstances of the laboratory's planning and construction, but for whatever reason, the laboratory had gotten off on the wrong foot with the NACA's most important customer.

The beleaguered staff at Cleveland might have been comforted to know it was not alone: the Washington office was caught up in its own prewar scuffle for facilities and in many ways fared worse. In 1940 Victory asked for more space in the Navy Building, where the NACA had been housed since 1920, because, he said, "It is of vital importance that our activity remain . . . in immediate proximity to the air organizations of the Army and Navy." In reply, the navy shunted the Committee's offices to the eighth-wing penthouse, letting it be known that "if Mr. Victory does much kicking about this space assignment he may find himself kicked out of the Navy Building." Apparently Victory did kick—as was his wont—and the following year the navy pressured

the Bureau of Aeronautics to remove the Committee entirely. Victory reported to Ames that the office controlling government space in the capital had offered the NACA its choice of "a negro public school, a small apartment house in southwest, or a garage." The Committee settled instead on renting the Leiter mansion in an exclusive section of Washington, with the understanding that after the war it would return to quarters near the military services.⁶

The competition for adequate quarters and facilities was merely the most irritating of the NACA's activities in the two years before Pearl Harbor. After President Roosevelt's approval of the mobilization plan, the NACA had gone on a war footing. Although the plan formally placed the NACA under the joint Army-Navy Aeronautical Board in the event of national emergency, it did not really change the way the Committee did its business. The services gained a power over the NACA that they never had to invoke, for the Committee voluntarily did everything it could to meet the requests of the services and to defer its own programs in the interest of national security. Requests from the services received priority over other investigations. When the military asked the Committee's advice on a technical question, as it did in December 1940 on continuing the development of a Pratt and Whitney liquid-cooled engine, the NACA followed streamlined procedures for returning authoritative recommendations at the earliest possible moment. All this was a change in degree, but not in kind, from the service that the NACA had for years provided to the military.⁷

The problem of advice was tied inextricably to the problem of coordination, an issue that grew more complicated as government agencies multiplied in preparation for war. Two important tasks of coordination fell to key Committee members. Vannevar Bush resigned as chairman of the NACA to head the National Defense Research Committee (later expanded into the Office of Scientific Research and Development) but he retained his NACA membership and supervised coordination between the two agencies. The National Defense Research Committee was modeled on the NACA, and aeronautics was specifically excluded from its jurisdiction in deference to the NACA.⁸

The other key coordination job was performed by George J. Mead, vice chairman of the NACA, who in 1940 became director of the Airplane and Engine Division of the Advisory Commission to the Council of National Defense (known as the National Defense Advisory Commission [NDAC], not to be confused with Bush's NDRC). Though Mead held the post for less than a year before resigning to devote his full efforts to NACA work, in that short time he helped set up the machinery with which the United States responded to President Roosevelt's dramatic call for 50,000 aircraft a year, established lines of communication between the NACA and the National Defense Advisory

Commission, and imposed upon the emerging system of cooperation his own strong views on the NACA's proper role in the war. Mead believed wholeheartedly that, as in World War I, the "proper function" of the NACA was to serve "as an unbiased technical adviser to any branch of the government on aeronautical matters." Both Vannevar Bush and Jerome Hunsaker agreed, ensuring acceptance of this policy throughout the war.⁹

Experience was to prove that formal arrangements for cooperation were not as important as the commitment to cooperation; although the structure of interagency committees and commissions changed with dizzying frequency, the NACA provided advice and services to all who needed them. Much the same was true of coordination of research. The NACA office of coordinator of research, established early in 1940 to integrate aeronautical research activities in the country, survived the outbreak of war by only two months, though its function continued for the duration. S. Paul Johnston resigned as coordinator in February 1942 to take a post with the National Defense Advisory Commission, partly because he had accomplished his initial task of gathering information on America's aeronautical research activities, partly because various NACA subcommittees could handle the letting of research contracts to educational institutions, partly because industry showed some resistance to the NACA's dictating all research programs throughout the country, and partly because Johnston's post had always encroached upon the prerogatives and territory of George Lewis. To fill Johnston's place, the NACA appointed an "assistant for coordination" to the director of aeronautical research, who continued (with less power and less visibility but equal effectiveness) to keep tabs on American aeronautical research and suggest to the NACA how duplication might be avoided and gaps in research filled.¹⁰ As war approached in 1941 and Hunsaker took over from Bush the chairmanship of the NACA, his main concern was how completely the Committee would have to abandon fundamental research in favor of applied research for the services. In late 1940, George Lewis had told Hunsaker that about 50 percent of the Committee's fundamental research had already been displaced by pressing problems of military research. A year later, on the eve of Pearl Harbor, the Committee reported to Congress that 71 percent of its work was on specific military projects. The NACA faced the real possibility of losing its identity in the war, but even Hunsaker was powerless to change things much.¹¹

WARTIME OPERATIONS

"Never was life more interesting," wrote John Victory in 1944. "Never have I been so busy. I take a keen delight in getting work done

and we are rendering service of truly great value to the war program." He had detected in himself the "symptoms of a breakdown," but considered a vacation "just out of the question" for the "volume of the work and even its urgency continue to increase."¹² Though Victory was wont to take himself too seriously, his comments reflect the pace and intensity of NACA activities during World War II, not only in the Washington headquarters but in the laboratories as well. In fact, the pace was even more hectic at the laboratories, for lack of gas rations kept Victory at home evenings and Sundays, while many of the facilities at the laboratories were running on two and even three shifts.

The NACA's work procedure during World War II was generally the same as it had been through the previous quarter century. Suggestions for research projects came into the headquarters from the military services, industry, the technical committees and subcommittees, and the laboratories. These were either referred to a technical committee for evaluation or (especially in the case of requests from the services) approved outright in George Lewis's office. The research was assigned to a laboratory, which in turn scheduled it for one of the wind tunnels or other test facilities, depending on its priority. As the work progressed, preliminary reports were prepared and referred where appropriate to the sponsoring or interested agency or party. When the entire investigation was completed, a final formal report was prepared and published and the research authorization was closed out.¹³

World War II changed some details of this procedure without altering the general sequence of events. For example, most of the Committee's war work was cleanup and testing of prototype models of military aircraft; before the war, the NACA had devoted little time to such engineering testing, for which the services themselves had been principally responsible. As an arm of the military services for the duration of the war, the NACA could not refuse such requests, though in practice it had seldom turned down military projects in the peacetime years.¹⁴

The NACA's two principal technical publications before the war had been the Technical Report (containing major research conclusions, usually at the end of an investigation) and the Technical Note (containing interim and less important results). Both were generally unclassified and widely distributed, though some Technical Notes had only limited distribution if they contained proprietary information or results considered so advantageous to the United States that they should not yet be shared with other nations. During World War II, the TR and TN series were virtually suspended; they were replaced by a series of wartime reports, all classified and with limited distribution, usually within the military services and among industry contractors having a need to know. This change in policy meant that during the war the

MODEL RESEARCH



One of the NACA's more dramatic flight-research projects was the ditching test of a B-24 in the James River in 1944. The military services were greatly concerned at the time with the safety of crews in planes forced down over water. (LaRC)

NACA issued a greatly increased volume of reports to a greatly reduced audience, concentrating more on interim reports of research in progress than on conclusive reports when all the results were in—a luxury that neither the NACA nor its customers could afford in the frantic rush to get new and better aircraft from prototype to construction to operations. How far the NACA was forced to stray from its peacetime ideal was revealed by John Victory in 1943, responding to a request for information about what the NACA was doing:

All of the research activities of the National Advisory Committee for Aeronautics are connected with immediate and vital problems of the Army and Navy air organizations, and all the results constitute classified information, distribution of which is covered by the restricted policies of the military services. The NACA does not issue news releases dealing with those research activities.¹⁵

Similar changes infected the meetings of the technical committees and subcommittees. Meetings retained the same format and the same purposes, but they were held more frequently and attended by far more industry representatives than in previous times. The presence of industry representatives posed two problems, but these quickly evaporated. First, government representatives expressed some concern about the discussion of classified information in the presence of such individuals, but the services readily conceded the necessity for doing at the NACA what they were doing elsewhere in Washington, as civilians and consultants joined the war effort in unprecedented numbers; no instance of compromised information seems to have resulted. The related question of how to deal with proprietary information had arisen early but, in the pace of wartime activities, the normal dangers of industrial espionage disappeared. All the manufacturers had more work than they could handle, and the war seems to have instilled in all a sincere desire to produce the best planes for the military services, regardless of where the ideas came from or where they were applied. Surely the varying firms still competed for government contracts and took institutional pride in turning out the best planes, but none of this was allowed to interfere with the flow of information to the place where it was needed.¹⁶

The overall committee structure of the NACA was remarkably stable during the war. Most of the changes were creations of technical subcommittees to address specific problems, such as metals for turbo-supercharger wheels and buckets, welding problems, heat exchangers, vibration, and dual rotation of propellers. None of these survived the war, but several others that were created during the war went on to a

lengthy service, like those on icing problems and heat resisting materials.¹⁷

Only one new main technical committee was added during the war, but its history held portents of changing times for the NACA. Ed Warner, who had long argued that the NACA should have a Committee on Operating Problems, became the first chairman of this body when it was formed in 1942 to address problems encountered in wartime flying. After the war, Warner would be succeeded in this post by William Littlewood, vice president of American Airlines. Littlewood had been brought onto the Main Committee in 1944 to replace the invaluable George Mead, whose health was failing. Littlewood's appointment was significant in that he was the first appointee to the Main Committee from an active position in the aviation industry—and from a commercial airline at that, not from a manufacturer. With him the last NACA barriers to industry representation fell, and the shape of the postwar NACA became clearer.¹⁸

In 1939, instead of using the word *conference* to title the annual industry meeting, Victory called it the "Fourteenth Annual Inspection of the N.A.C.A. Laboratories." The military terminology reflected both the nature of the work engaging the Committee at that time and the sad fact that the NACA could no longer discuss its projects freely with industry representatives. After 1939 there were no annual laboratory meetings at all, the necessary exchange of information taking place instead in closer personal contacts between the NACA staff and industry representatives. Manufacturers brought their planes and their problems to the laboratories on an ad hoc basis; the NACA staff visited factories more often and worked more closely with problems of development and design. In 1943, for example, the Committee reported that the Langley laboratory had a daily average of 45 visiting industry representatives who stayed a few days or a few weeks, then took the latest NACA results back to their factories and drawing boards.¹⁹

This closer cooperation with industry was revealed most forcefully by the creation of the Western Coordination Office in 1940. Since much of the aircraft industry was located in California, much of the liaison work facing the NACA lay there. In 1940 Edwin P. Hartman, a mechanical engineer with ten years' experience in aeronautical engineering at LMAL, was appointed western coordinating officer for the NACA and given quarters in a temporary building from which construction of the Ames laboratory was being supervised. Hartman began making regular rounds of the aircraft manufacturers in and around California and sending trip reports to headquarters. These proved so valuable and so much in demand that Hartman's activities increased. By 1942 he was spending two-thirds of his time in the Los Angeles area, where most of the manufacturers were located. At that juncture,

the Committee won approval to open a Western Coordination Office in Santa Monica. Hartman occupied the office for the rest of the NACA's lifetime and compiled in his regular reports a remarkable picture of the growth of the west coast aircraft-manufacturing industry.²⁰

Throughout the war the NACA workload grew faster than the available staff could handle. This generalization had always been true of the NACA, but in the past the limitation was money, a limit that Congress in its wisdom imposed upon the Committee. Now, in the crush of war, funds were available for virtually any good purpose, but no longer could the Committee muster the personnel or the facilities to make use of it. The NACA farmed out what research it could by contract, usually to universities, but this hardly dented the backlog.²¹

The greatest handicap was personnel. Many staff members not subject to the draft left the Committee for higher paying jobs in industry, where they could do equally patriotic and productive work. The NACA Overtime Act, approved 10 February 1942, alleviated this problem by making higher take-home salaries available to NACA personnel, but in December of the same year this special legislation was replaced by general government overtime regulations less generous than the NACA schedule had been. The drain of experienced personnel to industry remained a minor problem throughout the war, but a harbinger of more serious problems to come.²²

The key NACA personnel problem during the war was military service. The mobilization plan of 1939 had declared that the NACA would be considered an "essential industry" in the event of national emergency and that a deferment plan would be negotiated with the proper authorities. When war actually broke out, the "proper authorities" turned out to be the Bureau of Selective Service, which was far less understanding and sympathetic than the military services. Early in 1942, the army allowed NACA personnel holding reserve commissions to resign their commissions and thus avoid a call to active duty. The Selective Service, however, refused to make special arrangements for NACA personnel and instead put them under the standard replacement schedule for industrial establishments. This plan required the NACA to train replacements for experienced workers of draft-eligible age. While the Committee had no objection to this policy in the case of unskilled or semiskilled workers, it balked at trying to train green recruits to do the aeronautical research that its leading young engineers had been working at for years. The Selective Service policy, which remained in effect through 1942 and 1943, put a direct drain on key NACA personnel by making them eligible for call-up, and an indirect drain on the remaining staff by lowering morale and making the future uncertain.²³

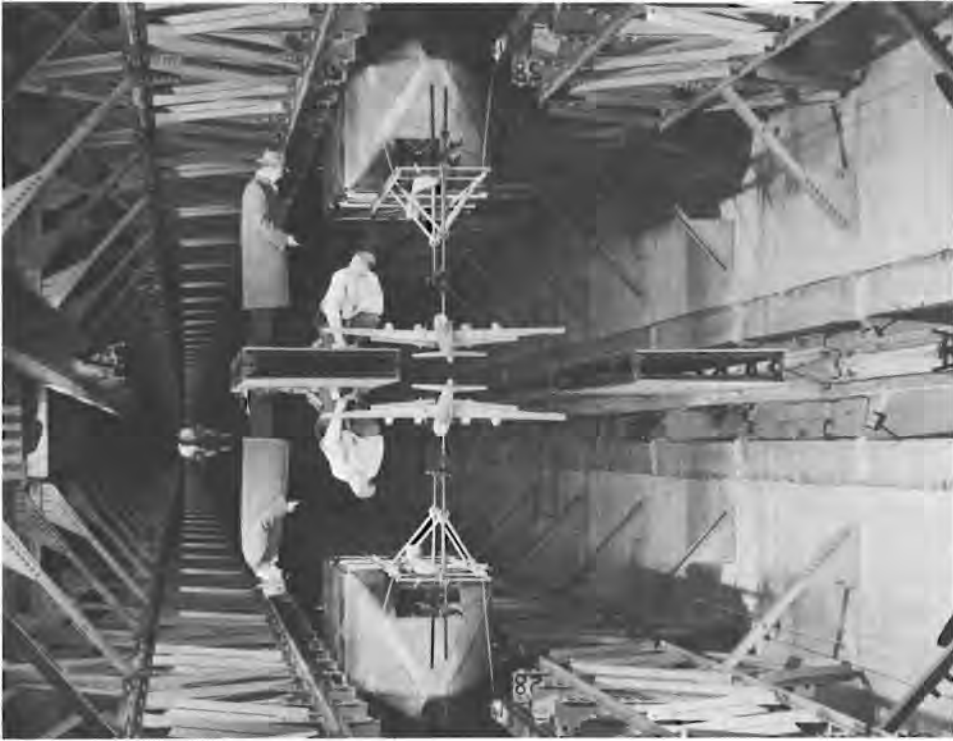
Late in 1943, despairing of any change in Selective Service policy, the Committee turned to the military services and worked out with

them a plan to circumvent the Selective Service. The "Army-Navy-NACA plan of 1 February 1944," approved by President Roosevelt on 10 February, provided that essential NACA personnel would be inducted into the armed services and then assigned to duty at the NACA laboratories where they had been working. Personnel from LMAL and AERL would receive enlisted reserve status in the Army Air Corps; those at headquarters and AAL would go to active duty in the navy. Within 9 months, 1646 NACA employees were serving under the plan, employees who might otherwise have been lost to the Committee. Another provision of the plan allowed the NACA to recruit new employees from Army enlisted personnel returning to the United States from overseas service. This relieved some of the shortages created by earlier policies and saw the NACA through the war. Though the compromises worked out on this difficult topic were never entirely satisfactory, they were better than those won by comparable agencies, and this special treatment reflected the NACA's rapport with the military services and the importance they attached to the continuation of the NACA's work.²⁴

Shortages of facilities were more easily solved than those of personnel. The NACA set first priority on construction of its own new wind tunnels, and it fought hard to acquire the necessary materials. But when industry or universities sought to build tunnels that did not compete for scarce resources of men and materiel with those of the NACA, the Committee generally approved. As of April 1943, Jerome Hunsaker was recommending that industry and universities be allowed to, even encouraged to, build new atmospheric tunnels of moderate size and speed, but no high-speed variable-density tunnels, which were already in sufficient supply within the NACA and the military services.²⁵

Although the NACA had all it could do to keep up with the congestion of U.S. military and civilian agencies and offices that sprang up during the war to deal with different aspects of aeronautical research, it made a sincere effort to cooperate with the Allies as well. Unfortunately, the course of the war in Europe made most of this cooperation impractical if not impossible. When the Germans overran France in 1940, John J. Ide was forced to close down the Paris office, rescue what confidential papers he could, and destroy the rest. Thereafter, Ide, an officer in the naval reserve, was called to active duty, and served out the war doing intelligence work in London. Some cooperation took place between the NACA and the aeronautical research institutions of the Soviet Union, but not on a scale to affect appreciably the NACA program.²⁶

It was with the British that most international cooperation was carried on during the war. Some of this merely continued the coopera-



Among the new facilities won by the NACA during World War II was towing tank #2. Here, two workers set up a model for test in the new tank. The illusion that they are suspended in space was created by printing the photograph upside down. (LaRC)

tion of prewar years, such as the exchange of publications and personnel between the NACA and the British Aeronautical Research Committee. Some came about through personal contacts, like the visits to England of Edward Warner in 1942 and Eastman Jacobs of LMAL in 1943. Some of the cooperation consisted of participation by the NACA staff and their British counterparts in activities of other agencies such as the Joint Aircraft Committee of the Army-Navy-British Purchasing Commission, a child of the National Defense Advisory Commission created in 1940 to coordinate the needs and resources of the American and British programs. While these measures kept the Committee in close touch with British aeronautical research, none was sufficiently early or unrestricted to save the NACA from the most damaging failure of its history: the failure to develop jet propulsion before other nations.²⁷

JET PROPULSION

The engine research policy of the NACA dated from 1916, when the Committee had played a pivotal role in reconciling differences between the armed services and the automobile-engine manufacturers then beginning to make aircraft engines. Because engine manufacture was viewed as a mature technology that required only adaptation to the field of aviation (i.e., development), the NACA decided early on to leave this research field to the industry, the services, and the National Bureau of Standards, which already had staff and facilities for engine research. Aerodynamics was the real infant technology in World War I; to this field the NACA devoted most of its resources: its wind tunnels and engineers. The one great American aeronautical achievement in World War I—development and production of the Liberty engine—seemed to confirm this judgment.²⁸

This is not to say that the NACA did no engine research over the years. The Committee on Power Plants for Aircraft lasted the entire life of the NACA, the only technical committee with such a record. The NACA produced more reports in the field of power plants than in any other except aerodynamics (although most of them were actually prepared for the NACA by the National Bureau of Standards); half the Committee's reports in 1918 were on propulsion. After the war, however, propulsion research was overshadowed by aerodynamics. In all, the NACA produced four times as many reports in aerodynamics as it did in propulsion. When the Aircraft Engine Research Laboratory was finally proposed in 1939, it was not so much to expand a capacity within the NACA as to close a gap that had been unperceived or unappreciated for years. As late as 1937, Joseph Ames had told the Bureau of the Budget that "for the immediate practical development of higher powered engines it is believed that no additional expenditures for scientific research by this Committee are required." But just two years later, the Special Survey Committee on Aeronautical Research Facilities reported "a serious lack of engine research facilities in the United States" creating an urgent need for a new laboratory. A BoB official inspecting construction at AERL in 1943 noted that "we are paying heavily for our lack of foresight."²⁹

The Committee could well claim after the fact that its longstanding policy of neglecting engine research had the tacit approval of the military services and even the industry, for neither in meetings nor at the annual industry conferences was the NACA called upon to involve itself more deeply in engine research. But the NACA remained open to criticism for lack of foresight. After all, members and staff had claimed repeatedly over the years that "it is the responsibility of the National Advisory Committee for Aeronautics to anticipate and to meet the

research needs of aviation, civil and military, and to provide the Army, the Navy, and the industry with that constant flow of new knowledge that is essential to American leadership in aircraft performance." ³⁰ Such boasts left them subject to blame for the lag in American engine development and even more for the failure to develop jet propulsion.

The fundamentals of the technology are simple enough. All powered aircraft are propelled by reactive force. Air is pushed backward, forcing the plane forward. Aircraft in the 1930s created the backward push by capturing and accelerating an air mass with a propeller. At relatively low speeds, this is still the most efficient way to drive a plane.

At higher speeds, however, another method of propulsion becomes practical. Air heated in an engine at greater than atmospheric pressure and allowed to escape through a nozzle at the rear will expand greatly upon exit, leaving the nozzle at high velocity. The thrust of the gas in one direction pushes the aircraft in the opposite direction.

There are two kinds of reaction propulsion by hot gases. In rockets, the fuel and oxygen are both contained within the engine. No intake of air is required. In so-called jet engines, air gathered from the atmosphere is compressed, mixed with fuel, and burned. The simplest engine of this type is the ramjet, which uses its own forward speed to literally ram air into itself to high pressures. But this engine must get up to high speed before it can work. More practical is the gas-turbine engine, in which the air is drawn in, compressed, mixed with fuel and burned, passed through a turbine, and exhausted in a powerful jet of hot gases. The turbine converts some of this thermal energy into mechanical energy which turns the compressor at the front of the engine—and in a turboprop engine, turns a conventional propeller as well.³¹

All of this was known in theory long before a practical jet engine for aircraft was built, and the NACA had dallied with the technology several times in its first quarter century. George Lewis wrote to George de Bothezat in 1920, reminding him that, during Lewis' recent visit to McCook Field, a Major Hallett had asked de Bothezat to "give him a statement as to the possibility of jet propulsion engines being used on aircraft." Lewis enclosed a published description of a device invented by M. Melot, recently exhibited at the Paris air show, and a copy of Robert Goddard's classic paper, "A Method of Reaching Extreme Altitudes." This familiarity with early rocket research shows that Lewis, new to his job at the NACA, was already informed on the latest developments in what was still a nascent technology. No distinction in terminology had yet been drawn between air-breathing and rocket versions of jet propulsion. Unfortunately for the Committee, any response by de Bothezat on this topic seems to have been lost in the

controversy and acrimony surrounding his departure from McCook Field later the same year.³²

In 1923, at the behest of the Army Air Service, Edgar Buckingham of the National Bureau of Standards undertook an investigation of the feasibility of jet propulsion. He concluded, in a report published by the NACA, that "propulsion by the reaction of a simple jet can not compete, in any respect, with air screw propulsion at such flying speeds as are now in prospect," because at those speeds (about 250 miles per hour) "the jet would . . . take about four times as much fuel per thrust horsepower-hour as the air screw, and the power plant would be heavier and much more complicated."³³ Though Buckingham was right about the impracticability of jet propulsion at low speeds, he accepted the common fallacy that a turbojet would weigh too much to be practical. He, and most others who considered the application of turbines to aircraft in the 1920s and 1930s, assumed that such turbines would resemble the heavy industrial turbines then being used in blast furnaces and boilers. Technology was already available, however, to make aircraft turbines much lighter.³⁴

When Charles G. Abbot raised the issue again at the annual industry conference at Langley laboratory in 1930, he received answers from two men who were to play key roles in the future. Eastman Jacobs of the Langley staff said that his work on the problem showed a need for more thrust than was currently attainable. Hugh Dryden, a brilliant young physicist then heading the National Bureau of Standards's Aerodynamics Section, told Abbot of Buckingham's work and reported that the NBS would be recommending the related technology of thrust augmentation to the NACA as a research project for the coming year. The NACA Executive Committee approved three research authorizations for this project the following month, and Dryden directed the studies, winning appointment to the prestigious Aerodynamics Committee the following year. The research, however, did not improve performance enough to substantially alter Buckingham's conclusions.³⁵

Another investigation of jet propulsion came to the attention of the NACA in 1938 when Vannevar Bush reported to George Lewis that the National Academy of Sciences had recently set up a committee to study, among other things, jets. This investigation resulted from a report by a naval officer who had observed the development of gas turbines in Europe. The navy asked the academy to appoint a committee to investigate the possibilities of gas turbines for marine propulsion. The committee, apparently under the leadership of Professor Lionel S. Marks of Harvard, included Theodore von Kármán and Robert A. Millikan of the Guggenheim Aeronautical Laboratory at the California Institute of Technology, and it addressed the "possibilities of the gas turbine for aircraft propulsion." Its report, submitted in June

1940, concluded that "the gas turbine could hardly be considered a feasible application to airplanes mainly because of the difficulty in complying with the stringent weight requirements imposed by aeronautics."³⁶

By this time jet aircraft had already flown secretly in Germany and would fly in England the following year. The United States was, quite simply, egregiously late in appreciating and developing jet propulsion for aircraft. In this tardiness, the NACA was no better and no worse than the other American institutions with which it shared responsibility for the development of aircraft propulsion. The military services never asked the NACA for an opinion on jet propulsion; instead, they asked their own consultant, the National Bureau of Standards, or the National Academy of Sciences. Only Charles G. Abbot, secretary of the Smithsonian Institution, seems to have asked the NACA about the subject, and he was told what the NACA had done and planned to do in 1930. Eastman Jacobs had done some early research on the subject, and in 1939 was at work again under a job order at Langley laboratory. But the Committee seems never to have appreciated the importance of the topic, and seems to have been slow in giving Jacobs full support. Its defense against these charges must be that it was not the agency primarily responsible for engine development in the United States, and that defense must stand in the bright glare of the claims the NACA staff and committee members had made for themselves over the years.³⁷

Whoever was to blame for American tardiness, the action increased dramatically early in 1941 when General Hap Arnold learned of German progress in the field. On 25 February Arnold wrote to Vannevar Bush emphasizing the importance and urgency of jet propulsion; after a meeting between Bush, Arnold, and Admiral Towers, Bush decided to expand the scope of a recently constituted NACA subcommittee on auxiliary jet propulsion. On 24 March he advised the Main Committee that he planned to create a special committee on jet propulsion, chaired by Dr. William F. Durand, charter member of the NACA and then the 82-year-old dean of the American engineering community. Durand's specialty had been propellers, but he was well versed in all aspects of aeronautical research, and his seniority and prestige lent weight and moment to the new committee. In fact it was Durand who was to turn the Committee's attention from rocket propulsion, which Arnold thought the Germans were developing, to jet propulsion, which Arnold subsequently learned the British had achieved.³⁸

Membership on the special committee went to the usual sampling of government and academic experts, as well as to three representatives of commercial firms engaged in turbine development: one from Allis Chalmers, one from Westinghouse, and one from General Elec-



William F. Durand, member of the NACA, 1915–1933 and 1941–1945; chairman of the Special Committee on Jet Propulsion. (LaRC)

tric. At Arnold's insistence, there were no representatives from the reciprocating aircraft-engine industry, because he feared they would oppose any radical new departures in engine development; later it was claimed that they were excluded because their "energies" were judged to be "completely absorbed in production problems." After meeting seven times in the course of five months, Durand's committee recommended that the services let contracts for three types of jet engine development—one to Allis Chalmers, one to Westinghouse, and one to General Electric. Progressives of 1915 might have blushed at the conflict of interest here, but Durand's committee was never intended to be either democratic or egalitarian. It was intended to get the United States back in the race for aircraft engine supremacy. The way to do that was to bring in the best industrial representatives available, review their research, and support the most promising ones. Not surprisingly, the Main Committee decided that the projects of all the companies represented on the special committee were worthy of support. The military services, who were of course also represented, took the committee's recommendation and awarded development contracts to the three firms.³⁹

The NACA had gone a long way toward rescuing the situation and reestablishing its credibility as the central agency for coordinating American aeronautical research. But it did not stop there. It also recommended that its own project for jet propulsion, under the direction of Eastman Jacobs's at the Langley laboratory, should receive full support and early trials. Jacobs's scheme was a variation on the Campini ducted fan which used a traditional reciprocating engine to drive a fan within a duct behind the engine. To get spurts of additional thrust for combat, fuel could be burned in the duct behind the fan, adding jet propulsion to the conventional thrust. At the time the Durand committee met in 1941, Jacobs had not solved the problem of stable combustion in the afterburner, but the Main Committee nonetheless recommended support. Though Jacobs would make considerable progress over the next two years, he never succeeded in developing an engine as appealing to the military services as the turbine engines developed by the commercial manufacturers. In 1943 the services turned down a request by the Committee to construct an airplane incorporating the Jacobs engine, and there the project died. Jacobs and some other staffers at Langley felt the services were wrong to ignore what Jacobs called a "conservative straightforward engineering design"; but what the services felt they needed—rightly, as it turned out—was a radical new design to help the Americans catch up with England and perhaps Germany.⁴⁰

After the original recommendations of the Durand committee, the NACA's wartime efforts in this field, as in most others in American aeronautics, were limited to coordinating and testing. Significantly and ominously, the NACA was kept in the dark about much that was happening in jet-engine development. When the services brought a Whittle engine to the United States and assigned General Electric the task of building a similar engine, entirely apart from the development contract that company already had on NACA recommendation, the NACA was not told, in keeping, it seems, with a general promise of secrecy made by Arnold to the British. Only through rumor did it learn of the jet-propelled airplane being developed by Bell Aircraft under contract to the services. When Warner wrote from England in 1943 that the British were supplying the United States with all the jet-propulsion information they had, Hunsaker suggested in reply the extent to which the NACA had been reduced from its traditional role: "The idea that they [the British] are supplying 'us' everything they have does not apply to NACA but may apply to the services. The details of this situation are somewhat sticky but I can give you the story orally." Part of the story was simply that the services had put an unprecedented lid of secrecy on all jet-propulsion development. Not only did this policy shut out the NACA more completely than ever

before from developments in military aviation, but it also prevented the manufacturers from freely exchanging information on their projects. In fact, the two sections of the General Electric Company working on the separate jet projects did not know that the other team existed, though of course rumors flew at a great rate. The "Buck Rogers" project for a jet airplane at Bell Aircraft was apparently unknown to some of the employees there. The full story of American jet development during the war has never been made public, but enough is known to suggest that it is a case history in the hazards of excessive secrecy.⁴¹

This general cloak of secrecy, however, does not fully explain the extent to which the Committee was excluded from its normally close and candid collaboration with the military services, as Hunsaker's letter to Warner suggests. What had really happened was the onset of a crisis of confidence, a suspicion on the part of the services that the NACA had let them down. Military men understood that they themselves were ultimately responsible for the state of military unpreparedness in which they found themselves. Depending on the NACA to tell them what was important had lulled them into a comfortable laxness in which they had left their own flanks unguarded. Now they were second-best in an important new technology, and they felt that their past reliance on the NACA had been a mistake. So they took to running this new technology by themselves, relying on their own judgment, their own sources of information. Since they wanted to keep the whole field as secret as possible, there was no reason to inform the NACA. The Committee had no "need to know"; keeping the NACA abreast of developments would serve only to multiply potential leaks of information without getting any assistance or advice in return, for the services expected none.

None of this was explicit. There were no confrontations, no exchanges of acrimony, no pointing of fingers. Outwardly all went on as before, and the written record remained as polite, cordial, and sterile as ever. But beneath the surface and between the lines was a cooling of attachments and a keeping of distances such as the NACA had never known. When Jerome Hunsaker sent General Arnold a paper on "Aeronautical Research" in September 1942, he received in return the suggestion that he concern himself less with the possibility of "frozen designs" in American aircraft production and more with developing better aircraft engines for fighters. "I do not feel that progress made in the improvements of engines is keeping pace with that of the airplane," wrote Arnold. Hunsaker derived from this letter the "impression that there is a feeling that American engine development has been outdistanced by that of foreign powers," and he asked for a meeting with the chief of the Army Materiel Command to clarify the army's position. He was told that the army expected to fight out the war with the aircraft

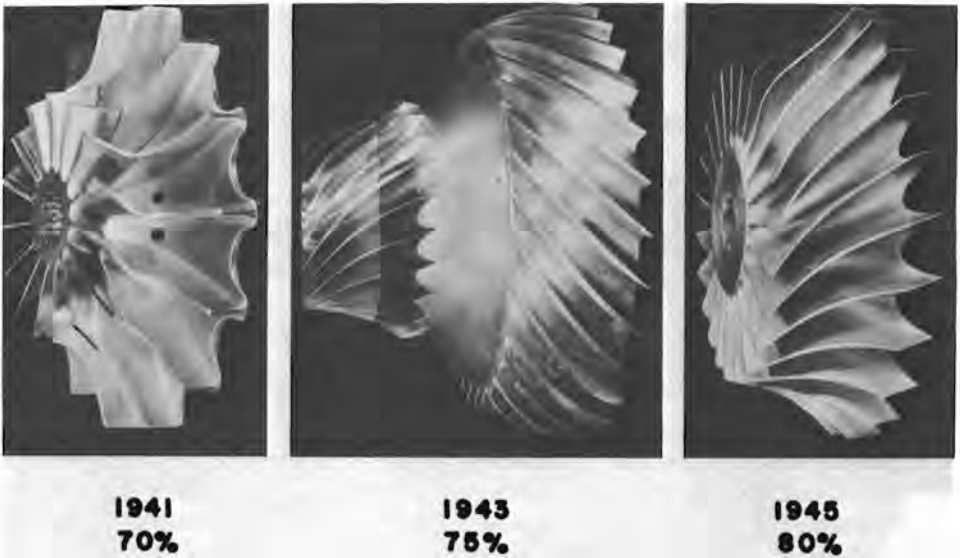
engines then in production (a reason given then and later by both the army and the NACA for delay in developing jet propulsion). The Committee should therefore occupy itself with refining the engines already in production, a role that effectively barred the NACA from the jet-propulsion development being pursued by the army. The Committee did become involved in testing such jet engines as reached prototype stage; but, when it attempted in the winter of 1942-1943 to penetrate army long-term councils, it was politely advised to stick to conventional engines.⁴²



General H.H. Arnold inspects the kind of work he wanted the NACA to do during World War II: a researcher at the Aircraft Engine Research Laboratory points out ice buildup on a conventional propeller blade during the general's tour of the laboratory 9 November 1944. George Lewis and John Victory look on at left. (LeRC)

Sensing this new situation without ever being candidly apprised of it, the NACA tried to cut its losses by doing for jet propulsion what it was best at doing. It had been working on compressor design for years in connection with turbosuperchargers. The principles and problems in both fields were almost identical and the NACA could transfer its expertise to the newer field, as indeed it did. Furthermore, the Com-

mittee could use its new laboratory at Cleveland for some of the testing required once the new engines reached prototype stage. Although the Cleveland laboratory had not been designed for research in jet propulsion, some of its equipment was suitable for testing both conventional and jet engines, and the Committee quickly sought appropriations for new equipment specifically suited to jet development.⁴³



Improved design of centrifugal superchargers during World War II led to significant increases in efficiency. (LeRC)

And Eastman Jacobs, stung and dissatisfied with the services' rejection of his ducted-fan proposal, began a line of argument that he maintained through the war and into the era of practical jet aviation: too much emphasis was being put on engine development and not enough on the means of fitting these new engines to aircraft. The engine and the airframe must be matched to each other, he maintained, or the efficiency of both would be compromised. Essentially he was arguing for more attention to the aerodynamics of jet engines, and aerodynamics was the NACA's forte, a way for the Committee to make a real contribution to jet-aircraft development even if it was largely excluded from development of the engines.⁴⁴

LOOKING BEYOND THE WAR

The NACA's failure to discover and develop jet propulsion should not be allowed to mask its real and significant contributions to American aerial victory in World War II. Though air power was not the sole,

or even the most, important ingredient of American victory in the war, it was a key ingredient; without the NACA, American aerial superiority would have been less complete, less early. Every American airplane that fought in the war, every aircraft engine, had been tested and improved in NACA facilities. Most of this cleanup and testing was incremental and anonymous, hard to trace to the NACA, and difficult to evaluate. With military officers, NACA engineers, and aircraft designers and manufacturers all poring over the same test results in an effort to improve the flying qualities of an aircraft, the credit for improvements must be spread widely. Some examples of NACA contributions can be isolated, as when the Committee predicted that the B-32 would fail and recommended that its development be abandoned. In some cases, the prescribed NACA fix for a problem aircraft was rejected by the manufacturer, as when Kelly Johnson of Lockheed ignored the first solution proposed by the NACA for the problems his P-38 was experiencing.⁴⁵

Two Committee achievements during the war were so obviously useful and noteworthy that the NACA took great pride in citing them. The first investigation undertaken at the new Ames laboratory—icing research—was so useful not only to military bombers operating at high altitudes and through all kinds of weather, but also to commercial operators, that it won for its principal investigator, Lewis A. Rodert, the Collier trophy of 1946. The low-drag wings of the P-51 Mustang, the result of years of NACA research on wing characteristics, became a hallmark of NACA achievement. Though some questioned that these laminar-flow wings (as they were often and incorrectly called) were responsible for the unparalleled performance of the Mustang, most agreed that they were a significant contribution to airfoil development and drag reduction. John Victory was pleased to report in later years that captured German documents revealed an inability by the Germans to account for the superior performance of the Mustang, even after they captured one intact and tested it, because their wind tunnels could not duplicate the low turbulence produced by the NACA.⁴⁶

After the war the NACA got its share of medals and accolades in the general euphoria and self-congratulation that came with the peace. Quickly, the Committee began to make a case for a return to its prewar role. But doubt had been cast on the record, and the captured German documents, scientists, and aircraft did nothing to dispel the suspicion that the NACA had been bested in aeronautical research. Thus, what might have been a smooth reversion to the good old days became instead a period of serious questioning, even within the Committee itself.⁴⁷

George Mead, the outside critic of prewar days who had led the march of industry into the NACA ranks, had undergone a full conversion and argued strongly for recapturing the old NACA independence.



In 1948, Air Force Chief of Staff Carl Spaatz presents medals for World War II service to Jerome Hunsaker, [George Mead?], George Lewis, John Victory, H.J.E. Reid, Smith DeFrance, and Edward Sharp. (LaRC)

As he saw it, the Committee had “been forced out of its role to wet nurse the designs of most companies, large and small,” which had maintained neither “adequate scientific personnel nor proper tools for their use, such as wind tunnels.” He also regretted that the NACA had been “dominated so completely by the military forces.” He wanted the Committee to become once again “more truly ‘national advisory’” instead of being “a service station for the Army and Navy.”⁴⁸

Jerome Hunsaker, also a critic in prewar days, agreed “in principle” with Mead but did not know just where the Committee would fit in. “We have become, to a large degree,” he said, “a service agency,” and he felt that—in view of some of the unique equipment held by the NACA—it “must expect demands to test or ‘perfect’ existing designs” as it had done during the war. The choice was not really between total independence or total service, all fundamental research or all testing, for throughout its history the NACA had in fact combined the two. The question was what the mixture would be in the postwar world.⁴⁹

An ominous sidelight on this question was the general relation of science to national defense as the war drew to a close. Numerous proposals were afoot to institutionalize scientific and technological advice in national defense. It would take several years to sort these out, but in 1944 several trends were already apparent. First, the military services would increasingly use contracts with universities and private

institutions to obtain the research and development formerly done in their own laboratories or not at all. The contract freed the "scientists against time" who had come to Washington during the war to return to their home institutions and there conduct the research that would obviously be needed in the postwar world.⁵⁰

Second, military authorities were beginning to realize the need for standing mechanisms to provide scientific advice, and they embraced the general belief—perhaps to help explain away their own failures—that the scientists had let them down in the prewar years and left them technologically inferior to the Germans in many areas. For their part, the scientists suspected that—once the war emergency was over—the services would no longer take their advice as seriously as they had during the war. Both sides were partially right, but the sum of their beliefs was a shared conviction that the best way to ensure the availability of technological sophistication in national defense for the future was to create permanent institutions through which the military could get advice and the scientists could make their voices heard. The NACA would be part of this effort, and in some respects a model.⁵¹

The NACA would not, however, be the model it wanted to be. The history of the Office of Scientific Research and Development, which grew out of the National Defense Research Committee, shows how completely things had changed and how dated the NACA pattern was. As historian A. Hunter Dupree has pointed out, one of the reasons for the creation of the OSRD was that

a wide gap existed between the weapons produced by NDRC research and the battlefield. The omitted step, which corresponded to engineering development, was emphasized in the change of title. Research and development were here coupled in a union that was to become standard in government terminology.⁵²

This trend posed a dilemma for the NACA. Traditionally, it had done fundamental research and left development to the military and the industry. If research and development were now becoming inseparable, as the World War II experience suggested, how was the NACA to return to its prewar status? If it combined research and development (as it had claimed to be doing during World War II), would it not be intruding on the territory of the military and the industry and creating that duplication of effort which Congress had always found intolerable? And if it did only basic research, could it hope to remain as useful as it had been in the past? When the NACA proposed a postwar National Defense Research Committee in 1944, to do for national security what it had done for aeronautics, the proposal went nowhere. The military services might establish their own advisory committees of outside experts, and they might contract with universities and private institutions



Upon his retirement as NACA's director of aeronautical research, George W. Lewis receives a testimonial plaque from NACA Chairman Jerome C. Hunsaker; Vannevar Bush and General Carl Spaatz look on. (USAF photo)

for basic research, but they would not permit a single body to perform both functions. In short, they would not endorse the NACA model.⁵³

These questions—the role of contracting out and the mix of basic research and development—were only the first of the uncertainties facing the NACA. What would be the NACA's relation to the aircraft industry, grown large and powerful during the war? Who would operate the new wind tunnels that would have to be built to study supersonic flight, now made possible by jet propulsion? Who would conduct high-speed flight research, and how? What would be the role of jets in military and commercial aviation? Were rockets and missiles a part of aeronautics? Where would NACA headquarters be located? How would wartime research results be declassified and distributed? Did the NACA favor an independent air force? Should Jack Ide be returned to his prewar post as the NACA's European representative? And—perhaps most important and most poignant—who was going to replace George Lewis? He suffered two heart attacks in November 1945 and could not thereafter resume the full duties he had performed for more than a quarter of a century. Lewis (said John Victory) did not take a day of vacation between Pearl Harbor and the armistice; his body seems to have held up only as long as it was needed.⁵⁴

9




The Writing on the Tunnel Wall, 1946-1950

After World War I, the NACA had found for itself a niche in American aeronautics; after World War II, it had to see if that niche still fit. It did not. The NACA had changed in the course of the war. American aeronautics and government support of science had changed even more. As it did after World War I, the NACA would have to find for itself a place in the new scheme of things. And once again it would have to develop internal policies and procedures suited to its new role.

THE NEW SCHEME OF THINGS

At first the NACA concentrated on the technical changes precipitated by World War II. Jerome Hunsaker claimed often and widely that the war had revolutionized aeronautics. Jet propulsion gave man the power to fly faster than sound. Even before the "sound barrier" was broken in 1947, knowledgeable people like Hunsaker perceived that the research problems of the future would be those associated with supersonic flight: compressibility, heat, and unprecedented complications in stability and control. In the last months of World War II, Hunsaker called for a national aeronautical-research policy that would recognize this revolution and restore the NACA to its prewar role of fundamental research on the "frontiers of flight." The NACA echoed the call of its chairman, making the aeronautical revolution of World War II the leitmotiv of its postwar requests for increased funding and an expanded program of research.¹

Another revolution resulting from World War II—this one in the structure of the American aeronautical community—was going to influence the new national policy more than Hunsaker and the NACA seem to have anticipated. At the end of the war, the aircraft-manufacturing industry was the largest in the United States, and the Army Air Forces had grown from a branch of the ground forces into a military service in

Subsonic airplanes 	Range of investigations		
	Subsonic	Transonic	Supersonic
Transonic airplanes and missiles 	Control at landing	██████████	
	Drag reduction	██████████	
	Propeller efficiency	██████████	
	Range	██████████	
	Cooling airflow	██████████	
	Flight controllability & maneuverability	██████████	██████████
	Air loads	██████████	
	Supersonic airplanes and missiles 	Control at landing	██████████
Drag reduction		██████████	
Variable air intakes & nozzles ..		██████████	
Ducting		██████████	
Duration		██████████	
Flight controllability & maneuverability		██████████	
Flutter		██████████	
Air loads		██████████	

The NACA prepared this chart in 1947 to illustrate the increasing volume and complexity of work it faced in the postwar period. (LeRC)

its own right, soon to be anointed with independent status equal to that of the army or navy. Although the NACA had also grown tremendously during the war, it was dwarfed by comparison.² Worse still for the Committee, industry and the air force—the two traditional allies and clients of the NACA—emerged from the war with some old and new bones to pick with the NACA. Not that the Committee had been immune to criticism in its first 30 years: far from it. But now the criticism was coming from its customary friends and supporters (and other new sources as well), just at the time when those allies had achieved the power and influence in national affairs hitherto denied them. The national aeronautical-research policy that Hunsaker wanted to formulate in the wake of the jet-propulsion revolution was going to be hammered out by an aeronautical community that was not as neatly in the NACA camp as it once had been.

Two other trends in national politics were to intrude upon the shaping of a new national policy for the NACA. First, World War II had made the United States keenly aware of the importance of science and technology in the modern world and led to numerous attempts to institutionalize these suddenly indispensable ingredients of national



- | | | |
|---|-----------------------------------|---|
| 1 7- by 10-Foot Tunnel and Laboratory | 12 Power Plant | 25 West Machine Shop |
| 2 Electrical Building | 14 Foundry | 26 Pilotless Aircraft Research Laboratory 7 |
| 3 West Substation | 15 Oil Baking Plant | and Fabrication Shop |
| 4 Activities Building | 16 Stability Wind Tunnel | 27 Instrument Research Laboratory |
| 5 Sewage Disposal Plant | 17 West Motor Shop | 28 Physical Research Laboratory |
| 6 Induction Aerodynamics Laboratory | 18 16-Foot High-Speed Tunnel | 29 Free-Flight Apparatus |
| 7 Aircraft Loads Calibration Laboratory | 19 Water Tower | 30 Flutter Tunnel |
| 8 Aircraft Loads Laboratory | 20 Structures Research Laboratory | 31 Supersonic Sphere |
| 9 2-Inch Supersonic Tunnel | 21 West Area Cafeteria | 32 4-Foot Supersonic Tunnel |
| 10 Gust Tunnel | 22 West Shop | 33 Frequency Converter Station |
| 11 Impact Basin | 23 Warehouse | 34 Post House |
| 13 New Heating Plant | 24 Lumber Storage Shed | |

The new west area of Langley laboratory as it appeared in 1948. All the facilities pictured here represent growth brought on by World War II, but even this was not enough to keep pace with the needs of the military services and industry. (LaRC)

existence. Second, the performance of the military services in the war came under close scrutiny and inaugurated a restructuring of the entire military establishment to fit the atomic age.

The postwar institutionalization of science and technology flowed from the experience of the Office of Scientific Research and Development. Historian A. Hunter Dupree has stated that 1940 marked a clear dividing line in the history of *Science in the Federal Government*, and “many of the characteristics of the wartime research effort were in fact permanent changes in the government’s relation to science.”⁸ Institutionalizing science and technology within the federal government was one such change. Before the war was over, bills appeared in Congress to continue the functions of the OSRD, and President Roosevelt asked Vannevar Bush to prepare a report for him on the subject. The bills reflected congressional receptivity to the idea of perpetuating something like the OSRD, but it was Roosevelt’s request that set in motion the machinery leading ultimately to the National Science Foundation. Bush’s report, *Science, the Endless Frontier*, recommended a scientific advisory body, consciously modeled on the NACA, to do for science what the NACA had done for aeronautics. Parts of this scheme came to fruition, but not before a protracted, often heated debate that divided

Washington and the scientific community and warned those who cared to listen that the NACA was no longer the ideal it had once been.⁴

One group—counting in its ranks Vannevar Bush, virtually all of the NACA, a large majority of the scientific community, and most of the contributors to *Science, the Endless Frontier*—favored a foundation controlled by a 24-man board appointed by the president. The board would select its own director to function in much the same capacity as George Lewis had for the NACA. This plan was in fact drafted by Bush, with help from John Victory. In the NACA files, across the top of one bill embodying this philosophy, is a penciled note, probably by Victory: "Organization to be run just exactly as NACA."⁵

In the opposite corner was another group—including President Truman; his director of the budget, Harold D. Smith; and other old Washington hands—who were just as anxious for a national science foundation, but wanted the director to be head of the agency, being immediately answerable to the president and advised by a subordinate consultative board. The opponents were primarily concerned with chain of command, lines of authority, and precepts of efficient and responsible organization. They discounted the scientists' misgivings that such an arrangement would interject politics into the scientific process, as the NACA had maintained for years in defense of its system.⁶

Congress passed a NACA-style strong-board bill in 1947. Truman vetoed it. Two years of intense, often acrimonious debate ensued before compromise legislation could be formulated. As finally instituted, the National Science Foundation embodied a director and a consultative board with parallel and complementary powers and functions. Even at that, disagreement on subordinate points was so strong that many issues had to be ignored or papered over in the legislation, to be worked out in practice in future years.

Most importantly for the NACA, the act itself (and Truman's rejection of the original scheme) signaled that the committee form of organization had fallen from favor in much of Washington, even in as esoteric a field as scientific research. When the NACA was formed, science may have been a small and curious enterprise worthy of an exceptional organization, but science was now big business, calling for careful organization and administration like other activities of government.⁷ In fact, the NACA form of operation had evolved over the years into something the government had never intended but had never repudiated. By the late 1940s it was found wanting, at least as a model for the National Science Foundation.

The military services meanwhile had begun a similar effort to institutionalize science and technology. In 1945 a Research Board for National Security was created within the National Academy of Sciences.

Composed of half military and half civilian members, it was intended to be a source of expert advice to the services. Truman and his budget director, however, did not want the Academy dictating military research policy, so the board was liquidated in 1946, to be replaced by a Research and Development Board within the military establishment. The title of this body reflected current opinion on the inseparability of research and development, and its positioning within the defense establishment was in harmony with the military suspicion that the Academy in particular, and the scientific community in general, had let the services down before the war. From now on the military would have its own source of scientific advice.⁸

Similar disenchantment with prewar mechanisms for scientific advice lay behind General Hap Arnold's creation of the Scientific Advisory Group (SAG) within the Army Air Forces. Vowing never again to be caught off guard as he had been in the early 1940s, Arnold enlisted Theodore von Kármán to organize a group of top scientists, survey the field of aeronautics, and advise the air force on the technical needs of the future. After surveying captured German resources as part of an Army Air Forces inspection team in mid-1945, von Kármán and his colleagues drafted "Where We Stand," a preliminary survey of the state of aeronautical facilities, and recommended building new facilities comparable to Germany's in the United States for the supersonic research that lay ahead. Before the end of the year, SAG completed its major work, *Toward New Horizons*, a 33-volume study containing detailed recommendations for future research in all areas of flight from power plants to medicine and psychology. One recommendation of the report—that the Army Air Forces maintain a permanent scientific advisory body—led to the creation in 1946 of the Scientific Advisory Board under von Kármán's chairmanship. From then on the air force no longer depended solely on the NACA for institutionalized scientific advice.⁹

These steps to formalize the integration of science and technology into national policy were taken while the government was also reviewing the role of the armed services in World War II and determining its military policy for the atomic age. In spite of the triumph of American arms in 1945, Congress dealt severely with the armed forces as the war ended. Calls for demobilization, cutbacks in defense spending, and critical scrutiny of military preparedness in 1941 swirled about the Capitol. The most exhaustive inquiry into military activities (and the one with the greatest impact on the NACA) was conducted in the first year after the war by Senator James M. Mead's Special Committee Investigating the National Defense Program. Mead's committee examined all aspects of national defense, including the role of aeronautics,

and it reached conclusions of equal import to the military establishment and the NACA.¹⁰

In line with the Mead committee recommendations, the military services were transformed in 1947 by the National Defense Reorganization Act. To the army and navy was added a separate and independent air force, all three unified within a National Military Establishment under a civilian secretary of defense. The newly created Research and Development Board (successor to the Research Board for National Security) was directly responsible to the new secretary. The National Military Establishment, which became the Department of Defense in 1949, was intended to coordinate the services, standardize compatible military policies, and eliminate interservice rivalry; but it had decades of tradition and habit to overcome, and throughout the NACA's remaining years the military services struggled uncomfortably with the new order.¹¹

The Mead committee also found room for improvement in the NACA record. In fact the hearings served as a clearinghouse for criticism of the NACA, especially by industry. This testimony convinced the Mead committee that, although the NACA had contributed significantly to aeronautical progress and deserved continued support, it had been guilty of "timidity" and "lack of forcefulness" in the prewar years by failing to request adequate funds to keep America abreast of its enemies. As a result, Germany had built better aeronautical-research facilities that had led to jet propulsion, swept-back wings, and other technical advances dangerous to the United States. Though it held the military jointly responsible for these failings, the Mead committee concluded that the NACA, "as the Government agency primarily responsible for the direction and coordination of aeronautical research, must assume aggressive, foresighted leadership in the research field."¹² This charge implied an absence of such leadership in the past.

For its part, the air force held the NACA more responsible than had the Mead committee for these shortcomings. Senior air force officers were circumspect in their public criticisms, but censure could be found between the lines of many official statements, including some by General Arnold himself.¹³ The NACA defense against these criticisms was not particularly effective: it argued that it was not far behind on jet propulsion, that it had discovered swept wings independently of the German work, that the Germans were ahead because of better facilities, that the NACA was under the control of the military during the war and was precluded by military policy from the fundamental research necessary for advances on a par with the Germans', and that comparing all the Committee's classified work with that of the Germans would show that, as George Lewis put it, "we are not so far behind." The staff at Langley actually drew up an "Appraisal of German Research



This swept-wing propeller-driven aircraft reveals the mixture of old and new that faced the NACA in 1947. The tufts of yarn on the wings reveal patterns of air-flow. (LaRC)

during the War Compared to That of the NACA,” and found themselves relatively blameless; but Hunsaker found the document “somewhat onesided” and recommended against publication. Hunsaker was willing to admit that “the Germans were in advance of this country in supersonic research, missile research, rocket research, and some phases of jet propulsion development,” and to accept the consequences.¹⁴

During this criticism of the NACA, Hunsaker took the initiative in developing a postwar aeronautical-research policy that would correct past mistakes, respond to the changed order of American aeronautics, and reconcile the traditional role of the Committee with newly emerging policies on science and national defense. Already familiar with sentiments in Washington, Hunsaker met with representatives of the aircraft industry in Cleveland and California to learn their views. He brought the question of postwar research policy before the NACA and sought to formulate a plan that would not only satisfy the perceived needs of the NACA and the government, but also allay industry fears of government encroachment on its domain of aeronautical development. A special NACA committee on postwar aeronautical-research policy drafted a plan that Hunsaker presented to the Mead committee the following January. In essence this scheme formalized the division of labor worked out among the NACA, the military services, and the industry in the years between the world wars.¹⁵

For more than a year, as the war ended and demobilization began, this policy remained an informal guide. Finally, in March 1946, the NACA formally adopted a slightly revised version of the policy as endorsed by the army, the navy, the Civil Aeronautics Administration, and the NACA Industry Consulting Committee (a newly created standing committee designed to give industry a permanent voice in NACA



NACA Chairman Jerome C. Hunsaker convenes a conference on research policy at the Ames laboratory on 8 June 1944, part of a personal campaign to arrive at a nationwide consensus on the future of the NACA. (ARC)

affairs). Minor changes in the wording of the policy in the intervening months attempted to clarify the roles of the NACA, the industry, and the services. All agreed that the NACA would do fundamental research. All agreed that the industry should do development. And all agreed that the military services should do evaluation. What they could not agree on, and what the policy did not define, was how to distinguish between these activities, and how one party could prevent the others from encroaching. And the policy did not say whether research could any longer be productively separated from development.¹⁶

In contrast to the National Aeronautical Research Policy, other NACA responses to changed policies on science and national defense were readily understandable. The Committee handed over to the National Inventors Council created in 1940 by the secretary of commerce most of its duties as Aeronautical Patents and Design Board, even though it was never legally relieved of this responsibility. The Joint Army-Navy Board had lapsed into disuse in 1943 and was formally abolished in 1947, returning the NACA nominally to the independent status it had enjoyed before the war. And in 1948, the NACA organic legislation was amended to provide for 17 instead of 15 members on the Main Committee; this added a representative of the new military Research and Development Board along with one more private member, changing the ratio of government-to-private members to 10:7.¹⁷

Addition of a representative of the Research and Development Board assured that the military would remain the dominant bloc on the Main Committee, with 5 out of 17 votes. But the greatest shift in power on the NACA in the 1940s was toward industry, which won three seats where it had none before. This reflected, as Hunsaker told the Mead committee, that "industry as a result of the war [had] become large and

responsible and [had] come of age." And it showed every sign of remaining strong in the postwar world. Even with the cancellation of \$26 billion in military contracts in 1945, the industry was able to hold together as it had not at the end of World War I; by the end of the decade, it was again growing and prosperous.¹⁸

THE RISE OF INDUSTRY

The American aircraft industry genuinely appreciated the contributions made by the NACA over the years, and most firms were happy to supply the commendations the Committee felt obliged to parade before Congress and the Bureau of the Budget. These compliments did not, however, mean that the industry was free of criticisms of the NACA. Many felt, for example, that the NACA was too slow in publishing results of its research, that it concealed negative results, that it concentrated too much on aerodynamics, and that it was not always scrupulously correct in its handling of proprietary information. But these were venial sins, not mortal. Though one industry representative suggested to the NACA in 1944 that it was perhaps time for the Committee to pass out of existence—a sentiment echoed by Senator Mead—most others felt it still had an important role to fill. The industry wanted not to destroy the NACA with its criticism, but to gain a greater voice in Committee affairs and thus make the Committee more responsive to industry needs.¹⁹

During the war, the aircraft industry had taken great strides toward achieving this stronger voice. The Industry Consulting Committee (ICC) formed in 1945, composed of heads of major aircraft manufacturing and operating firms, was not a consulting committee at all but an advisory committee. It did not wait to be consulted by the NACA, but instead met on its own initiative and advised the Committee how to improve NACA-industry relations. Though the NACA did not, of course, agree with all the complaints or adopt all the reforms, it took the industry position seriously and met frequently with the ICC in an attempt to work out compromises.²⁰

One of the first ICC suggestions, and one of the earliest to be adopted, was expansion of industry representation on the Main Committee. When the ICC was formed, the Main Committee had only one industry representative: airline executive William Littlewood, who had succeeded George Mead when the latter retired in 1944. Within months of its establishment, the ICC recommended that Littlewood be joined by a representative of an airframe manufacturer and a representative of an engine manufacturer. When the next vacancies appeared in April of the following year, A.E. Raymond, vice president of Douglas Aircraft, and R.M. Hazen, chief engineer of the Allison Division of

General Motors, joined the Main Committee just one month after industry endorsed the National Aeronautical Research Policy. Industry representation on the Main Committee became a tradition that endured the rest of the NACA's days and gave the industry a voice second only to the military's.²¹

At the time these industry representatives joined the Main Committee there were only six members from private life, meaning that the industry controlled half the outside seats. Vannevar Bush found this deeply disturbing. Writing to Hunsaker late in 1946, he noted:

The basic idea back of NACA, and the concept on which a great deal of its success has been based, is that the governing board will be made up of *ex officio* members plus . . . individuals representing science and the public somewhat generally. I have no doubt in my mind whatever that a man in an industrial post can divorce himself in his thinking from his industrial connections to sit on a public board as a representative of his profession, and as a citizen, without his thinking and actions being in any way influenced by his industrial connections. But I do not believe that the public or the Congress would be convinced that this is the case except when experience had given the demonstration, and I believe, therefore, that the general point of view is very likely to be that these individuals will represent the interests of industry in the NACA, say to balance the interests of various parts of the government. . . . It is far better that the members of NACA outside of the *ex officio* members should represent science and the public, but should not be in their personal connections so involved that their interest also takes the form of interest from a specialized standpoint connected with the health and development of the industry as an element in our economic picture.²²

Bush had considered expanding the membership of the Main Committee, an idea that seemed even better the following year when the National Military Establishment was created. But finally he decided "the only out-and-out solution [was] to reverse our steps and return to the policy that was prevalent between the two wars, with no representation of specific groups, except those in government." As things stood, he did not think the Committee had "enough completely independent individuals for the various activities of the NACA, such as the chairmanship, the vice chairmanship, and the headship of various important committees, to carry on the affairs of NACA along the original contemplated lines which were so successful." The extrapolation of Bush's concern was that the NACA might soon be reduced to interest-group politics, accompanied by factions, vote-swapping, and pluralism. When impartial academics had held the nongovernment seats on the Main Committee, the public weal seemed secure. When industry representa-

tives took over those seats, there was chance of mischief, or at least the suspicion of mischief, the appearance of mischief.

Hunsaker, who himself sat on the boards of directors of four firms (three of them on the fringes of aviation), did not share Bush's concern, though he did "reluctantly agree" that the danger Bush cited might be perceived by Congress and the public. Hunsaker believed that

the public service is most inefficient when the principle of disinterest is carried to the limit of having nobody who really understands the problems. Popular distrust of the expert is part of our inheritance from the early Republic. Witness the War Production Board [of World War I] with a publisher in charge of aircraft production and an advertising man deciding on cargo planes! The original act establishing the NACA required "persons who shall be acquainted with the needs of aeronautical science . . . , or skilled in aeronautical engineering or its allied sciences." Littlewood, Raymond, and Hazen exactly comply with this language of the act and strengthen the committee by their intimate knowledge of what is needed.²³

Hunsaker went on in this letter to defend his own record and to explain his own connections with industry, apparently less alive than he might have been to the importance of the NACA's—like Caesar's wife's—not only being pure, but also seeming to be pure. He wanted to circulate his letter to all members of the NACA, but Lewis recommended that he first delete the paragraph quoted because it "could be used in an investigation," presumably of industry influence within the NACA. Hunsaker, Lewis, and Bush might agree about the merits of controlled industry representation on the Main Committee; but it was Lewis, the old Washington hand and veteran of the bureaucratic wars, who understood the real dangers of making the industry too visible in Committee affairs.²⁴ These dangers were to be realized in the coming years.

In 1946, however, the immediate problem was the status of industry representatives on the technical committees and subcommittees. One motive for creating the Industry Consulting Committee in the first place had been to head off this issue of industry representation. It did not succeed; in fact, the ICC became a focus of the continuing attempt by industry to make members of the NACA subcommittees representatives of the firms for which they worked. The NACA opposed this idea relentlessly and succeeded in holding off the industry move, or at least maintaining what Hunsaker called "the fiction of no representation."²⁵

The NACA wanted as members of its technical committees and subcommittees the best informed and most hard-working individuals in their respective fields. This was the only way to get the best advice available on what research was being done, what problems were the

most pressing, and what research wanted doing. To promote free discussion, committee meetings were held to be confidential, and no minutes of the meetings or other printed material provided to the members in the line of duty could be published or even made available to colleagues outside the committee. To the NACA, committee membership was a personal position attaching to the individual because of his expertise and willingness to cooperate with the government in the best interests of American aeronautics.²⁶

To the industry, committee memberships were positions of considerable prestige that reflected favorably not only on the individual but on his company as well. They provided an opportunity to stay abreast of the latest developments in aeronautics even when those developments were still classified or under the proprietary control of another firm. They provided contact with other experts. And they provided an opportunity to influence the course of NACA research. These undeniable benefits of committee membership led many in industry to advocate distribution of memberships evenly throughout the industry in order to achieve equal representation. If an engineer from Douglas was on the Subcommittee on High-Speed Aerodynamics, then one from Lockheed ought to be on it as well.²⁷

Informally the NACA had always tried to balance the sources of industry membership on technical committees and subcommittees so that no one company or geographical area would dominate a field. This was common sense, for the NACA wanted the widest possible variety of opinions and perspectives, so long as they came from competent people. All things being equal, the NACA would try to distribute its memberships evenly throughout the aviation industry. But publicly it had to maintain that members were chosen on their merits as private individuals and in no way represented their firms. As Hunsaker remarked early in this debate, "the appointment of industry representatives sounds very innocent, but if they are appointed for the purpose of being representatives, it would upset our applecart." Bush was even more emphatic. He felt that if industry could dictate committee membership, "it would be fatal."²⁸ Although the NACA had allowed industry representation on the Main Committee, the Industry Consulting Committee, and the main technical committees, it publicly insisted that the technical subcommittees remain lily pure.

Although the solution was not ideal, industry soon realized that on this one issue the NACA would not, perhaps even could not, budge. In the later years of the 1940s, therefore, it concentrated on its two main demands. First, the NACA should pursue a research program more suited to the needs of industry and distribute the results more quickly. Second, NACA research should not encroach on the development that industry considered to be its exclusive domain. Industry used its new

strength within the Committee to achieve the first demand. It used its increased influence with Congress and the executive branch of government to ensure the second. Industry effectiveness in this regard is seen most clearly in the saga of the Unitary Wind Tunnel Plan.

THE NATIONAL UNITARY WIND TUNNEL PLAN

The "unitary" program originated as two independent (in fact competitive) programs begun almost simultaneously by the Army Air Forces and the NACA and developed along lines so similar that coincidence fails to explain their likeness. The NACA track started in April 1945 with a letter to George Lewis from an employee at the Engine Research Laboratory in Cleveland. Bruce Ayer wrote because he felt that the staff at the laboratory had not given "sufficient consideration" to his views. So he went over their heads, taking no little risk in an organization as hierarchically structured and procedurally disciplined as the NACA. Ayer considered the Committee's facilities "woefully inadequate" for the supersonic research of the future, and he recommended an "Altitude and Supersonic Research Laboratory" at a site like the new Bonneville dam on the Columbia River, where there would be ample water for cooling and power generation.²⁹

With this one recommendation, Ayer covered all the major points in the forthcoming technical debate over postwar wind-tunnel facilities in the United States. The advent of jet propulsion meant that research problems of the future would be in high-speed, probably high-altitude, flight. Wind tunnels for this regime would require enormous amounts of power, far beyond the capacity of existing aeronautical research centers, including those of the NACA.

Ayer received a polite and appreciative response from Lewis, but no action. Not until the following summer when NACA representatives returned from duty with the Alsos mission in Germany did his recommendation win support at headquarters and in Cleveland. The 100,000-horsepower water-driven supersonic wind tunnel under construction by the Germans just outside Munich greatly impressed the NACA representatives, as did a planned 500,000-horsepower tunnel designed to produce mach numbers between 7 and 10. In a 7 November memorandum to headquarters, AERL Manager Edward Sharp concluded that "the utilization of water power for wind tunnel drive appears to be the only feasible method for large supersonic wind tunnels." He recommended that the NACA "Confidentially" contact the Federal Power Commission and the Reclamation Service "with a view to determining the best locations for future laboratory sites at which would be located all of the future large supersonic tunnels to be built in this country." As if that were not clear enough, he went on to state



John W. Crowley, Jr., associate director of aeronautical research, in 1948. (LaRC)

that “the Committee should at once take steps to *preempt this field of high-speed research* and an aggressive and vigorous policy should be adopted in the interest of keeping America first in scientific development along these lines.” He repeated in closing that the matter should be handled “in the highest confidence.”³⁰

Sharp took this memorandum to Washington personally and discussed it with the staff. John W. Crowley, recently recruited from Langley to fill in for the stricken George Lewis, led the headquarters group that authorized Sharp to pursue the matter. By the time Sharp reported in December, he had abandoned the notion of direct water-power drive, settled on Boulder Dam near Las Vegas as the best site, and raised the projected power requirements as high as 2,000,000 horsepower, a fourfold increase over that of the largest tunnel the Germans had been planning. The Committee was already considering budgets that would allot twice as much construction money to the new facility as would go to all the rest of the Committee’s laboratories combined.³¹ In less than nine months the new supersonic laboratory had gone from an unheeded suggestion to the keystone of the NACA’s plans for the future.

The issue was presented to the NACA High Speed Panel in December and January and received that group's endorsement, along with the recommendation that the site for the new facility include space to accommodate an extremely long unobstructed runway for takeoff and landing of supersonic aircraft, and an inland missile range for the testing of rockets and pilotless aircraft. When Sharp reported on progress in February 1946, the new facility had been given a name, the Supersonic Research Center. By then Sharp had heard of similar army and navy plans, and he recommended that the NACA take immediate action on its own proposal so that it would not be forced to share the limited number of sites available in the United States. "The hour may already be late," he warned.³²

It was late indeed. The army had been working quietly on a similar proposal since June 1945, when it too learned for the first time of the research facilities under construction or planned by the Germans. Moving almost exactly in step with the NACA, the Army Air Forces investigated the need for new facilities informally at Wright Field, just miles from AERL, until October, when it established a formal committee to prepare plans for an "air engineering development center." On 10 December 1945 a formal plan was published and sent on its way through Air Force and War Department channels.³³

At the beginning of 1946, then, the NACA and the Army Air Forces each had plans for new research centers, both necessitated by the jet-propulsion revolution, both stimulated by the discovery of advanced facilities in Germany, and both reflecting badly on the NACA, which looked to be once again behind the times. Even as the Committee was sponsoring a sympathetic history of its wartime achievements, to be called *Frontiers of Flight*, it was learning that the Germans were much further out on the frontier. The NACA was scrambling to catch up and the air force was showing signs of taking on the responsibility itself.³⁴

Exactly when each side learned of the plans of the other is not clear. At the October 1945 meeting of the NACA, General Arnold mentioned that several agencies wanted supersonic research facilities. Out of the ensuing discussion came a letter from Hunsaker to the secretaries of war and navy reporting the NACA's conclusion that "a unitary program" of aeronautical research, especially with respect to supersonic wind tunnels, was essential to orderly development. He asked the secretaries to add this proposal to the agenda of the Research Board for National Security, which was then considering the overall question of postwar research and development. But the RBNS dissolved before the secretaries could write.

At the 17 December meeting of the Executive Committee, General Crawford reported that the Army Air Forces were considering a super-

sonic research center and investigating possible sites. This revelation prompted Edward Sharp to ask a friend at Wright Field about the air force plans. He learned that the center would probably be in the Rocky Mountains, would include five tunnels—one designed to reach mach 8 to 10—and would cost about \$100 million. Sharp's friend reported that the air force was acting in good faith and did not intend to violate the NACA's area of fundamental research. He suggested that the Committee contact General Crawford, who would be happy to supply the latest information and who in any case was obliged by his membership on the NACA to be forthcoming on this matter. When the headquarters staff did contact the general, they discovered that his office was "not too enthusiastic" about prospects for the plan, feeling they had "not enough to go to bat with the [Bureau of the B]udget for the dough." Whether that was the truth or an evasion cannot be determined. On 1 March 1946, Hunsaker was still pleading for coordination. Telling the Guided Missiles Committee of the Research and Development Board of the NACA's plans for a supersonic research center, Hunsaker noted that the same facilities "obviously cannot be duplicated for all the services, and that the same tools must be used by all."³⁵

No evidence of the early cooperation Hunsaker sought has come to light. On the contrary, there is considerable evidence that the NACA and the Army Air Forces were in deep and surreptitious competition. In the NACA meeting room, all was harmony and seeming candor, but behind the scenes there was intense jockeying for position. At the NACA Executive Committee meeting of 21 March 1946, Hunsaker announced that the NACA staff believed there was need for a "National Supersonic Research Center . . . adequate to meet the needs of industry and of the military services." The army and navy representatives agreed that such a project should be large enough to meet future needs of the services, and joined in recommending that the staff prepare a supplemental estimate to be considered at the next meeting.³⁶

The very next day, however, just three weeks after Hunsaker's plea to the Research and Development Board, General Curtis LeMay, recently appointed to the new office of Deputy Chief of Air Staff for Research and Development, entered the offices of the Aircraft Industries Association (AIA) and presented what were later described by an informant as "beautifully prepared" booklets, one a "sales brochure" for a proposed Air Engineering Development Center, to cost more than half a billion dollars. Industry and AIA personnel who happened to be in the office that day "recognized the project as so large that it could be done only once," and they feared that the NACA, their first choice to run any such facility, was in danger of being forestalled. They were reluctant, however, "to take anything like a formal stand against

the army proposal," for they depended as much on the services for contracts as they did on the NACA for research. Though they would move "as slowly as possible," they were sure the army would "press them for speed."³⁷

The AIA suggested that the NACA quickly call a meeting with key government and industry representatives and present its own plan for providing supersonic facilities for the whole country. Presumably the industry was prepared to endorse a NACA plan so long as no reference was made to the army plan. Industry personnel feared that the army would "take development away from" them; they saw "little room in the area the Army has mapped out." The NACA could save the situation, but speed was of the essence, for "the high-powered and high-pressure presentation of the Army's proposal [was] such as to lead laymen and congressmen to jump at it."³⁸

The NACA acted quickly. Two days later a headquarters conference decided to send out a NACA proposal for its own supersonic research center to key industry and government personnel for their evaluation before the next meeting of the Executive Committee on 25 April. A separate memo went to Edwin Hartman in the Western Coordination Office, tipping him off that "the army has ambitions along these lines" and asking him to get what response he could from the industry. Hartman replied on 29 April with news that the NACA neither anticipated nor desired. "The companies had agreed among themselves," reported Hartman, "to give out no information regarding their individual feelings toward the NACA proposal until a joint statement had been prepared and submitted to the NACA through the AIA." But the west coast manufacturers were unable to agree among themselves on how research should be divided between industry, the NACA, the military services, and educational institutions; on how to choose between the army and NACA proposals; on where new laboratories should be located; or on how to assure that the industry had adequate facilities for its own development work. The industry was critical of the amount of control the NACA had exerted over testing of prototypes during the war, and it found the overall NACA proposal "neither adequate nor wholly acceptable." Still, industry spokesmen did not want a new center to be controlled by the military, so they found themselves caught in the middle.³⁹

Without the clear endorsement of the industry, neither the NACA nor the army proposal would get far in Congress. Compromise became essential. Revealingly, an industry man was appointed to combine the two proposals into a single package acceptable to all concerned. At the 25 April 1946 meeting of the NACA, Arthur E. Raymond of Douglas Aircraft was appointed chairman of a special panel on supersonic laboratory requirements. In June 1946 the panel recommended a unitary

wind-tunnel plan incorporating the main features of the rival proposals, a national supersonic research center for the NACA and an air engineering development center for the Army Air Forces, at a total cost in excess of \$2 billion. The principal change recommended by the Raymond panel was a provision for wind tunnels at universities, both to allow independent testing and research and to serve as training tools for the engineers of the future who would be needed to operate the tunnels contemplated in the new proposal. On the recommendation of the panel, an independent engineering firm, Sverdrup and Parcel, was contracted to conduct a preliminary design analysis of the two recommended laboratories. When the firm reported later in the summer, it estimated the total cost to be in excess of \$3 billion.⁴⁰

The exorbitant costs in these early proposals reflected the first response to a complex political problem. The NACA, the Army Air Forces, and the industry all wanted supersonic facilities adequate to their projected needs. The NACA believed that it had the necessary expertise as well as the responsibility for conducting all fundamental supersonic research for the entire nation. The military services, dominated on this issue by the air force, felt that they had to ensure their readiness for any military threat the United States might face, and they had the responsibility for providing whatever research might be necessary to meet that threat. They nominally agreed that their proper field was testing and evaluation, but the line between development and evaluation was no more distinct than the NACA's line between research and development. Squeezed between them was an industry that feared encroachment by two arms of government on the area it insisted on holding exclusively: development. Unable or unwilling to build expensive supersonic tunnels, industry wanted the government to pay for the tunnels and then make them available to industry—either at government laboratories or at universities, where tunnels might serve dual purposes of training and testing. The initial compromise, then, was to provide tunnels for all; the National Supersonic Research Center would have research tunnels for the NACA and development tunnels for industry, the Air Engineering Development Center would have evaluation tunnels for the military and development tunnels for the industry, and the existing NACA laboratories would get still more tunnels for the industry. The price of industry support, for both the NACA and the military, was to increase the size of the pie and give industry a large slice of its own without diminishing the share of the government agencies. Everyone understood that some NACA research would spill over into development as would some military evaluation, but there seemed to be more than enough facilities for everyone and plenty of latitude to work out boundaries and responsibilities.⁴¹

The progress of these proposals from the grand scale of the Raymond panel in the summer of 1946 to the Unitary Wind Tunnel Plan Act of 1949 is a tale of Byzantine intricacy deserving a study of its own.⁴² A brief review of the interested parties and the hobbyhorses they were riding will suggest the complexity of the political and legislative maneuvering. The Joint Chiefs of Staff and the defense establishment, which was changing during these years from the unsatisfactory National Military Establishment into the Department of Defense, were attempting to decide where air power and guided missiles would fit into American defense policy in the face of a worsening cold war. The chiefs made their own recommendations on aeronautical-research facilities, but they attached less importance to them than did the men whose sole responsibility was aeronautical development. Vannevar Bush found his allegiance divided again when he took over chairmanship of the Research and Development Board in 1947. He retained his NACA membership for one more year, but was hard put to reconcile the enormous expense of the Committee's NSRC with other worthy proposals that came before his board at the Pentagon. Within the air force, Hap Arnold and his successors agreed with Theodore von Kármán and others on the Scientific Advisory Board that the continued supremacy of American air power (which they believed to have been the key to victory in World War II and the indispensable ingredient of national security in the future) would turn on the technical advances produced by intensive research and development. They could afford to be second to none, and they could entrust that responsibility to no one else. The navy, also alive to the importance of aeronautical technology (and increasingly concerned about its power within a defense establishment where an army-air force alliance seemed a real threat) fought to keep the air force from entirely dominating aeronautical research, even acting as something of a spoiler for air force plans. The Bureau of the Budget wanted to coordinate the various proposals, so as to prevent interservice and interagency rivalry from spilling into the congressional arena and to fit the plans generated by the aeronautic factions into the administration's overall budget. Congress gave off contradictory messages, on the one hand asking for early demobilization and major postwar cutbacks in defense spending and on the other chiding the NACA and the services for lagging behind the Germans. Congress would not stint on necessary defense expenditures, but failed to define what was necessary, and as always it kept an eagle eye out for duplication and waste. The NACA wanted to regain its role in fundamental research and dominate the new field of supersonic research. Industry wanted to protect its field of development against encroachment by government agencies and at the same time gain access to facilities built

at government expense. Out of this complex of wills emerged a result no one had willed.⁴³

That it took more than three years to get from the Raymond panel recommendations to the Unitary Wind Tunnel Plan Act suggests how fierce and complicated was the maneuvering. That the plan finally approved authorized less than a tenth of the amount recommended by the Raymond panel suggests how completely the principals worked at cross purposes. Had they formulated a truly "unitary" plan that compromised their disagreements, they might have received swifter and more generous results; instead, they simply awarded to each competitor everything requested. When pressed to reduce the enormous cost, they presented to Congress and the other reviewing agencies in the executive branch a picture of disagreement, duplication, inefficiency, and parochialism reminiscent of the shortcomings revealed by the Mead committee. The House Armed Services Committee noted in its report on the unitary plan bill that since the Raymond panel recommendations, "little, if anything, [had] been done during the intervening 2 or 3 years . . . to expedite their implementation," leading the committee to conclude that "some of the very same conditions which previously led to our taking second place in the race for more advanced aeronautical weapons may still be present today and that the existence of such conditions can lead to a repetition of our earlier experience—possibly with more disastrous consequences."⁴⁴ The skepticism and lack of confidence that permeate the committee report help to explain why the legislation finally passed was so stingy.

The National Unitary Wind Tunnel Plan Act of 1949 consisted of two titles.⁴⁵ Title I authorized \$136 million for the NACA to build three supersonic wind tunnels, one at each of its existing laboratories, and \$10 million to build tunnels at educational institutions. There was no National Supersonic Research Center. And, most devastating of all, the tunnels to be built at the NACA labs were earmarked for industry use. The House Armed Services Committee was adamant on this last point:

Inasmuch as the primary purpose of the facilities to be allocated to the NACA is to provide wind tunnels necessary for testing aircraft and guided missiles under development by industry, it is the sense of the committee that strong language should be incorporated in the bill which will insure that these facilities, although allocated to NACA on a so-called housekeeping basis and staffed by its personnel, shall be available to satisfy industry's requirements for the testing of experimental models in the course of development of new aircraft and missiles. It is absolutely essential that tests be scheduled and conducted in accordance with industry's requirements and the laboratory time be allocated with proper emphasis upon the requirements

of the various contractors engaged in the development of new types of military aircraft for the services.⁴⁶

From its original grand scheme to be the agency conducting all supersonic research in the United States, the NACA had been reduced to "housekeeping" for industry.

Title II, which provided for an Air Engineering Development Center, was not nearly so harsh on the air force, though it allowed only \$100 million to begin construction. The committee allotted this sum with the understanding that future construction would expand the center greatly. Although the committee was obviously wary of what it characterized as "Air Force plans for a huge new supersonic center patterned more or less along the lines of the vast German establishment at Peenemunde," it was not willing to eliminate the center altogether as it had done with the NSRC.⁴⁷

The wording of the Unitary Wind Tunnel Plan Act and the documents surrounding it foreshadows not only the future of wind-tunnel research in the United States but also the place of the NACA in the changed world of American aviation after World War II. First, at virtually every step of the review and authorization process between the Raymond panel and the final bill, the plan was cut back. This reduction was caused in part by the exaggerated response of the NACA and other agencies concerned with aeronautics to the revelation of German advances; but it also reflected a cynicism in Washington about how far the research and development enthusiasm of World War II should be carried, especially in a field where conventional wisdom had been shown in such a bad light by those same German advances.⁴⁸

Second, at almost every step along the way, industry enjoyed unprecedented influence and power. It seems to have emerged from the war with its reputation untarnished, and it won from both the executive and legislative branches of government concessions that would have been unthinkable in the days when the NACA was created. National concern about a military-industry complex would surface in less than a decade, but in these immediate postwar years the aircraft industry pretty much had its way with government.⁴⁹

What the industry won, the NACA lost, at least on paper. Technically it lost control over the few tunnels built for it under the Unitary Plan, though in practice industry use of these tunnels would never be sufficiently great to deprive the NACA staff of all the time it needed in supersonic tunnels. In fact, before the unitary plan was adopted, the NACA already had several supersonic tunnels of its own in operation, tunnels which it had been willing all along to share with industry once it had the National Supersonic Research Center. It was the center that was perceived to be the real loss to the NACA, for with it the Commit-

tee lost an exclusive hold on one end of the aeronautical research spectrum. Nor was this new condition an inadvertent outcome of congressional oversight. The House Armed Services Committee made explicit what it was about:

It would be fruitless to criticize or to impute blame to the able and devoted scientific personnel employed by the NACA during the prewar years for their failure to keep pace with German aeronautical research. . . . But it would be the height of folly to close our eyes to the obvious lesson to be drawn from that experience—the lesson that we must not place the bulk of our aeronautical research eggs in one basket—the NACA basket. Even the most competent and best qualified scientists and research workers can always profit from the stimulating effects of healthy outside competition.⁵⁰

Finally, the air force ended up with pretty much what it asked for at the outset. Its new center, soon to be named the Arnold Engineering Development Center, was approved even though Congress was critical of the military services for their failures before the war, and even though Congress was deeply skeptical of air force plans for the center. “A serious question may very well be raised,” noted the Armed Services Committee, “as to whether the military may not be stepping outside of its proper sphere when it enters into the arena of research as distinguished from development and evaluation.” The committee then presented an informed commentary on “Differentiation between Research, Development, and Evaluation,” assigning the first to the NACA and private institutions, the second to industry, and the third to the services, concluding that “the services, by their very nature and organization and the training of their personnel, are not well qualified to undertake activities in the fields of research and development as distinguished from evaluation.”⁵¹ The committee nevertheless authorized facilities at AEDC that were clearly for development and conceivably for research.

So the NACA came out third in the battle for facilities after World War II. In some respects this was not as serious as the Unitary Wind Tunnel Plan Act made it look; later experience would show that the original plans for supersonic facilities were grandiose to a fault, the older tunnels were not as outdated as had been feared, and the workload in the supersonic tunnels never prevented the NACA from getting ample time in the tunnels it operated nominally for industry. Furthermore, there is a point (which the NACA may have already reached in the 1930s) when highly sophisticated research tools can lure the researcher into too much experimenting and not enough thinking. Hugh Dryden reported after a trip to England in 1948 that “their lack of money has forced them to make the best use of their brains.”⁵² The

tyranny of the tunnel was real for the NACA, chaining the staff to a kind of problem-solving research that might well have been supplemented by more time spent at the blackboard or just staring out the window. The real tyranny of the tunnel is that it can lead to busy hands and idle minds. The defeat of the unitary wind tunnel plan was not in itself a fatal blow for the NACA, but it was a harbinger of the Committee's diminished standing with agencies and individuals who would control its destiny.

HARD TIMES

George Lewis had seen the drift of things as soon as the war was over. Writing to an old friend of the Committee in 1945, he said:

Unfortunately, after a great war that has been over strenuous both mentally and physically to everybody concerned, there is a general let-down; and unfortunately, this let-down is accompanied by a very critical mood. The dear old NACA is coming in for its share, so we will again have to depend on our friends for all the support they can give us.⁵³

The truly unfortunate aspect of this predicament for the NACA was that too many of its friends were disappearing from the scene just when the Committee needed them most. This was especially true on Capitol Hill. The NACA's best friend in the Senate, Hiram Bingham, had been defeated in 1933, and the NACA never found his like again. In the House the situation was worse still. Judge Woodrum retired in 1945, after 22 years of representing the 6th congressional district of Virginia and looking after the interests of the Langley laboratory. During 16 of those years he had chaired the Independent Offices Appropriations Subcommittee that reviewed—one might say rubber-stamped—the NACA budget. Victory confided to the congressman that his departure was a "calamity to the public interest" that left his "friends in the NACA heartbroken."⁵⁴

Part of the calamity for the NACA was that Woodrum's successor, after the Democrats regained control of Congress in 1949, was a young Texas congressman unfamiliar with the NACA's golden days and harboring no NACA laboratory in his home state. Albert Thomas inflicted on the NACA in 1950 a painful and unexpected blow by singlehandedly reducing the Committee's already shrunken share of the unitary wind-tunnel plan. The act had authorized the NACA to spend \$136 million on its share of the tunnels, plus \$10 million in university tunnels; Thomas tricked the Committee out of almost half when it came before his subcommittee of the Appropriations Committee. As a Bureau of the Budget office explained it:

The hearing lasted about 15 minutes. After a very brief discussion of the purpose of the wind tunnels to be built, Mr. Thomas asked NACA how much of the total authorization of \$146 million they expected would ultimately be required. When NACA hesitated to reply, he suggested a figure of \$75 million. After hurried consultation NACA representatives estimated about \$100 million.

Mr. Thomas then asked whether that meant that if a \$100-million cash appropriation was made in 1950 to be available until expended, it would then be unnecessary for NACA to request further funds under the Unitary Plan program. NACA representatives had to agree, and that was the end of the hearing.⁵⁵

That was bad enough, but Thomas immediately followed up by appropriating only the \$75 million he had suggested, maintaining that the NACA had agreed to this reduction. The NACA protested that it never made any such agreement, but it was powerless to deter the congressman.

This was no isolated instance of Thomas's hostility to the NACA. In later years Thomas would lead the campaign to make the Committee submit its budget annually to authorization hearings, a practice that the NACA had avoided in all its earlier years, claiming that its organic legislation provided a continuing authorization. Thomas would have none of that. In his book, any agency with a budget of more than \$50 million a year (such as the NACA had enjoyed consistently after 1940) should justify itself annually to Congress. In fact Thomas had grave reservations about the wisdom of letting a committee administer a budget that size in the first place, and he bluntly—as it turned out, prophetically—warned John Victory in 1950 that the Committee's days were numbered.⁵⁶

Nor was Thomas alone. Not only were many of the Committee's old friends gone, but many old enemies—and some new ones—were still very much around. In one of his last major acts of public service, Herbert Hoover took yet another swipe at the NACA. His Commission on Organization of the Executive Branch of the Government recommended (as he himself had recommended as president in 1932) absorption of the NACA into the Department of Commerce. The same old objection was at work: "This agency is not directly in the basic line of Presidential authority, and it is unsound organization for it to be governed by a committee. We doubt whether it is sufficiently important, despite its size, to warrant independent status."⁵⁷ Even the NACA's defenders, like Willis Shapley in the Bureau of the Budget, conceded that the Committee form of organization was undesirable, but the Hoover Commission recommendation was rejected for the time being because Congress had no enthusiasm for restructuring the Committee merely as a matter of principle. Furthermore, there was no

agreement on where the NACA should be put if it were incorporated into one of the executive departments.⁵⁸ The NACA owed its independence in the late 1940s not so much to its record or its reputation as to general disagreement about where to put it. That could only be cold comfort to the loyal staff and friends who remembered the golden days and believed in the Committee's unique (and unappreciated) contributions to the advance of aeronautics.

10

New Genius, Old Bottle, 1945-1950

The task of staking out for the NACA a defensible field of activity in the postwar world of American aeronautics fell largely to Jerome Hunsaker in his role as chairman of the Committee. The task of working that field fell largely to Hugh Dryden, who succeeded the failing George Lewis in 1947. Dryden's job fell into four major categories: first, to institute organizational and procedural reforms to adapt the agency more closely to his own style of management; second, to clear up unfinished business from World War II; third, to respond to industry demands, some of which he was independently in sympathy with; finally, to identify new areas of research into which the NACA could and should move. Some of these tasks were already under way when he arrived. Some he initiated. All came to bear the stamp of his administration.

DIRECTOR OF THE NACA

Hugh Latimer Dryden wrote his first paper on aeronautics in 1910, when he was 12 years old and the airplane was not yet 7. In "The Advantages of an Airship over an Airplane," he argued that the former was better suited to commerce, the latter to sport, a conclusion that his teacher prophetically found "illogical" though at the time it was a thoroughly sound judgment.¹ He got an F on the paper, making all the rest of his 55 years a refutation of his maiden essay on aviation.

Dryden was nothing if not a fast learner. In fact, he was something of a prodigy. He completed high school in Baltimore at the age of 14, then went directly to Johns Hopkins, where he had already been taking courses. He took his baccalaureate in three years, his master's in two more. His master's thesis on "Airplanes: An Introduction to Physical Principles Embodied in Their Use," placed him among only a handful in the United States to be formally educated in this new field; most of the others had studied at MIT with Jerome Hunsaker.²

One of Dryden's instructors at Hopkins, physics professor Joseph S. Ames, recommended the newly fledged physicist to the National Bureau of Standards as "the brightest young man he had ever had, without exception."³ At the Bureau, Dryden was tutored by Ames and allowed to conduct experiments in the wind tunnel on his own time, completing the requirement for the Ph.D. in less than a year while holding down a fulltime job. In 1919 he took his doctorate in physics and mathematics at the age of 20, the youngest doctor ever at Johns Hopkins. His dissertation on "Air Forces on Circular Cylinders" stimulated sophisticated research in the field for more than a decade.

Dryden's career at the National Bureau of Standards spanned almost 30 years, during which he specialized in research on wind-tunnel turbulence and boundary layer, contributed to other fields of research, worked closely with the NACA, and published often in NACA reports.⁴ During World War II his career broadened dramatically and drew him into an ever widening range of activities. He served on the National Defense Research Committee, and personally administered a guided-missile development program in cooperation with the navy. He was deputy to von Kármán in the Scientific Advisory Group's mission to Europe and became a charter member of the Air Force Scientific Advisory Board. In 1944 Dryden was elected to the National Academy of Sciences, where he would later head the engineering section and serve as home secretary for the last decade of his life. At the National Bureau of Standards he became assistant director in January 1946 and associate director a few months later.

His record—coupled with his years of service to the NACA, where he was vice chairman of the prestigious Aerodynamics Committee at war's end, and would soon become chairman of its subcommittee on high-speed aerodynamics—made him a natural choice to succeed George Lewis. He was in fact Lewis' choice, quickly endorsed by Hunsaker and the rest of the Main Committee. The director of the National Bureau of Standards, an ex-officio member of the NACA, reluctantly let him go.⁵

By prearrangement, Lewis stayed on as consultant to the Committee, and the research staff at headquarters was enlarged slightly to provide expert technical advice for the new director of aeronautical research. By design or happenstance, Dryden brought no close associates with him to the NACA and thus assumed his new position surrounded by a predecessor and staff schooled in the old ways. Nevertheless, Dryden soon made it clear that his mousy appearance and mild manner camouflaged a firm will and a determination to run things his way. After less than two months in office, he advised the Main Committee at its annual meeting in 1947 that he was planning "a better formulation of the Committee's research programs." That euphemism



Showing the resolve with which he took over the directorship of the NACA, Hugh L. Dryden poses in front of the motor and fan powering Langley's 19-foot pressure tunnel. (LaRC)

was his way of announcing some sweeping revisions in the internal workings of the NACA.⁶

The revisions began with a formal delineation of Dryden's authority and responsibilities and his relationship to John Victory. The roles adopted by Lewis and Victory over the years were not entirely to Dryden's liking; he preferred an arrangement more in keeping with the one he had known at the National Bureau of Standards.

The change was precipitated by external events. Since 1944, when Lewis was overburdened with war work and his health was already failing, the rules of the NACA had provided that Victory "upon authorization by the Chairman, may exercise functions required by law to be performed by a head of department or agency." Hunsaker described this revision of the rules to President Roosevelt as a "perfecting amendment" that did not "involve any substantive change in policy or procedure." It merely allowed Victory to sign on behalf of Hunsaker the reams of paperwork that nominally required approval by the head of the agency. Victory was the chief administrative officer and the logical one for this pro forma function.⁷

Outside the Committee, however, the amendment created confusion as to who headed the agency, the director of research or the secretary. An executive pay bill introduced in 1949 provided a pay increase for top civil-service executives. Though the NACA was at first not included in this bill, Hunsaker fought with the Bureau of the Budget and won the inclusion of one NACA position. That put a

premium on establishing officially who was head of the agency. Clearly it was Dryden, and just as clearly the NACA regulations needed amendment to settle the issue formally.

On 7 February 1949, Hunsaker submitted to President Truman a set of proposed amendments to the NACA Rules and Regulations. The changes in article 2 elevated Victory to the position of executive secretary and created a new post of associate director for research, to which John Crowley acceded after having served the interregnum between Lewis and Dryden. Most important, the new rules designated Dryden "director" instead of "director of research" and provided that he would "be the head of the agency in all matters except those which by law or regulation require action by the Chairman." This would end the division of labor worked out unofficially by Lewis and Victory, with the director of research managing the technical business of the agency and the secretary handling the administration. Now there would be a single head of the agency, with one technical and one administrative deputy.

This profoundly simple and momentous step became entangled and lost sight of, however, in the politics of the same executive pay act that had precipitated it. While the amendments to the NACA rules were pending, the possibility arose that the pay bill might be amended to include a second position for the NACA. Who, then, should get that raise—Victory, or John Crowley, the associate director of aeronautical research? To the NACA it was clear that Victory was second in line, but the Division of Administrative Management at the Bureau of the Budget doubted whether an administrative officer with "no program responsibilities" should be assistant head of a technical agency. With that observation the issue was joined, and the expansion of Dryden's role was upstaged by a dispute over the history and personality of John F. Victory.⁸

The management personnel at BoB looked on the amendment of the NACA regulations as a "subterfuge," "a device for obtaining a better pay rate for the Executive Secretary." When they questioned the logic of the arrangement, they were advised that Victory was a special case: his long and unique service had led the Committee to this organizational scheme; when he retired, the associate director of aeronautical research would become the assistant head of the agency and Victory would be replaced by an executive officer. "At bottom," concluded the management personnel, "the whole matter involves personal considerations."⁹

Not so, said Willis Shapley, of BoB's National Security Branch, the section that handled NACA appropriations. The proposed amendments reflected the NACA organization as it then existed: far from being a subterfuge to get the executive secretary a higher pay rate, it had the effect of preventing him from getting the director's raise, "on which he

had a reasonable claim" under the old regulations. Furthermore, said Shapley, it was not self-evident to him that an administrative man should not be assistant head of the agency. While he conceded that the NACA planned to replace Victory with a technical man when he retired, Shapley wondered about the advisability of giving over such an agency entirely to the scientists. He wrote to the assistant director of BoB:

A specialized scientific agency like the NACA requires somewhere in the top command someone whose qualifications extend beyond the scientific fields covered by the agency, and while some members of the main committee meet this need in part, I believe that it would be desirable if either the head or the assistant head of the agency be a nontechnical person. The Research and Development Board is learning the hard way that the management of a scientific research and development program does not require scientists, but administrators and it is well known that it is very rarely that one finds scientists who are also administrators. In my opinion the Bureau of the Budget would be making a serious mistake to base any action on the assumption that scientific agencies should in all cases be headed by scientists. Specifically, I think there is no merit in the argument that the assistant head of NACA should necessarily be a scientist.

Shapley stopped just short of saying that science is too important to be left to scientists, but his meaning was clear: Neither the NACA nor the BoB should lose sight of the need for sound management and administration in any government bureau, no matter how scientific its mission. For the time being, however, the NACA and Shapley saw eye to eye and the proposed amendments to the rules were approved.¹⁰

As often happened in the NACA's history, Victory's personality intruded on this business and obscured the truly significant issue—Dryden's elevation to director. Although that personality changed little in the 43 years of the NACA's history, it had undergone a shift in orientation that altered Victory's behavior just at the time of this flap with the BoB. In the 30 years up to the end of World War II, Victory had both grown and swelled in office. The Committee's reputation for efficiency and economy owed much to his fastidious administration, and his expertise in the ways of Washington was admired by even his critics. Unfortunately, he was always officious and priggish, and in his later years he grew downright pompous and oracular. With the war won and George Lewis gone, Victory came to view himself as something of a dean to the American aeronautical community, by longevity and association if not by importance. Though obsequious still to members of the Main Committee and others whom he considered touched by greatness, he would pontificate to lesser mortals on any occasion

and virtually any topic. Like the Committee he served and molded in so many ways, Victory seems to have spent too much time reading his bouquet file, and he became imbued with a sense of self-importance and historicity out of proportion to his real but finite achievements. He took to the lecture circuit after the war, billed more than once as "Mr. Aviation," armed with anecdotes and sermons about the contributions of the NACA and the transcendent importance of aviation. In 1949 he took leave from his Committee duties to write a history of aviation, which he never finished. In the 1950s he began a history of the NACA, which he carried into retirement and left undone at his death. In short, he yielded to his less becoming traits and neglected the habits of a lifetime that had indelibly marked the style and reputation of the Committee. The NACA genuinely appreciated his long and valuable service, and his job was secure for as long as he wanted it. But to some at BoB and elsewhere, it was not clear that his worth was any longer increasing with the years.¹¹

After 1949, however, Dryden was in name and in fact the director of the NACA,¹² working comfortably with Jerome Hunsaker, who seemed happy to hand over some of his wartime responsibilities to this trusted colleague. Though Hunsaker was nominally an engineer running an engineering department in an engineering school, he was a scientist at heart, having more in common with Dryden than he ever had with Lewis.¹³ Dryden and Hunsaker held earned doctorates; shared membership in the National Academy of Sciences, the American Philosophical Society, the American Physical Society, and other professional organizations; published in scholarly journals; and viewed the NACA with a detachment and perspective that Lewis perforce could not attain. Perhaps more than anything, they wanted to see the NACA more open and participatory than it had been under the Lewis regime.

One way to achieve this was to revitalize the technical committees, a change in operating procedure almost on a par with Dryden's elevation to director. During and immediately after World War II, there was grumbling and confusion both within the NACA staff and among the committee membership about the proper role of the technical committees. Though there were opinions to the contrary, most critics felt the technical committees were passive or ineffective, rubber-stamping the recommendations served up to them by the NACA staff and providing free information to members who contributed nothing. Lewis had authorized the replacement of deadwood but failed to clarify or expand the role of the committees, perhaps because of the press of war business followed quickly by his own physical collapse, perhaps because he really did not want the committees to grow too powerful and thus cut into his own considerable autonomy.¹⁴



John F. Victory, first employee of the NACA and ultimately its executive secretary. (LaRC)

The sad state of affairs was revealed in one particularly damning memo of late 1946, in which one of the headquarters staff asserted that technical-committee members were woefully ignorant of even the basic information necessary to discharge their duties. Upon their appointment, new members were given only a certificate of membership, a one-paragraph statement of the committee's function, a list of the members, an oath of office, and information on the Espionage Act, the safeguarding of confidential information, and government travel regulations. Tellingly the staff member noted that

the new subcommittee member receives no information regarding the membership or functions of the parent committee to which his subcommittee reports, or any inkling of the nature of other NACA committees. And if it were not for the fortunate circumstance that the membership of the main Committee appears at the top of the NACA letterhead, he would not even be advised of that important information.

The staff member recommended that in the future technical-committee members be briefed on NACA history, policy, research organization,

committee structure, research policy and programs, and facilities; that the committees meet regularly at the various laboratories and become acquainted with the research staff; and that they attend the regular laboratory inspections.¹⁵

Some in the NACA felt that the technical committees already played too large a role, and Lewis seems to have been one of them. In any event, nothing was done about the recommended reform of committee procedures until Dryden took over. Then a thorough analysis led to publication on 1 January 1950 of a new directive on "Functions and Responsibilities of Standing Committees and Subcommittees of the National Advisory Committee for Aeronautics," a document containing many of the reforms suggested to Lewis in 1946.¹⁶ This was the first written formulation of how the NACA research program should work, from policy-setting by the Main Committee, through management by the director and his staff, to actual research in the laboratory. Much of the directive formalized what had been done for years, but it placed a new emphasis on the role to be played by the standing committees. Specifically, they were responsible for the following:

1. Review research in progress by the NACA and by other agencies.
2. Recommend problems that should be investigated by the NACA or by other agencies.
3. Assist in the formulation and coordination of programs for research by the NACA and by other agencies.
4. Serve as a medium for the interchange of information regarding investigations and developments in progress or proposed.

Of course no published policy could by itself change the comfortable habits established over the years. Almost two years after the new policy took effect, one subcommittee member complained to the NACA that his group was "far from being an effective body." It spent "too much time . . . talking about what has happened in the past," he said, "and too little . . . discussing what should be done in the future." He felt that "the Subcommittee follows meekly, and does not lead boldly."¹⁷ This may have been what Lewis had wanted in his day, but it was not what Dryden and Hunsaker wanted. In the years following publication of the new policy, they built up the technical committees of the NACA so that in the 1950s, at least, these bodies were more active, aggressive, and informed than their prewar predecessors had been.¹⁸

Revival of the annual industry conferences after World War II posed a similar problem, one in which George Lewis was more amenable to change. In the 1940s and 1950s, there were several laboratories to visit, literally hundreds of specialists from industry, academia, and

government to accommodate, and a NACA research program to explain that simply could not be summarized in any digestible way. "It is not like the old days when we could have all the group down in one day," lamented George Lewis in 1947,¹⁹ yet something like the old conferences seemed a useful, even indispensable, part of the NACA tradition.

The solution was to have a series of rotating inspections at the various laboratories, modeled upon the military inspection routine adopted just before World War II but retaining the old NACA tradition of carefully orchestrated and exhaustively rehearsed presentations by the working engineers. The Langley and Ames laboratories alternated as conference hosts every other year. An inspection was held every year at the Cleveland installation which became the Flight Propulsion Research Laboratory in 1947 and the Lewis Flight Propulsion Laboratory in 1948, when the former director of aeronautical research died.

The undisguised purpose of these conferences was, as it always had been to some extent, public relations. Even Dryden appreciated the importance of this function and took no steps to temper this "selling" of the NACA. As he wrote in a 1949 address,

the director of research has certain duties which are kin to those of the sales departments and public relations departments of commercial firms. The program and its results must be "sold" to many groups, the supplier of funds, the technical design group or other user group of the results of the research, often to the general public. This is true not only in the direction of industrial or applied research but also equally in the purest of pure sciences. The user group may be only the fellow members of a limited professional group and the scientist may be his own research director, but unless this group as well as the individual scientist is sold on the competence and merit of the work, support will suffer.²⁰

So Dryden let Victory continue to have his way with the inspections, turning them into glossy extravaganzas, hosting hundreds of guests at the laboratories over the course of several days, and taking poetic license with technicalities of research in order to impress his guests with the complexity of the NACA task and the skill with which it was being accomplished.²¹

For his part Dryden supervised the numerous technical conferences held each year on specific topics with a limited number of informed guests. These smaller meetings took over the function of information exchange once performed by the prewar industry conference. Stressing content more than style, they were less spectacular but no less effective. One set of conferences was for substance, one for show. Both served the purposes of the Committee.

THE TRANSITION FROM WAR TO PEACE

Not all the Committee's business could await the arrival of Dryden and the subsequent reordering of the staff hierarchy. As World War II drew to a close, the NACA had been in military harness for more than half a decade. The transition to peacetime operations called for fundamental policy decisions by Lewis and John Crowley. Though Dryden would oversee (and in some instances modify) these decisions, he had always to cope with an inertia of several years' growth. Chief among these transitional issues were the return to fundamental research, the declassification of wartime reports, the reestablishment of the Committee's European Office, and the clarification of the postwar draft status of NACA personnel.

Far and away the most serious of these issues, at least to the leaders of the NACA, was the need to return to fundamental research. The most common complaint in the immediate postwar years arose from the lamentable shortage of fundamental data caused by the NACA's wartime preoccupation with cleanup and testing of military prototypes.²² Politics motivated this plea in part, for the NACA was anxious to reestablish its claim to virtually exclusive dominance in fundamental aeronautical research. In part the claim was justified by the legitimate requests from industry for answers to new and basic questions about high-speed flight. Still the call for fundamental research echoing from the NACA had about it the ring of dogmatism. For one thing, the term itself was a study in compromise, more suited to blurring boundaries between research functions than clarifying them. Nor was it entirely clear to everyone within the NACA that it was in the Committee's best interests to return to this role, even if it were possible.

First of all, much development work had to be done in NACA tunnels. As had always been the case, some NACA tunnels had unique capabilities unavailable elsewhere in the United States. When industry or the military services needed a 40- by 80-foot full-scale tunnel, the NACA had to accommodate the research, fundamental or not. Furthermore, the industry and the services had grown accustomed during the war to consulting the NACA on an unprecedented range of development problems from cleanup and testing to problem-solving and redesign; always more interested in getting the current prototype up to specifications than in solving problems of the future, they were reluctant to let the NACA abandon the development services they had come to rely on.

More serious still was whether the NACA staff was really qualified now to do the fundamental research that the Committee claimed as its territory. Edwin Hartman, the NACA's western coordination officer and himself an aeronautical engineer familiar with both the NACA and the



Among the unique facilities of the NACA was Langley's free-flight wind tunnel. In this 1946 test of a fighter model with forward-swept wings, the "pilot" at lower left maneuvers the model while the tunnel operators keep watch at right. (LaRC)

industry, had suggested in 1944 that after the war the Committee should direct more of its attention to development: "the research for which in the past the Committee has received the most credit is of the development type," he wrote, citing the NACA cowling and the Committee's work on deicing as telling examples. The success of the cowling was undeniable. The deicing research, begun in 1928 at the request of the army and coming to fruition in World War II, was about to win the NACA's second Collier trophy, emphasizing the worth of Hartman's analysis. Lewis A. Rodert, first at Langley and later at Ames and Cleveland, had led the NACA deicing research program through every conceivable avenue of attack on the problem, trying mechanical, chemical, and thermal methods of deicing, using flight tests and the specially developed ice-research tunnel at Cleveland, and studying the nature of ice build-up and decay, the aerodynamical and structural consequences of various deicing devices, and the practical application of thermal deicing through heat exchange with exhaust gases (the method finally settled upon in World War II and deemed worthy of the Collier trophy). This was cut-and-try research, involving no fundamental scientific breakthrough or new theoretical understanding, but rather painstaking, methodical, careful research of the engineering sort. It was



The critical need for icing research is revealed in these two photographs from the mid-1940s. Above, interior view of a B-17 windshield during flight in moderate ice conditions; the left windshield has a double-panel heated-air installation. The DC-3 pictured below had just landed at Seattle, Washington, at 3 in the afternoon. (ARC)

fundamental in the sense that it applied to all flight, but otherwise it was engineering or development research.²³

Hartman went beyond merely commending the Committee's development work, however; he asserted in writing that "no more than 20 percent of the Committee's present engineering staff is qualified or capable of performing fundamental research." This unfortunate situation resulted from two currents in the NACA's history, one recent and

one of long standing. The rapid expansion of the NACA during World War II, the loss of some researchers to industry and the military services, and the shift in work from fundamental research to routine testing and problem-solving on prototype military aircraft had diluted the prewar staff with a large number of engineers and technicians who did not meet the Committee's earlier standards for researchers. Many of those people were now ensconced in the civil service and unwilling to relinquish their secure if unpromising positions on the NACA ladder. As a percentage of its total workforce, the Committee simply had less talent and research potential than it had before the war.²⁴

But Hartman's letter raised another issue, one that had been lurking below the surface since Max Munk was forced out in 1926. If the NACA was doing basic or fundamental research—"scientific study of the problems of flight"—where were the scientists, where were the people to distinguish NACA research from what the Committee called the "engineering research" conducted by the armed forces? Men like Theodore Theodorsen at LMAL surely qualified as practicing scientists in both their scholarly credentials and the nature of their work, but the NACA had only a handful of them, and even these were careful to keep their work rather close to applied science. The NACA could rightly claim that the proper place for aeronautical theory was in the universities, on which they drew consistently over the years; but, just as there was no clear dividing line between fundamental research and development, so was there no clear dividing line between fundamental research and theory. Hartman's recommendation that the NACA continue to devote a large part of its work to development spotlighted not only the wartime dilution of the staff but also a continuing weakness on the theoretical end of the research spectrum.²⁵

This issue was raised the following summer by a disgruntled LMAL employee who appeared unannounced one day at the Bureau of the Budget with a list of grievances about the operation of the Langley laboratory. The man claimed that the NACA did not get the best scientists available, leaving the LMAL to be "run by men who are not themselves research scientists and who do not have sufficient scientific background or initiative to make the fullest use of the ability of scientists in subordinate positions." The source of this problem was the NACA system of recruiting young engineers fresh out of college and training them up to the NACA way. In promoting these men, length of service was valued "out of all proportion to scientific ability," and Dr. Lewis was reported to have "placed loyalty to the NACA ahead of anything else in evaluating the members of his staff." The critic complained that staffers of scientific bent were denied attendance at meetings and visits to other establishments (a common complaint among scientists with restricted budgets), depriving them of contact with their



During a visit to the Langley laboratory in 1951, NACA Director Hugh L. Dryden explained the difference between basic and applied research, omitting the concept of “fundamental” research the NACA often claimed for itself. (LaRC)

peers outside the Committee, and that “some sort of formalized appeals procedure” was needed at Langley if the competent scientists there were to be heard through the layers of engineering bureaucracy that separated them from top NACA management.²⁶

While the complaints of disgruntled employees cannot be taken as the measure of an institution, this man’s observations warrant consideration. They corresponded to Hartman’s, had the ring of truth, and touched a resonant chord at the Bureau of the Budget. Willis Shapley, to whom the man told his tale, reported that his “description of the situation at Langley Field corresponds very closely to the account” he and other members of the BoB staff had heard the previous fall from another source. Whether or not this perception of the NACA was accurate, it was shared by some within the NACA staff, and more importantly by some outsiders close to Committee affairs and influential in determining the Committee’s fate.

For more than one reason, then, the NACA did not return after World War II to the concentration on fundamental research it had enjoyed before the war. Pressures from industry and the military as well as the strengths and weaknesses of its own staff ensured that the NACA would actually engage in both fundamental and development research. Of course it claimed only fundamental research, but it would

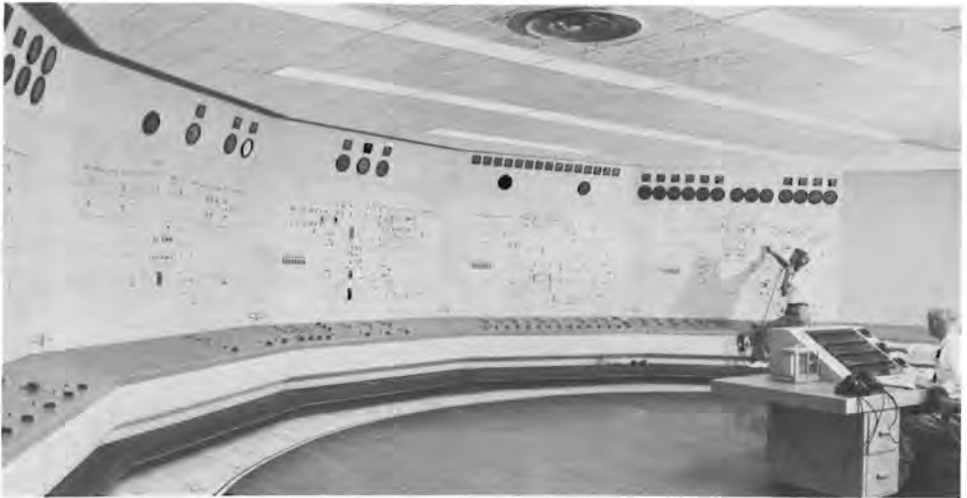
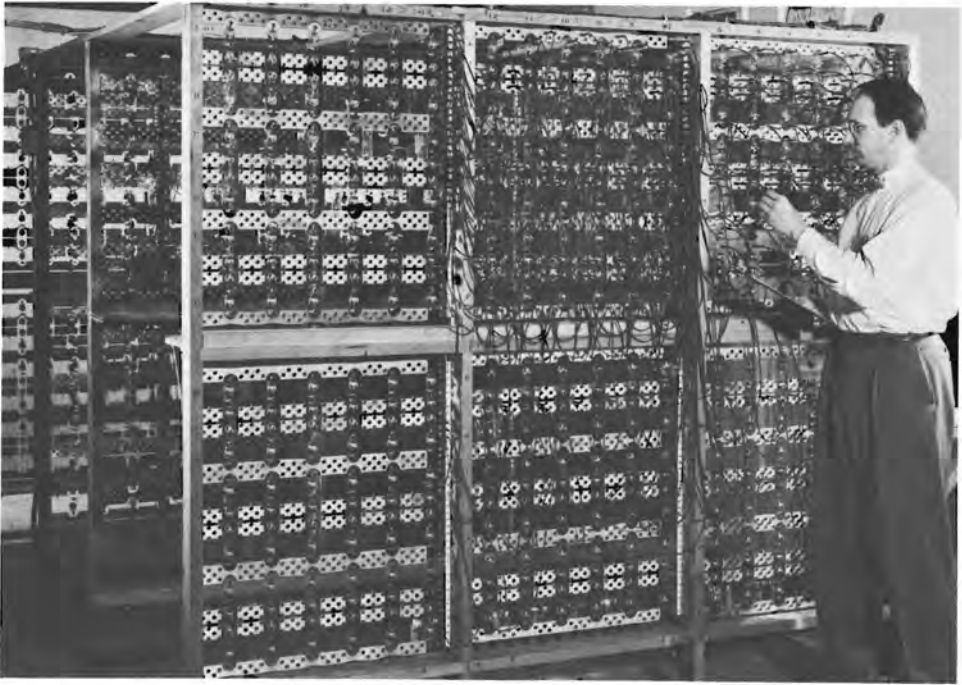
readily concede when pressed that some of its work was developmental and that there was no really clear dividing line between the two. To cover such a broad front, it of course needed more money, and this meant that throughout the late 1940s the NACA asked for ever-increasing appropriations. The justification always stressed national security and the pressing needs of the military both for fundamental data on high-speed flight and for problem-solving on the new generation of jet-propelled aircraft then in the making. Though the NACA had fallen foul of the BoB in 1944, when it badly overestimated its requirements, it recovered quickly in the postwar years, regaining its high esteem at the Bureau and winning generally strong support there. Congress, too, after the initial demobilization cutbacks, gave the Committee most of what it requested through the 1940s, a tacit endorsement of the NACA's role and performance.²⁷

The means and the mandate to conduct fundamental research were merely the first among the postwar transition issues facing the NACA. Equally pressing was the need to declassify the results of its wartime research. Because some of its prewar work was on military projects or industrial developments with proprietary restrictions, the NACA had some limited experience with classifying and later declassifying its research results, but nothing on the scale of what it faced in 1945. Virtually all its work in World War II was for the military; virtually all of it was classified. The NACA was anxious to have its wartime achievements more widely known and the industry was anxious to learn what the NACA had accomplished on projects that only the participating firms were privy to. Furthermore, a presidential order had mandated a governmentwide program of declassification, and some critics suspected that the NACA was dragging its feet. For all these reasons the Committee was eager to publish any wartime reports freed from national-security or proprietary restrictions.²⁸

The Committee reviewed its wartime reports, selected those that could be declassified and were still important, and published them in a new series called *Wartime Reports* developed for just this purpose. Between 1946 and 1948, the NACA published more than 1200 of the more than 3000 reports it had generated during the war. And in place of the numerous wartime categories of classified reports, the NACA instituted in 1946 the *Research Memorandum*, a less formal report than either the *Technical Report* or the *Technical Note*. This new series, intended for limited distribution, provided a medium for publication of classified material and also served as an advanced research report on preliminary results for industry and the services.²⁹

Even this series, however, did not resolve all the problems of classification in the postwar world. With so much of the NACA program still directed toward military applications, many results could not

MODEL RESEARCH



The cost of research increased dramatically in the postwar years. The electrical analog device shown at top was needed to simulate the heat generated at high speeds by air friction on aircraft. Though primitive by comparison with modern computers, the device nonetheless added to research costs. (ARC) Just three years after that photograph was taken, the new control room shown below was opened in the Lewis laboratory's engine-research building. (LeRC)

be published. The NACA always deferred to the military on what reports to classify and for how long. More complicated was the question of what to do with discoveries that might have military applications as yet undetermined. Here the NACA sacrificed on the altar of national security the personal advantages its staff members might have gained from early publication of their research results. The NACA's errors were always on the side of overclassifying.³⁰

A third problem of postwar transition requiring action by the NACA came to the attention of the Main Committee when Hunsaker returned from a trip to England in the summer of 1946. He reported wasteful duplication in London by competing American agencies gathering aeronautical information and intelligence. The Main Committee agreed with him that the NACA should resolve this problem by reestablishing its European office, which might in time perform the functions of all the various attachés and representatives then in London. John Jay Ide, who had been called from the naval reserve to active duty after the closing of the NACA Paris office in 1940, was just then leaving active duty, having spent the war years working on aeronautical intelligence in London. He was the natural choice to fill the post and was soon formally proposed by the NACA to the U.S. ambassador in London. Ide insisted on being attached to the embassy staff, for this connection greatly facilitated housing and other living arrangements in overcrowded London, and in any event Ide had always wanted embassy status to ease his travels and visits about Europe. London was the logical place for him to locate, for he had served there during the war and cooperation was stronger and more consistent with England than with any other country. The American ambassador in London, however, vetoed the Ide appointment because his staff was already overlarge and not the least of the glut was in aviation experts. Though the State Department favored the NACA plan, it refused to overrule the ambassador.³¹

In 1949 the Committee decided to reestablish the Paris office on its own hook much as it had been before the war. The Committee's new nemesis, however, thwarted the plan. Congressman Albert Thomas, now chairman of the House Appropriations Committee, decided that the Paris office would be an unwarranted duplication of the work already being done by military attachés. He refused to fund the item in the Committee's budget for 1951 and in conference he won the Senate to his position. The 1951 NACA appropriation bill specified that "no part of this appropriation shall be available for the operation of a field office outside the continental or territorial limits of the United States." The NACA considered trying to overturn this ruling, but soon thought better of it. In 1952 Ide received from the Committee its distinguished

service medal and passed from the NACA's history like the Paris office, one more cherished hallmark of the Committee's golden days.³²

The final postwar conversion problem to face the NACA was the draft status of its personnel. During the war Victory had negotiated a series of agreements with the military and the Selective Service to keep critical NACA personnel on the job. With the termination of the war, these agreements expired and many on the staff became subject to the draft. Again it was Victory who took the lead in working out a new set of compromises³³ that got the Committee by the immediate postwar crunch with little trouble. The greater significance of the draft question, however, was its relationship to the upcoming battle over recruitment, retention, and pay of qualified NACA employees. In this area Victory was to make perhaps his greatest contribution, both to the NACA and to the country at large. This is properly a story of the 1950s and will therefore be treated at length in chapter 11. But it should be kept in mind that the postwar crisis over draft eligibility links Victory's later work on retention of qualified civil servants with his wartime struggles for draft exemption, where the foundation for the entire policy was laid.

SATISFYING INDUSTRY

The third great task facing Dryden when he joined the NACA—after restructuring the agency and completing wartime work—was to meet the demands of industry. As before, some of the responses here were already under way when he took over. During World War II and immediately thereafter, the industry had won representation on the Main Committee and increased representation on the technical committees and subcommittees. These seats, coupled with the role of the Industry Consulting Committee, gave industry a forum to voice its demands. Most important, the increased role in the technical committees gave industry a major influence on the pace and direction of the NACA research program. Partly this was a reflection of the shakeup in committee memberships begun by Lewis during and immediately after the war. Partly it was a reflection of Dryden's conviction that the technical committees should play a stronger role in policy formulation. For the rest of NACA's years, the technical committees were more aggressive and influential than ever; as industry grew after the war to hold up to 50 percent of the seats on these committees, it came to have the strongest single bloc voice in how that influence should be exerted.³⁴

Industry's other principal demand after World War II was for better dissemination of NACA research results, getting more information out sooner to a wider audience. Really this lay behind industry

demands for greater "representation" on the technical committees, because there was no better way to get the latest NACA information than to be on the committee overseeing the NACA program. On this issue, however, the NACA held firm under both Lewis and Dryden. Membership on NACA technical committees was an individual's service to the country, not an NACA service to industry. It was a means whereby the NACA could get the best technical advice available, not a mechanism whereby the industry could stay apprised of technical developments in the NACA and elsewhere. Though the NACA did distribute its memberships as equitably as its own needs for expertise and talent would allow, it never satisfied industry demands for information. So the Committee was forced to disseminate information to industry through other channels.

One channel existed before Dryden joined the Committee. In 1946 Lewis had created a Division of Research Information at NACA headquarters, prompted by "the greater productive capacity of the laboratories, combined with the greater need for the quick application of research findings by the military services and the aircraft industry as a result of the rapid changes taking place in the science of aeronautics." Each of the three subordinate offices in this new division was intended to solve one phase of the problem.³⁵

The Office of Aeronautical Intelligence was to continue, and speed up if possible, the function for which it had been created in 1918: serving as a central clearinghouse of aeronautical information, gathering documents not only from within the NACA but also from government and private, military and civilian, academic and industrial laboratories all over the world. Of course, things had changed since the 1930s. Aeronautics had become far more complex, more people were at work in the field, the European office was no more, and much of the best new work was classified. Aeronautical Intelligence could never stay abreast of all the latest developments as it had before the war; but, within the limits imposed by this increased complexity, the office tried to collect and disseminate the most important information.³⁶

The Office of Publications consisted of the old editorial staff, one of the more controversial groups at headquarters. NACA reports were accorded almost biblical credence by aeronautical engineers around the world, a source of great pride to Lewis and the entire NACA staff. Behind this accomplishment lay an exhaustive and exhausting editing process, involving layers of review and revision at the laboratory and at headquarters before any NACA report saw the light of day. Reliability crowned this process; undue caution and delay were its hazards. The philosophy at work was the engineer's, one greatly at odds with the scientist's that Hugh Dryden brought to the NACA in 1947. The engineer wants a solid, dependable, careful report that will last through

time. The scientist wants his latest results in print as soon as possible, believing that the free exchange of ideas, even the disproving of one idea by another, will advance the state of knowledge. This year's report may be outdated or even proven wrong by next year's, but if it advances knowledge it will serve its purpose. Of course, the engineer wants to get into print as soon as possible to establish the priority of his work, and the scientist wants his research to be as sound and verifiable as possible, but there is nonetheless a real and distinguishable difference in their attitude toward publication.

When Lewis created the Office of Publications in 1946, he clearly meant to expedite the editing and publication of NACA reports, but not at the expense of reliability. In part he was institutionalizing expedients that had arisen during the war when duplication and distribution of Technical Notes and the various wartime reports were taken over by the Langley laboratory. No Technical Reports were published during the war, and after the war the Technical Reports series in the NACA *Annual Report* became a mere compendium of the best and most significant Technical Notes, republished in a more permanent and more widely distributed form. Dryden continued and streamlined this procedure, letting the laboratories establish their own review and editing criteria. The result was a more scientific publishing policy that still retained the caution and much of the reliability of an engineering report.³⁷

The Office of Research Analysis was an entirely new creation in 1946, addressed to a problem that had floated about the NACA for years: criticism of the NACA for incomplete analysis of the data generated in its laboratories. Ed Warner, especially, was relentless in his complaint that the NACA was missing the implications of its research, failing to tell the design engineer what the data meant and how it might be interpreted. During World War II this criticism grew louder. The staff excused itself by pleading the press of war business. This could not explain away the shortcomings in earlier years, when a certain lack of daring seemed to be at work, and it left the Committee open to the demand that it improve when the war was over. To this task was the Office of Research Analysis devoted, giving the NACA for the first time a mechanism for examining the purport of NACA research, and other aeronautical research as well, and for extrapolating a program for future investigation.³⁸

The division of research information did not, however, satisfy the industry demand for more and faster information. The industry insisted that the NACA also publish a list of all its current projects so that everyone could know what the NACA was working on, when new results might be available, and what direction the NACA program was taking. The NACA resisted this request for more than four years,

hoping perhaps that the division of research information would obviate the need for such a list. Dryden took up the resistance where Lewis had left off, telling industry representatives that the NACA had hundreds of research projects under way at any one time, none of which could be neatly summarized in a form that would be both informative and of reasonable length. Such a list would overburden the staff and cost more in time and money than it was worth.³⁹

RAPID THRUST INCREASE



STEADY HOVERING FLIGHT



The NACA conducted so many different research projects at the same time that it was reluctant to provide industry with a complete inventory. The research pictured here—a 1949 study using balsa dust to reveal the airflow generated by a $\frac{1}{15}$ -scale model coaxial helicopter rotor—was not yet ready for release to industry. (LaRC)

But industry was not to be denied, and the NACA finally compromised. It agreed to publish an annual listing of its research projects, with no description beyond the project titles. The Committee published these lists for the remainder of its history and, though the staff remained disgruntled, the industry received the report with enthusiasm and real interest.⁴⁰

One suspects there was more here than merely staying abreast of NACA work. A minor source of controversy for years was the issue of negative results. If the NACA ran a series of tests on a new idea or device and found it wanting, should it publish the results? This was largely a question of institutional self-confidence and security. If one is sure of his position and his worth, he won't hesitate to admit his mistakes, especially if he thinks those mistakes were reasonable guesses in a complex and confusing field, and if he thinks his errant pursuits might prevent others from walking the same dead-end path.

Lewis's record on this touchy issue is mixed. In 1934 he said that "in many respects it is desirable to include negative information which prevents others from investigating methods that have been found unsatisfactory," but in 1946 his newly created Office of Research Analysis

withheld "the most recent findings" from the gust tunnel because "the factual data are not too favorable for America's would-be high speed transports." Politics surely helped determine what the NACA did or did not publish, and surely the NACA was more sensitive than most agencies about advertising its shortcomings to Congress. Even the cool and scientific Jerome Hunsaker became uncharacteristically testy on this point when he was prodded by the Mead committee in 1946. "You wouldn't expect us to publish a discussion of a dead cat," he stated rhetorically. As a matter of fact, many in the industry would probably have wanted to know what the cat died of.⁴¹

The publication of negative results remained a problem for the Committee. In 1950, for example, headquarters advised the Ames laboratory that "the brief reporting of unsuccessful attempts is considered of some value in itself in informing and warning the readers," but went on to suggest that the treatment of an unsuccessful research strategy in a proposed technical note was "overly detailed and detracted from the presentation of the more successful method."⁴² No industry action could keep this sort of thing from going on within the NACA, but the annual list of projects would at least tell the industry whether the NACA had buried a whole research project.

The list of projects also helped to substitute for the loss of the old industry conferences. Industry representatives knew it was no longer possible to be briefed on all the NACA projects in a single day at Langley, or even in a single visit to all the laboratories, and they welcomed the specific conferences on isolated topics that provided the detailed exchange of information they used to get at Langley. The list of projects filled the gap between the specialized meetings and the new "inspections" and showed where the specific topics fit into the overall NACA research program.

Another change in policy brought about by the passing of George Lewis was the slackening of restrictions on publication of NACA research methods. From the time of the variable-density wind tunnel, the development of innovative research techniques and equipment had been one of the NACA's greatest achievements, but Lewis seldom allowed this information to be published lest the NACA's competitors learn how to duplicate its results. Though this barrier began to fall as soon as John Crowley became acting director of aeronautical research, the habit of secrecy about research techniques and equipment was so deeply ingrained that it was years before such publications began issuing from the laboratories.⁴³

The postwar years also brought some lesser responses to industry suggestions or demands. The NACA engaged in more contracting with universities, in part to blunt past criticism that it was "standoffish" to academics and in part because such contracts really benefited everyone

concerned. They lessened the research load on NACA tunnels, lent support to independent laboratories, kept the NACA in touch with some of the best theoretical minds in aeronautics and with the latest research, and helped to train the new engineers needed in growing numbers by both the NACA and industry. And the NACA established a new policy on proprietary information, granting greater safeguards to industry.⁴⁴

WHITHER NACA?

The fourth major problem confronting Hugh Dryden when he took over the NACA in 1947 was choosing new fields of research for the Committee. Many new projects emerged in these years, from aircraft-fire prevention to the aerodynamics of internal flow (the airflow within the ducts and turbines needed to support jet propulsion). But three areas overshadowed the others in urgency, importance, and glamor: high-speed flight, missiles and rockets, and nuclear power for aircraft propulsion. Through his technical-committee memberships during the war, Dryden had been instrumental in launching all three. After joining the NACA, he guided them through the politics that came to surround them, with fateful consequences for both himself and the NACA.

High-speed flight was the new area in which the NACA had the clearest mandate. In fact, in its original plans for a national supersonic research center, the NACA had hoped to have an exclusive role in this research. Though that was not to be, the NACA did not know it in 1945. What it did know was that until supersonic tunnels became available, other means would have to be found to conduct high-speed research. In his role as vice chairman of the Aerodynamics Committee and chairman of the High Speed Aerodynamics Committee, Dryden was deeply involved in the solution of this problem.⁴⁵

The most obvious solution was the research aircraft program, a joint venture between the NACA, the military services, and industry to develop and fly supersonic aircraft. The story of this unprecedented cooperative program and the NACA role within it has been told in Richard Hallion's *Supersonic Flight*⁴⁶ and need not be repeated here. Three features of the program, however, deserve mention for their influence on NACA history.

First, the cooperation between the NACA, the services, and the industry exemplified the seamless web of coordination that had evolved during World War II into an indispensable ingredient of radical aircraft development. Military sponsorship was needed for money and *raison d'être*; the NACA was needed for fundamental concepts of design and instrumentation; and industry was needed for design, development, and production facilities. Additionally, each of the three partners had

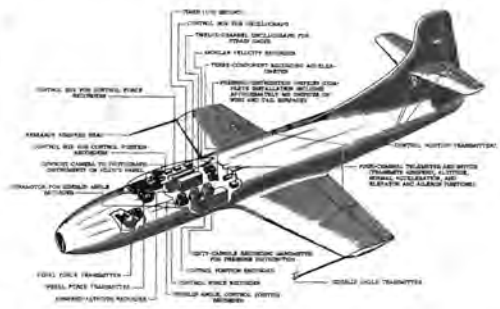


Fire prevention leads to the ultimate in destructive testing: an experimental fire-source inerting system prevents a fire, as this plane is crash-tested and the jet engine torn from the left wing is sent tumbling through the fuel spray behind the aircraft. No fire resulted. (LeRC)

talent and expertise in areas for which it was not formally responsible. Industry could speak to wing-flutter theory just as readily as the military could address fabrication techniques, and the NACA had at least one resident expert on everything. So successful was this industry-military-NACA collaboration that it succeeded in "breaking the sound barrier" within 2.5 years of letting the first contract for a supersonic aircraft.

Second, the NACA won in this program a plum that it would lose in the struggle over a unitary wind-tunnel plan. Its proposal for a national supersonic research center had included an airfield for high-speed flight testing. When it lost the NSRC, it lost the field. But meanwhile the Committee had sent a small detachment of Langley engineers to Muroc Air Base in the desert of southern California, where the research aircraft were to be test-flown. Originally no more than a liaison detachment existing at the indulgence of the air force, this group expanded over the years to become the NACA Muroc Flight Test Unit in 1947, the NACA High-Speed Flight Research Station in 1949 (still a satellite of LMAL), and finally the High Speed Flight Station (HSFS) in 1954, an autonomous NACA research organization ranking just below the three great NACA laboratories. Richard Hallion has told this story also in his *On the Frontier: Flight Research at Dryden, 1946-1981*.⁴⁷

The third observation warranted by the research-aircraft story is that reality looked very different at the NACA laboratories and at headquarters. Relying largely on the recollections of the Langley staff, Hallion has described them as forcing the research aircraft program upon a conservative headquarters in something of a revolt of the engineers. At headquarters, it looked as if the Langley staff had to be restrained from pursuing reckless experiments that could destroy not only an expensive aircraft, but the entire NACA as well. In the event, the Langley crowd was right, but that does not automatically discredit the headquarters perspective. Stack and his colleagues had only to keep a small airplane aloft; Lewis and the headquarters staff had to sustain the entire NACA. The laboratory staffs were largely insulated from the Washington politics that made Lewis choose as he did, even while they were immersed in aeronautical data that made them choose as they did. All organizations with field units controlled by a headquarters know of the tensions between the branches: the field personnel, on the cutting edge of the agency's mission, resent direction from a headquarters less informed than they of the problems on the frontier and mired instead in a morass of seemingly senseless red tape, whereas the headquarters personnel think the field staffs cannot see the forest for the trees. These problems of empathy and communication are compounded in a research agency like the NACA, where the field work is esoteric and



Isolated from Washington politics, John Stack poses in 1946 amid the models and research equipment that would help him win his first Collier trophy the following year. The model in the background is the supersonic D-558, shown at right in cutaway to reveal the extensive NACA instrumentation used in 1947 at Muroc Air Base to test the plane's flight performance. (LaRC)

unpredictable and the headquarters is constantly on call to justify the agency's existence.

Langley staffers were fond of recalling how they triumphed over headquarters in the research-airplane program, and of lamenting less successful contests with the forces of bureaucracy. These conflicts were not, however, as clearcut as they thought; even now, establishing who was right is difficult. The research-aircraft program was a success, but more clearly as a psychological breakthrough and a public-relations coup than as a research enterprise. Breaking the "sound barrier" brought the NACA another Collier trophy, popular and political support, and worldwide approbation within the aeronautical community. But Clarence L. "Kelly" Johnson, the design genius of Lockheed Aircraft Corporation, considered the whole enterprise merely an engaging stunt costing millions of dollars that could have been more profitably spent on other research projects. Even the defenders of the program are hard pressed to justify it in terms of cost effectiveness. Ironically, the technical staff at Langley congratulated itself for a success measured by the intangibles of publicity and prestige that the headquarters was berated for pursuing. This example points up the hazards of claiming credit or laying blame for the achievements and shortcomings of the NACA, and leaves unanswered and unanswerable the question whether the NACA's conservatism hastened its demise or prolonged its life.⁴⁸

The research-aircraft program took on a life of its own and overshadowed its original purpose. At first it was just an expedient for conducting high-speed research. Other methods used by the NACA in the late 1940s, while less spectacular, produced equally useful data. Since the wind tunnel was at the heart of the NACA tradition, the

Committee devoted substantial amounts of money and manpower to improving wind-tunnel design, especially in the anomalous transonic region just below and above the speed of sound where previous aerodynamic research proved inadequate. In a normal wind tunnel, proximity of the tunnel walls distorts the flow over the model from what it would be in the open, and this undesirable effect increases drastically at transonic speeds. The problem at these speeds was to devise a new kind of tunnel that would reduce this effect to acceptable limits. John Stack's group at Langley took the lead in this campaign, as it had in the research-aircraft program, with equally stunning results.



Bumps provide transonic flow before the transonic tunnel is developed; left, a stability model mounted on a bump in the Langley 7- by 10-foot tunnel in 1947. Right, a smaller model is mounted on the wing of a test aircraft. Both models experience transonic flow while the airstream is moving subsonically with respect to the tunnel or the test aircraft. (LaRC)

Another way to gather data in the transonic and supersonic regions, both in tunnels and in flight testing, was to place small models on the upper edges of wings where the airflow could pass through and beyond transonic range even though the airfoil itself remained at subsonic speed relative to the air. The problem with this method was that, to fit within the high-speed layer of air passing over the wing, the models had to be exceptionally small, thus yielding low Reynolds numbers and questionable results. Yet another method was to drop models from high altitude and let them fall to supersonic speeds. This technique was compromised by the difficulties of telemetering the measured data before the model crashed.⁴⁹

This period also saw much low-speed, conventional testing of high-speed models and airfoils, for one major problem was how to design

supersonic aircraft that could also maintain stability and control at speeds low enough for safe and practical landing. Stability and control were in fact the main problems of high-speed flight,⁵⁰ but they were now critical not only in the old regime but also in new areas where the rules were not the same.

The NACA's role in missile and rocket research was less clear. Here, Hunsaker took the initiative. In December 1944 he prepared a memorandum on guided missiles in which he stated outright that "the policy of the Committee is to include scientific and engineering research bearing on the design of guided missiles and their means of propulsion and control." When he presented this to the Main Committee, one of the military members wanted to know if "these new missiles [were] airplanes." Hunsaker had come armed with the official NACA definition of an aircraft as "any weight-carrying device designed to be supported by the air either by buoyancy or by dynamic action," which he clearly felt encompassed missiles. Though Vannevar Bush recommended caution—"We cannot tell how far this thing will go," he said—Hunsaker quickly won agreement that "the NACA should have the same relation to guided missiles as it has to airplanes." The following month the Executive Committee authorized Hunsaker to appoint a special committee on self-propelled guided missiles with Hugh L. Dryden as chairman.⁵¹



The NACA did some missile research in its wind tunnels. Here, a Northrup Snark missile stands ready for testing in the Ames full-scale wind tunnel. (ARC)

Soon, however, Bush's note of caution proved prophetic. Missiles and rockets were then (and for the foreseeable future) exclusively military devices; research on them needed coordination, especially between the navy and the air force, but not the kind of coordination the

NACA had done in the past in bringing together civilian and military interests, private and public sectors. All the necessary coordination could be done within the military establishment, and when its Research and Development Board came into existence under the chairmanship of Vannevar Bush, it quickly established its own guided missiles committee. This rendered Dryden's committee redundant, and it was abolished in 1947. The NACA continued to do research in guided missiles and rockets, and members of its staff sat on the military committees coordinating these programs, but in this case the NACA played no central role.⁵²



An aerial view of early facilities at the Pilotless Aircraft Research Station, Wallops Island, Virginia, in 1947. The launch ramp in the foreground sent rockets out over the Atlantic Ocean, beyond the beach at the right of the photograph. (LaRC)

The NACA's research in missiles and rockets, especially before supersonic wind tunnels became available, called for flight testing. None of the existing NACA laboratories was suitable for launching missiles, so the Committee acquired use of a small island, Wallops, on the Virginia coast north of LMAL. This installation began as the Pilotless Aircraft Research Division of Langley, run by a small contingent of Langley engineers, much as the High Speed Flight Station had begun. In time it grew into the semiautonomous Wallops Island Pilotless Aircraft Research Station, though while in NACA it never broke loose of Langley as the HSFS had.⁵³

As the last new facility the NACA was to obtain, Wallops Island closed two chapters of the Committee's history. First, Wallops gave the

NACA the other ingredient of the National Supersonic Research Center that had been lost in the compromise unitary plan. The original NACA proposal had called for a missile-launch facility; with Wallops and Muroc and the tunnels built at the existing laboratories, the Committee got everything it wanted in its proposal—everything, that is, except the new center and a monopoly on supersonic research. Second, in the decade from 1938 to 1948 four new research facilities had been created out of nuclei drawn from LMAL. Langley had served as the mother laboratory from which all others were born, a pattern that was to repeat itself, though not without exception, when the NACA became NASA.



The unitary plan supersonic wind tunnel at the Langley laboratory had two test sections; the exit passages joined at this irregularly shaped section of the tunnel. Technicians in both passages are working on the guide vanes. (LaRC)

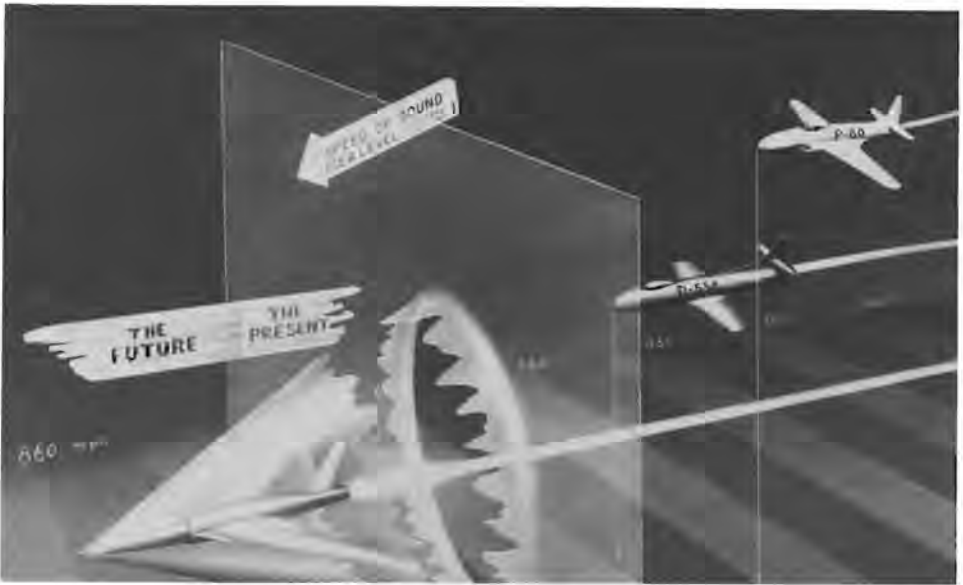
The third great field of postwar research, nuclear propulsion for aircraft, was the one in which the Committee's role, and Dryden's in particular, would return to haunt them in later years. At first, nuclear propulsion for aircraft seemed a natural pursuit for the NACA. When one of the navy members of the Main Committee asked the NACA to enter this field, the Committee agreed and turned to Edward U. Condon, then director of the Bureau of Standards, a veteran of the Manhattan Project, and an adviser still closely involved in atomic energy matters. Condon himself agreed with the sense of the NACA

that a special committee should be set up to guide this program. Before he could recommend this formally, however, General Curtis LeMay, deputy chief of the Air Staff for Research and Development, wrote him that the Army Air Forces already had this research area thoroughly in hand through its NEPA (Nuclear Energy for Propulsion of Aircraft) project, "the sole approved activity to pursue research and development in this field." LeMay warned that "the establishment of a new and separate N.A.C.A. committee or group to pursue such work, would, in essence, duplicate to a large degree authority and responsibility already vested in the A.A.F. and, insofar as is presently understood, would be contrary to the desire of the Atomic Energy Commission."⁵⁴

Condon, a maverick who would soon run afoul of the witch hunt in Washington that accompanied the "red scare" of the late 1940s and early 1950s, chose to ignore LeMay's warning and recommended that the NACA go ahead with plans to establish its own committee. The NACA, however, was far more politic. It withdrew instead into the subordinate role dictated by LeMay. Although it did important research in this area at the Cleveland laboratory, it conceded to the military, as it had done in missile and rocket research, the leading and coordinating role it had enjoyed in such fields before World War II.⁵⁵

Of course, supersonic flight, missiles and rockets, and nuclear propulsion for aircraft were only the most dramatic of the new fields of research into which the NACA moved in the late 1940s, but the Committee's record in these areas reveals the general drift of events. The NACA was clearly losing ground in the jockeying for position behind the scenes, even though the public image was one of achievement and triumph. Within six years after the end of World War II, the Committee had gone a long way toward restoring its reputation and dimming the memories of how it had been bested by Germany during the war. In those six years it won three of the five Collier trophies that it was to receive in its entire history, and the achievements that won those awards reflect the transition the NACA was going through.

Lewis A. Rodert won the trophy in 1946 for his work on thermal ice prevention. Two decades of research lay behind his accomplishments—the old, plodding, unglamorous, cut-and-try engineering so greatly appreciated by industry and the services and so true to the notion of a practical solution to a problem of flight. The following year John Stack shared the trophy with industry and the air force for breaking the sound barrier. As previously noted, this achievement was more important psychologically than technically: the barrier existed only in the minds of skeptics who thought it could not be broken. Once it was broken, the NACA could bask in the glory of a feat that had more popular appeal than technical worth. The symbolic importance of the



NACA veterans liked to claim that there was never a sound barrier. That view was not shared by staffers at the Ames laboratory who prepared this NACA exhibit for the Santa Clara County Fair in September 1947, just one month before the barrier was broken. (ARC)

Collier award for the NACA was that, by sharing the award with industry and the military as Dryden insisted, the NACA became publicly identified with the military-industrial teamwork that had dominated aircraft development in World War II.⁵⁶

In 1951 John Stack shared the Collier trophy again, this time with his associates at Langley, for developing a transonic wind tunnel in which wall effects had been reduced enough to yield reliable data in the most troublesome of speed ranges. Although other researchers had despaired of achieving valid wind-tunnel results in the transonic range, Stack and his colleagues had persevered to a success emulated and copied around the world. Once more it was fresh, brilliant, daring research that was winning public accolades for the Committee in contrast to the more mundane achievements of icing research, even though the latter might benefit a larger group and be more widely appreciated by knowledgeable people.

The NACA could and did exploit all these achievements to win continued support from the Bureau of the Budget, the Congress, and the general public.⁵⁷ Breaking the sound barrier was especially important, for it captured the imagination of those who knew little of the



Left, a worker examines a model in the test section of Langley's 16-foot high-speed wind tunnel in 1951, shortly after the tunnel was repowered and equipped with the new slotted throat that reduced wall effects and permitted accurate testing in the anomalous transonic region around mach 1. Right, two workers survey the return passage of the same tunnel; the diameter here is 58 feet. (LaRC)



John Victory (left) and Hugh Dryden (left, center) display some concern about the prospects of John Stack's (right, center) lasting out the evening of celebration in Hampton's Chamberlin Hotel, marking the award of Stack's second Collier trophy. The ever steady Henry Reid stands beside Stack. (LaRC)

technicalities of flight but could understand what it meant to fly faster than your voice and leave a sonic boom in your wake. But, to those who had a glimpse behind the scenes where the NACA was suffering from both internal dissent and unprecedented criticism from the industry and the military, the future looked less rosy. The new position into which the NACA was being forced in the late 1940s was neither as powerful nor as comfortable as that of the prewar years. On the NACA budget officer's copy of the "Estimates of Appropriations, Fiscal Year 1950," someone had penciled "'whither are we going'." ⁵⁸

11

Doubting Thomases, 1950-1955

All government agencies, the NACA included, run on money. Funding is a measure of institutional health and prospects. With more funding, an agency can presumably do more of whatever it does, be it defending the country, delivering the mail, or conducting aeronautical research. Over the years, especially through World War II, the NACA had always gotten pretty much what it wanted. It was a small, efficient organization with a good reputation in the Bureau of the Budget and in Congress, operating in a field where few bureaucrats or lawmakers were qualified to criticize its work. There is evidence that the NACA tended to ask for as much money as it thought it could get, leaving itself open to charges of conservatism and lack of vision; but it generally fared well in the Washington scramble for funding.

Even after World War II, when the Committee was at its nadir in reputation and influence, when it was losing important battles over the Unitary Wind-Tunnel Plan, missile-research coordination, and nuclear-powered aircraft, it still won steadily increasing funding from Congress.

Nothing prepared the Committee for the unprecedented funding reverses it suffered in the early 1950s. Shortage of money dominated these years, as never before in the Committee's past. Analysis of these money crises becomes an analysis of the Committee's political history as well, showing how the NACA budget (and hence the NACA) fared in comparison with aviation in general, the military services, and federal funding for research and development; why the NACA's funding was cut in these years and by whom; how the Committee responded to the cuts; and what all this portended for the future.

A REVERSAL IN WAR

The NACA had prospered in war. World War I had provided the impetus for its creation in 1915, after several aborted attempts in the preceding years of peace revealed how difficult it was to move Congress when the national interest was not transparently obvious. The

money made available in World War I bought the facilities at Langley Field that were to guarantee the NACA's ability to conduct its own research. In World War II the NACA had quadrupled in staff, funding, and facilities, a growth from which it had not receded appreciably in postwar years, despite congressional enthusiasm for demobilization and retrenchment. The NACA had every reason to believe that the Korean war, though officially only a police action, would result in a similar expansion of the Committee's activities and resources.

If anything, the NACA might even have thought it would profit more from the Korean war than from previous hostilities. First, the lesson of World War II that the Committee rehearsed most relentlessly was still fresh in the mind of Congress: drawing the NACA away from its fundamental research during the war to clean up and test military aircraft had exhausted the nation's supply of basic aeronautical knowledge. In future wars, the NACA would have to do specific work for the military and keep up its fundamental program as well.



A technician works at the wingtip of a model facing into the camera from the test section of the Ames laboratory's full-scale tunnel. (ARC)

Furthermore, the NACA was more closely tied to the military after World War II than before, even though the military had always been at the heart of the NACA mandate and activities. When Congress insisted that NACA construction required separate authorizations before funds were appropriated, this function was assumed by the House and Senate armed services committees. When the United States Code appeared in 1948, the NACA had been shifted from Title 49, Transportation, to Title 50, War. The following year the Bureau of the Budget shifted the NACA from functional classification "Transportation and Communica-

tions" to "National Defense" because the committee's growth in the previous decade had "been based entirely on military considerations" and "all NACA officials agree[d] that the primary mission of the agency for the foreseeable future [was] military in nature." There was a conviction within the BoB and elsewhere that, in the future, technological fallout would rain down from military developments onto civilian concerns; thus, the former should get most of the nation's research money. Though the entire aircraft industry played an increasingly important role in NACA affairs, it was primarily the manufacturing branch—concerned mostly with military contracts—that held sway in NACA councils. The aircraft operators were only beginning to be heard.¹

When military expenditures, especially for aviation, rose dramatically in response to the North Korean invasion of South Korea in June 1950, there was every reason to believe that NACA appropriations would rise with them. The services publicly avowed their intention to rely heavily on the NACA both for cleanup and testing and for fundamental data; they went so far as to assume primary responsibility for defending NACA increases before Congress.²

The theme of the NACA campaign appeared in the *Annual Report* for 1950 just four months after the North Korean invasion. "For the third time in its history," the report began,

the Committee is conducting its program of scientific research in an atmosphere of world crisis. . . . The U.S. is spending billions to strengthen its air power. It is mandatory that the aircraft procured be superior in performance and military effectiveness. . . . We are in a sustained international contest with stakes so great we dare not lose. . . .

During World War II, the Committee curtailed its program of basic research in order to concentrate on applying available scientific knowledge to the immediate improvement of aircraft scheduled for war production. This course was mandatory in view of the limited manpower and research facilities then available, but it was at the expense of the advancement of knowledge of the scientific problems of flight. Although some adjustment is required in the event of emergencies, it must not occur again to the degree effected during World War II.³

Behind the scenes, the NACA was making an even stronger pitch, looking toward an expansion barely suggested in the annual report. Late in 1951, John Stack of the Langley laboratory, one of the world's leading authorities on high-speed research and twice recipient of the Collier trophy, prepared a VIP briefing on "NACA research potential and current and future needs." Relying on intelligence reports from Korea and the Soviet Union, Stack extrapolated the observed perform-

ance of the Russian MiG-15 (about mach 1) and the reported performance of the MiG-19 (at least mach 1.5) and concluded that the Soviets had aircraft capable of operating at still higher speeds. "We are lagging," he concluded, partly "because of the common but erroneous concept of the Russians as a backward peasantry deficient to the extreme in the industrial arts." He thanked "the Providence of the Korean 'Police Action'" for revealing to the U.S. that the Soviets after World War II had engaged in an enormous aeronautical research effort far outstripping that of the United States. One NACA staff member counseled that Stack depict this as the "same story as mid-thirties Hitler effort," which in fact it did resemble.⁴

Stack used speed, "the prime requisite for military superiority over the enemy's airplanes," to demonstrate how far the United States was behind. He divided the modern history of flight into three periods. In the subsonic period (from 1925 to 1945) speeds increased from about 150 miles per hour to 500 miles per hour, or about 16.5 miles per hour per year. In the transonic era (from 1946 to 1951) speeds of U.S. planes rose to 680 miles per hour, increasing at an annual rate of almost twice the subsonic era. But this was too slow by a third to match the MiG-15, less than half the rate necessary to match the MiG-19.⁵

The reason for this, according to Stack, was the shortage of American research facilities and personnel compared to those of the Russians. NACA personnel figures showed that 84 man-years lay behind every mile-per-hour speed increase in the subsonic era, whereas 227 man-years were required in the transonic era. The increment was dictated by the complexities of high-speed flight, in which an aircraft had to perform acceptably in the subsonic regime for takeoff and landing and to do its operational flying through and above the speed of sound, where the researcher as yet had no proven theory to guide him. The NACA laboratories were short by 50 percent of the level needed to keep pace with the Russians—assuming that Russian scientists were as efficient as those in the NACA, which Stack clearly would not allow. He cited intelligence sources suggesting that "the Russians expended at least three times the man power in their research establishments that we did."

Therefore, concluded Stack, the NACA should expand from its 1951 manning level of about 7000 to 10,000 in 1952 and 14,000 the following year. New facilities, comparable to those assumed to be in the hands of the Russians, should be made available to the expanded staff, so that the NACA research equipment would once more have the level of sophistication it enjoyed in the 1930s. In essence, Stack was arguing for a doubling of the NACA during the next two years, and he warned that if the war situation "remains tense" thereafter, "further expansion to match our adversary will likely be necessary."

Stack's case was riddled with dubious assumptions and specious logic, but it clearly revealed the thinking of the NACA: the Korean war would lead to renewed expansion.⁶

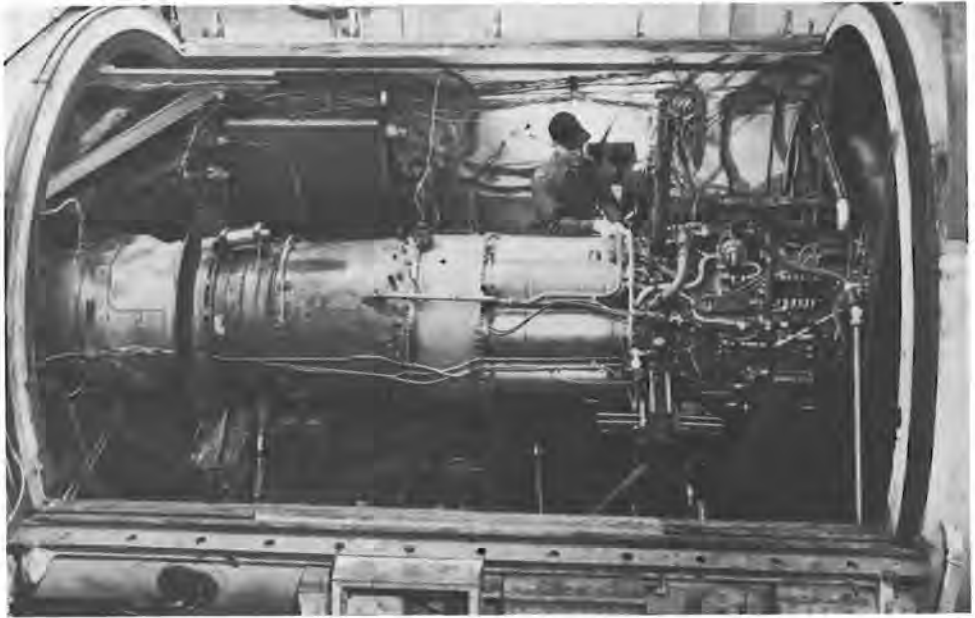
The opposite occurred. Cuts had already been made in the NACA appropriation for fiscal 1951 when the Korean war broke out in the summer of 1950. These were restored in a 1951 supplemental appropriation and in an increased budget for 1952. But thereafter, for three consecutive years, NACA funding fell, the first such declines in the Committee's history. In the summer of 1950 the Senate refused to exempt the NACA from a 10-percent general reduction in appropriations, "one of the very few agencies in the national defense field" to be so treated, reported a BoB official. While the Korean war was still going on Congress reduced 1953 NACA funding below the 1952 level both for construction and equipment and for salaries and expenses. In the next two years it slashed construction and equipment appropriations to the point where the minor increases in salaries and expenses the Committee won were insufficient to keep the total funding at the previous year's level. In the next four years after 1952, the Committee received only a single, small supplemental appropriation.⁷

These figures, serious enough in their own right, were more so in comparison with other government expenditures. By 1953, U.S. military aircraft production was almost four times the 1950 level, the military budget had more than tripled, and military obligations for research and development had almost quadrupled. In the same period the NACA operating budget had increased a mere 15 percent and the Committee's authorizations for new construction never regained the 1950 level which had included funds for the unitary wind-tunnel plan. In short, the NACA was getting a smaller slice of a larger pie, just when it was demanding a larger portion to keep the United States abreast of the Soviet Union in an increasingly expensive area of international competition.⁸

Some of the NACA's losses in the early 1950s can be attributed to the advent of the Eisenhower administration. Even before taking office, Eisenhower began working toward a negotiated settlement in Korea; the achievement of that goal in July 1953 deflated, if it did not eliminate, the national emergency. Eisenhower also introduced early in his first term an economy drive to balance the federal budget. The resulting trims in expenditures, especially in 1954 and 1955, hit all agencies hard, even the Department of Defense. And Eisenhower brought into the White House a skepticism about research and development that was soon to pervade his administration and be most colorfully reflected by Secretary of Defense Charles E. ("Engine Charlie") Wilson, famous for allowing that he didn't care why the grass was green or why fried potatoes turned brown. The new National Security Council concluded

that “the Federal Government is spending too much money on research and development and is not spending it very well.” The NACA suffered along with other federal research agencies in this climate.⁹

But the Eisenhower administration alone does not account for all the cutbacks suffered by the NACA in the early fifties. The real villain of this piece was in Congress.



This is research that even Charles E. Wilson could understand. An axial-flow turbojet with shroud-cooled afterburner is checked before high-altitude combustion and control studies begin in an altitude test chamber at Lewis laboratory in the early 1950s. (LeRC)

THE FAT IN THE FIRE

The NACA nemesis of the 1950s was Congressman Albert F. Thomas, chairman of the Independent Offices Appropriations Subcommittee of the House Appropriations Committee. More than any other man in Washington, Thomas found fault with the NACA and worked to pare its size and prerogatives. In much of this, he was speaking for his subcommittee and for what Victory called in 1950 “a very troublesome Congress.”¹⁰ But there was more to it than that. His name appears over and over again in the records of the NACA and the Bureau of the Budget, not as mere spokesman but as leader of the attack. There is no doubt that Thomas was the locus of opposition to the Committee in the 1950s.

The Bureau of the Budget believed, from Thomas's public statements in committee, that the bone he had to pick with the NACA was overexpansion. The BoB staff saw no particular malice or ill will in this, for this was a common theme in the House Appropriations Committee and its subcommittees at the time, especially with regard to research and development expenditures. When the Korean war broke out, however, and Thomas's committee continued to cut NACA appropriations below the amounts recommended by the Armed Services Committee, the BoB staff became perplexed.¹¹

The question of authorizations was one example of what the NACA was up against. Though the issue has a long history, it was Thomas who finally forced the NACA to obtain authorizing legislation for its construction appropriations. Following the explosive growth of government in World War II, BoB required all federal agencies in 1945 to submit draft legislation covering any appropriations that might be subject to a point of order in Congress, i.e., that might be in technical violation of laws and procedures governing the appropriation of federal funds. The NACA declared itself blameless, but the BoB found several questionable areas, the most serious being the appropriation of construction funds without authorizing legislation. Victory took the position that the organic NACA act, contained in the naval appropriations bill of 1915, met this requirement. The Bureau disagreed, but deferred action until the next NACA construction request. In the meantime, the NACA Membership Act of 1948 seemed to confirm Victory's position, for it in essence repassed the Committee's organic legislation without any substantive change except for membership.¹²

Albert Thomas, however, was not satisfied. In 1949 he raised the issue again, stating that his committee believed that "an agency which has grown to the size and importance attained by NACA should have broad, basic legislation authorizing all functions, including authorization for the construction of specific projects." Though the House Armed Services Committee delayed this action for a year, legislation passed in 1950, authorizing the NACA to "equip, maintain, and operate offices, laboratories, and research stations under its direction" and to "acquire additional land for, undertake additional construction at, and purchase and install additional equipment for existing laboratories and research stations under its direction."¹³ In the long run this legislation probably helped the NACA, lending to its construction requests the endorsement of the House Armed Services Committee, but it was viewed by Victory at least as an unwelcome explication of the specific powers of the NACA. Victory preferred to construe these on a rather sweeping scale from the Committee's broad and vague organic legislation. If the NACA had to get specific congressional authorization for something as basic as acquiring and equipping laboratories, it

might end by having to submit other traditional prerogatives of the Committee to congressional review.

In the same breath with which he launched his campaign to force authorizing legislation upon the NACA, Thomas suggested that the basic organizational structure of the Committee should be changed. He stated that his committee felt that the importance of the NACA, "which is the backbone of all future development in the field of national defense as far as aeronautics is concerned, justifies the appointment of a full-time Chairman at \$15,000 per annum to be appointed by the President, by and with the advice and consent of the Senate." The resulting organization, with a paid full-time chairman and an unpaid part-time board, would have paralleled the Research and Development Board and the Munitions Board of the National Military Establishment. These bodies, however, were soon to prove unsatisfactory and fall victims to different reorganizations. The Bureau of the Budget was mildly opposed to the Thomas proposal. John Victory was adamant. He personally enlisted the congressman from the district that included the Ames laboratory to head off the Thomas proposal on the floor of Congress. This accomplished, Victory visited Thomas to present the NACA's case: the Committee had been successful because it had attracted the best men of American aviation to serve as a patriotic duty. To pay the chairman would be to reduce the position to that of a hired hand, and demean the other committee members as well. Important and influential men might serve voluntarily on a prestigious committee as a civic duty, but they might be reluctant to serve as an advisory board to a paid government functionary.¹⁴

Whether or not Thomas found this convincing, he abandoned his proposal to change the chairmanship of the NACA to a paid position. According to Victory, Thomas confessed he hadn't understood the full ramifications of his proposal, but he made clear the motivation behind it. He closed their interview by warning Victory that any agency grown as large as the NACA had to expect that its strange type of organization would be subject to criticism. He asserted that he was just trying to help, by providing the Committee with a better scheme of organization. Hugh Dryden, for one, was willing to accept this claim, interpreting Thomas' proposal as a compliment to Hunsaker.¹⁵

The depth of the congressman's admiration for the NACA chairman was thrown into some doubt the following year when Hunsaker appeared before Thomas to defend the 1952 appropriation request. The following excerpt from the hearings (later excised at Thomas's request) reveals neither man in his best light.

Thomas: Now the question is that you have some fat in here—I put some eight or nine hours on this budget last night—and we are

going to give you an opportunity to tell us where we are going to cut it. We just cannot do business as usual. We are in war. We do not want to cripple your agency; we want you to function and do your job; but there is too much fat in here.

I have this idea in mind, and I would like you to comment on it. This is a companion industry, we will call it, to industry. In private industry, anybody who works 7000 or 8000 employees has a whale of a big industry, especially if it spends \$80 million. That is a whole lot larger than the budget you get for MIT and fair Harvard combined; with all of their departments; is it not?

Hunsaker: You do not want a reply to that; do you?

Thomas: Yes.

Hunsaker: This is embarrassing to me, as I am on the defensive. You made the assertion that there is fat in this budget.

Thomas: That is right. I still say it.

Hunsaker: I will say, to the best of my knowledge and belief and representing my colleagues, this is our best and considered judgement in the interest of the country. We have not put any fat in here deliberately that you might get satisfaction from cutting out.

Thomas: Now, just keep your shoes on, Doctor.

Hunsaker: I cannot keep my shoes on when you say there is too much fat in here.

Thomas: Take them off, then.

Hunsaker: I will take them off and take my coat off, too, if you like.

Thomas: Let your size be your guide, my friend.

Hunsaker: This is on the record.

Thomas: Just keep your shoes on now. All of us here have a job to do, and do not be so touchy about it. We want to treat you nice and are going to treat you nice.

Hunsaker: That is fine. I thought maybe you were not going to when you made your first opening statement.

Thomas: We find a lot of fat in every budget, and we are not going to give you a blank check, as distinguished as you are.

Hunsaker: Hardly.

Thomas: Is that clear to you now?

Hunsaker: Quite.¹⁶

There is in Thomas's performance that day something of the anti-intellectual, something of the conscientious congressman, and something of the bully. In Hunsaker's uncharacteristic response there is something of the frustration the NACA was coming to feel for this man so important to its fortunes. One thing was sure: the conflict between the NACA and Albert Thomas had become personal and intense.

In 1952 Thomas asked the General Accounting Office to audit the NACA. The report provided grist for both Thomas's mill and the

NACA's. Generally the auditors were favorably impressed with the Committee's performance, advising Congress that

selective tests made during our review indicate that NACA activities are generally conducted satisfactorily. This is attributable, we believe, to the high quality of its employees, their high morale, and their sincere interest in the development of aeronautics. Although in isolated instances there is evidence of uneven distribution of workload, general overstaffing is not evident.¹⁷

On the other hand, the accountants found that the NACA was using salaries and expenses funds for construction and equipment, a practice reminiscent of the old Committee technique of procuring facilities and then demanding from Congress the personnel and resources to staff them. The GAO recommended that in the future Congress should specify the purposes for which it was appropriating construction and equipment funds and explicitly prohibit the Committee from using salaries and expenses funds for this purpose.



NACA's continuing need for construction and equipment funds is illustrated by this 1953 test of Martin Aircraft Company's experimental XP6M-1 jet-powered seaplane. Though the towing tank itself was constructed in 1931, the auxiliary equipment had to be updated periodically to keep pace with advancing technology. (LaRC)

The GAO recommended that the Committee establish positions for a comptroller and a legal officer, to gain tighter control over internal

fiscal management and external contracting and procurement. In every aspect of NACA activity, from purpose and organization through research activities to administration, the auditors found evidence of an agency that had outgrown its old *modus operandi* without adopting a new one. Because aeronautics had grown so diverse and complex in the United States, the report stated, it was "no longer practicable for the NACA to supervise and direct all of the Nation's aeronautical research," as intended in its organic legislation. Research authorizations were so generalized and so numerous, and procedures so varied from laboratory to laboratory, that the director of the NACA had neither control over the actual research being conducted nor reliable data about research projects in progress. Management decisions were being made without adequate information, and administrative control from headquarters was lacking because of the "rapid expansion and decentralization of NACA" and the research autonomy accorded to the laboratories. Whether or not the management criteria employed by the GAO were appropriate to a research organization, the report appeared to provide ample evidence of inefficiency and waste. This was just the picture of the NACA, in fact of all government agencies, that seemed to be entertained by Albert Thomas. He had lectured Hunsaker in 1951, "you cannot escape the fact that private enterprise is certainly from 20 to 30 percent more efficient than the Government." The NACA survived the GAO audit of 1953, and similar audits in 1954 and 1955, without radically changing its organization or procedures; but these ordeals could hardly be expected to increase the Committee's credit with Albert Thomas.¹⁸

Of course, many of Thomas's criticisms of the NACA only reflected opinions widely shared on Capitol Hill. For example, the Senate Committee on Expenditures in the Executive Department echoed Thomas's concern that the organizational structure of the NACA was inappropriate to its size. A report by that committee in 1948 had identified only two "committees" among the independent agencies of the Executive Branch. Only nine independent agencies had more people than the NACA; the Department of Labor had considerably fewer. The Senate Committee on Appropriations brought up the old complaint of how much NACA work at government expense profited private industry. And a BoB official noted in 1953 that "there have been many broad statements recently on the amount of duplication in research and development program and facilities," implying doubts that the NACA had to assuage when it took its construction authorization bill before the Senate Armed Services Committee. When the British successfully flew the Comet jet airliner years ahead of any comparable American plane, John Victory found himself before the House Committee on Interstate and Foreign Commerce, trying to convince the members that this was a

question of economics and not a shortcoming of American aeronautical capability.¹⁹ Thomas was by no means the only member of Congress turning a jaundiced eye on the NACA in the early 1950s. He was merely the most visible, the most relentless, and the most powerful.

This catalog of woes for the NACA does not mean that the Committee had no defenders on the Hill. The armed services committees of both houses, friendly as they were to the military and attentive to recommendations from men in uniform, generally gave the NACA unstinting support and encouragement, and the Senate Committee on Appropriations was consistently more sympathetic to the NACA than was its counterpart in the House. Senator Richard Nixon promised in 1952 to see that any cuts in NACA appropriations would be restored in the Senate, and presumably he carried that disposition into the Eisenhower administration when he became vice president the following year. And congressmen from districts where NACA laboratories and stations were located could generally be relied upon to support the Committee. Unfortunately, none of the congressmen were so well placed or so committed to their views as was Albert Thomas.²⁰

THE NACA DEFENSE

When asked on a Washington radio program in late 1952 to name his most difficult administrative problem, John Victory replied "trying to remain a discreet and ethical scientific organization" in the face of congressional indifference to what he saw as the overriding importance of aeronautical research.²¹ Cuts imposed upon the NACA in these years were so unprecedented, so incongruous with the war emergency and the growing demands of the military for help in its expanding aviation program, and so frustrating to the members and staff of the NACA, who felt hobbled in a desperate race, that they were sorely pressed to control their tempers and their scruples. The righteousness of their cause seemed to justify extraordinary means, but they resisted the temptation to move dramatically. The response of the Committee, at least at first, was passive and defensive. Deferentially the NACA submitted supplemental appropriation requests to Congress. When these too were rejected, the Committee in soldierly fashion tightened its belt and resolved to make do with less.

In its relations with the military and industry, whom Hunsaker now referred to openly as the Committee's clients, the NACA was equally cautious not to make waves, not to antagonize those to whom it looked for support. As in the past, it answered all military requests for research or assistance, even those that contributed nothing to fundamental knowledge. Of course it preferred investigations of fundamental significance and asked the services to restrict requests to this category



“What—me worry?” A NACA employee in 1954 tests the feasibility of the “jet board,” a form of individual jet propulsion. The trick in maintaining balance is not to think about it but to trust to natural reflexes. A colleague takes cover at right, while the crane at left provides a safety wire in case reflexes fail. The NACA often felt it had just this kind of support from Congress in the early 1950s. (LaRC)

when possible. But the press of war demanded that the NACA engage anew in cleanup and testing and problem-solving. With the memory of World War II still fresh and the need for fundamental research in high-speed flight ever more pressing, this pattern was especially distasteful to the Committee. Short of turning its back on the military, however, there seemed no help for it.²²

The NACA even relinquished its 1940s dream of cornering the market on supersonic research in the United States. By 1953 the air force had run into serious problems with its new engineering research center. The contractor hired to design, construct, staff, and operate the center had been repeatedly late and over cost, a result that many of the NACA staff had predicted in the 1940s when they saw how inexperienced the firm was in aeronautical research construction. The poor performance, coupled with handsome salaries to top administrative personnel and profit margins as high as 60 percent, finally brought on a congressional investigation and the suggestion that the NACA take over the center. The Committee quickly declined, more anxious, it seems, to stay on the good side of the air force than to gain the control over supersonic research that it once coveted. The air force was determined to hang onto the center and run it by contract, and the NACA was not about to cross its most important single client.²³

With industry, the story was much the same. As most of the Committee's work for industry was on military projects, requests for investigations, though they may have originated with industry, came through the services and received the same treatment as military requests. This had always been going on to a certain degree; now it was prevalent. The one area where industry was entitled to call upon the NACA for its own work was in the unitary wind tunnels that were coming into operation in the early 1950s. As dictated by Congress, the NACA had established procedures guaranteeing that these tunnels would be available to industry for development work. The same procedures were subsequently adopted for all NACA tunnels, an indication of both the growing influence of the industry on the NACA and the little demand that the industry in practice made for the tunnels. Working primarily for the military, the industry seldom needed tunnel time for civilian projects, in either the supersonic or the other tunnels.²⁴



The Ames 40- by 80-foot full-scale wind tunnel could just accommodate the 72.5-foot wingspan of the Douglas A3D Skywarrior. (ARC)

The one area in which the NACA did hold its ground and deny to industry a much sought-after concession was the collection of fees. The aircraft manufacturers wanted the NACA to charge fees for all tunnel work, arguing that payment would give them the right to conduct investigations their own way, without the services or the NACA looking over their shoulders, and without the hazard of proprietary information's falling into the wrong hands. The NACA agreed to charge fees for strictly proprietary work, but not for contract work. The effect of

charging industry fees on development work under contract to the military services would be for aeronautical R&D funds to pass from the military, through the contractor—who would remove an overhead percentage—and via the NACA back into the general fund of the Treasury. The NACA could not use this money to conduct other operations, but would have to do additional bookkeeping to account for it. The services would incur a needless drain on their research funds. Better that Congress appropriate to the NACA the funds needed to do the government's investigations, rather than appropriate the same money plus the contractor's fee to the air force, which was in less financial trouble than the NACA.²⁵

This skirmish the NACA won, because all the government members (and even some of the industry ones) agreed. On all else, however, the industry pretty much had its way. In 1953, industry representatives chaired all five of the NACA's main technical committees, 16 of the 21 technical subcommittees, and both of the special subcommittees. By this time, more than 40 percent of all technical-committee memberships were in the hands of industry representatives and their numbers were still growing. This is not to imply a conspiracy at work, or a monolithic industry subverting the NACA to its own purposes: Industry had merely won the voice in NACA affairs that it had wanted all along.²⁶

The NACA's deferential courting of the military and industry, intensified in the early 1950s, proved enormously successful. To the collection of compliments that Victory amassed in the period 1952 to 1956, he gave the filing title "Bouquets to NACA." These were spent like so much currency all over Washington and contributed to what one supporter characterized as "as fine a public relations job as it is possible to do." The faults and shortcomings of the Committee were kept within chambers, and the public image of a devoted, competent, efficient agency was polished and propagated in hopes of reversing the funding trend of recent years. Nor was this all puffery, for there is every evidence in the minutes of NACA meetings and in correspondence with both industry and the services that the NACA was in fact doing a commendable job and meeting the demands of both its major clients. Gone are the complaints, grievances, and grumblings that rumbled through the NACA files in the immediate postwar period. With its principal clients, at least, the NACA had recouped its past losses and had once more become the indispensable institution it had always tried to be. The problem was that in the process it had reduced itself to being almost entirely a service agency to those clients. No longer was it the autonomous, premier aeronautical research institution in America, the central clearinghouse of aeronautical intelligence and information, the coordinator and arbiter of research priorities, the last word on



The NACA was often called upon to solve operating problems encountered by commercial airlines, like the hail damage suffered by this DC-6 in the early 1950s; see NACA TN-2734, Sept. 1952. (LaRC)

questions of usage and standardization, the pioneer on the frontiers of flight blazing a trail through a forest of fundamental mysteries. The NACA still performed all of these functions to a degree, but they no longer characterized the agency.²⁷

Internally, the austerity and adversity of these years were just as influential in slowly shifting the character of the agency. Shortages of funds began to intrude for the first time on the NACA's ability to attract and retain a qualified staff. As early as 1927, Joseph Ames had enunciated the Committee's position on this issue when he told the Bureau of the Budget that "our Committee will be doing its duty to the country only if it finds the right man and is able to make him contented with his surroundings." At the time, this problem seemed one of recruitment and policy entirely within the control of the Committee. He told the Bureau:

The first purpose of such a Committee as ours must be to find a man, or men, with the necessary knowledge, imagination and enthusiasm. Having found the men, we must see that they are allowed the utmost freedom of action and that their environment is sympathetic.

Money we can get, laboratory facilities and assistants may be supplied, but our deepest concern is with the human side of the question.²⁸

Over the years, this philosophy had been adequate to the need. In the 1920s, the NACA successfully recruited young engineers fresh out of college and trained them on the job. The facilities and the reputation of the Committee attracted these men, offering (as one recruit later recalled) a better graduate education in aeronautical engineering than he could get anywhere else in the world. What is more, the aircraft industry had its ups and downs, while the NACA provided steady employment and security in an unsure profession. The Depression and the austere years of the mid- and late 1930s had made employment with the Committee even more attractive.

World War II changed all that. The mushrooming aircraft industry paid top dollar to attract the best engineering talent. This pressure, combined with the draft and the Committee's own growth, put the NACA in a personnel bind during World War II from which it never fully recovered. Though the NACA finally worked out its personnel problems with the Selective Service System and negotiated a new and acceptable agreement after the war, it never was able to counter high industry salaries. All of government was suffering in the postwar years from industry's ability to buy up the best scientists and engineers, but aeronautics led all the industries except petroleum in the disparity between government and industry salaries.²⁹

The resultant drain of aeronautical engineers from the NACA tended to raise the average age of the professional staff, for the old NACA hands resisted the temptation and stayed on out of loyalty or inertia, while the best youngsters served a brief apprenticeship with the Committee and then took their talent and their experience to higher paying jobs in industry.

To stem this tide, the NACA tried throughout its last ten years, generally through the efforts of John Victory, to secure higher pay for its employees.³⁰ Two mechanisms, both originated independently of the NACA, were quickly appropriated to the Committee's needs: money and education. Congress passed Public Law 80-313 in 1947 as an "interim measure" to allow the secretary of defense to pay as many as 45 of his scientific and technical employees salaries ranging up to those of cabinet secretaries. The pay and prestige of these PL-313 positions, as they came to be called, were expected to aid the secretary in recruiting the technical personnel needed in his department. Though industry still paid more, PL-313 was meant to close the gap enough to make government a competitive employer.

Amendments to this basic act in 1949, 1956, and 1958 raised the salary levels and also gave to the NACA a smaller, but significant, number of positions: 10 in 1949, 30 in 1956, and 90 in 1958.³¹ These allotments were fewer than the NACA requested (in fact, insisted it must have) but they were enough to reduce its personnel drain. The Committee did not, however, use these positions to recruit new men to the NACA as the original legislation had intended, but rather to reward those who had stayed over the years and had declined higher paying offers from the outside. There was logic and justice in this policy, but the long-range effect was to retain the old-timers while giving up the bright young men to industry. Of course the latter might stay on in hopes of succeeding in time to the higher paying positions now at the NACA's disposal, but many of them felt that an increased salary in hand was worth a PL-313 in the bush.

Two other recruitment and retention tools allowed the NACA to offer higher salaries beginning in 1949. The Executive Salary Act, which raised Dryden's salary and led to the clarification of his role as head of the agency, also removed him from the PL-313 quota, thus allowing the Committee one more high-paid billet. More important, the Classification Act of 1949, besides changing federal position classification into a single orderly ranking of 15 General Schedule grades (GS-1 through GS-15), created three new grades (GS-16 through GS-18) which would be controlled by the Civil Service Commission. In 1949 there were 400 positions in these grades; in 1958 there were more than 1500, and many additional ones provided by special legislation. Agencies could apply to the commission for any number of these, which the commission distributed on the basis of need. The NACA tried repeatedly and aggressively to secure as many of these as it could, again distributing what it won almost exclusively to old NACA hands. In its first round, the NACA received only three GS-16s. By 1956 this number had been increased to three GS-17s and 25 GS-16s, far fewer than the Committee felt it deserved. Part of the reason for the commission's reluctance to grant more supergrades to the NACA was that the Committee already had quotas for PL-313 positions. Part of the reason was that many posts recommended by the NACA for the higher rates were administrative jobs that the Civil Service Commission considered inappropriate for special salaries within a scientific and technical organization. The NACA was persuasive when it argued that it had to pay the chief of the Supersonic Propulsion Division a high salary to keep him from going over to industry, but it failed to explain why the headquarters security officer should be paid more than a security officer in any other agency.

In the long run, then, the government salary measures instituted after World War II to slow the drain of scientific and technical person-

nel to industry, while they helped the NACA somewhat, also created for the agency (and for other agencies as well) a dilemma that it never resolved. In attempting to compete in the marketplace with salaries that approached those of industry, the government was placing on certain of its employees a value unrelated to the standards of merit normally applied to civil servants: loyalty, competence, seniority. Dryden and Victory wanted to reward members of the NACA staff who had contributed most to the success of the agency, but the PL-313 law was designed to reward those in demand on the outside. To use the positions as the commission intended, Dryden and Victory would have had to pass over administrators of long and faithful service to the NACA in order to reward some novice whizkids more important perhaps to the field of aeronautics than they were to the NACA. That raised a nice question of which was more important to the NACA: aeronautics or the National Advisory Committee for Aeronautics, the ends or the means. Here, as elsewhere, the Committee was sliding into the natural but dangerous conviction that the means were more important than the ends.

The second method used by the NACA in the 1940s and 1950s to help solve the retention problem was the training of key personnel. If the NACA still wanted to recruit young engineers and train them on the job and at the same time stay abreast of the state of the art and keep its own personnel competitive in accomplishment and credentials with those competing for supergrade and PL-313 positions, it had to have an active program allowing employees to return to school for graduate work and refresher courses. Again, the NACA was asking for a program already enjoyed by other agencies in Washington; in this case, it had little trouble in getting Congress to go along. Public Law 472 of 1950 authorized the Committee to grant its employees up to one year of paid leave for graduate study or research at accredited institutions of higher education.³²

While wrestling with these personnel problems in the early 1950s, the NACA also had to decide which research it could undertake with increasing demands and decreasing funds. On the one hand it had to continue the research programs in which it had labored for years: i.e., traditional aeronautics. On the other hand it had to decide which of the new technologies emerging after World War II warranted part of the Committee's attention and resources. With those resources as tight as they were, these decisions essentially had to be made year by year, in spite of the general commitment the NACA had undertaken in the 1940s. Now every decision to pursue some line of research was at the same time a decision to abandon or neglect some other line.

Of the new fields, the Committee's *Annual Report* for 1955 declared missiles and nuclear propulsion for aircraft to be the most important.

But that declaration was as much a public posture reflecting the world strategic situation and the policy of the Eisenhower administration as it was an accurate reflection of the Committee's priorities. About this time the NACA also concluded what came to be called Round I of the supersonic-flight research program and committed itself to Round II: the design, development, and flight of a mach 7 aircraft capable of flying to "several hundred thousand" feet—what was to become the X-15. When an industry representative on the Aerodynamics Committee suggested that "the NACA is the logical organization to carry on the basic studies in space flight control and stability," the Committee adopted a resolution that "the NACA devote a modest effort to problems associated with unmanned and manned flight at altitudes from 50 miles to infinity and at speeds from mach number 10.0 to the velocity of escape from the earth's gravity." When this resolution came before the next regular meeting of the NACA Executive Committee, Dryden pointed out the sort of bind such proposals imposed on the Committee. If such a project were put on the NACA's list with low priority, nothing would be done about it, for there were too many higher priority projects ahead of it. But the Executive Committee felt the recommendation had merit, and—as the NACA had learned with jet propulsion—there were hazards in not taking the lead in introducing new technologies. In this case the NACA weasel-worded its way out of the bind by resolving to devote a modest effort to "the definition and formulation of the problems" of space flight, rather than to actual solution of the problems. But this piece of legerdemain did not hide the fact that the NACA was spread too thin to cover all the bases. It had to gamble on what to pursue and what to neglect, and its continuing claim that it was responsible for predicting the future course of aviation grew more hazardous with each guess.³³

One crisis of priorities in these years had a longer history and was more completely of the Committee's own making. Structural design was identified in 1952 as a major impediment to the technological advancement of high-speed flight. Ironically, the Aerodynamics Committee had initiated the poll of the aircraft manufacturing industry that produced this consensus. Aerodynamics had always been the queen of the aeronautical sciences and the NACA's premier activity, dominating its research program and making the wind tunnel a symbol of NACA investigations. The danger of this preoccupation had been pointed up on the eve of World War II, when it was discovered too late that propulsion was the reverse salient holding back faster flight. Now the NACA faced a similar crisis, but in a time of severely limited budgets. Though the Aerodynamics Committee had discovered and made known the problem, it was unwilling to sacrifice any of its own programs and projects in order to augment structures research, even as industry was



Not all NACA research was conducted in wind tunnels. This million-pound testing machine was used at the Langley laboratory for structures research. (LaRC)

insisting that the NACA program in structures had to be increased as much as fivefold.³⁴

The Structures Committee took up this campaign and, in the wake of a series of structural failures in high-performance military aircraft, prevailed upon the NACA to venture a supplemental appropriation request in 1952. Though the Committee members no doubt considered the request necessary and correct, they seem not to have been completely alive to its adverse implications. At the Bureau of the Budget, Willis Shapley defended the request, but another staff member noted that Congress would not only suspect an attempt to circumvent the cuts recently made in the 1953 NACA budget, but would also find it "difficult to understand why it took so long to identify the urgency of this problem." It looked as if the NACA had been caught unawares again, as it had with jets in World War II. Still, BoB sent the request to Congress. Congress denied it.³⁵

ENOUGH?

In the summer of 1954, the NACA cried enough. At the direction of the Main Committee, Hunsaker requested and was granted a meeting with President Eisenhower. The chairman and Dryden told the president that they needed a \$13-million increase in the NACA budget for 1956, to place the unitary tunnels into full operation as well as to

undertake critical new research in structures, in stability and control of high-speed aircraft and missiles, and in other "selected technical fields."³⁶

To their surprise, Eisenhower not only agreed, he went them one better. He suggested that they request a supplemental for 1955 to get started on these projects before fiscal 1956 began the following July. Seemingly rusty on military customs, Hunsaker and Dryden came away from this meeting not realizing that a "suggestion" from the commander-in-chief was a polite order. As they contemplated taking the idea before their next meeting with the Bureau of the Budget, the White House called to find out why it had not yet been submitted. Within days, NACA representatives and a White House aide were before the BoB director with a supplemental estimate.

The timing of the NACA approach to Eisenhower could not have been better. Hunsaker reported that "the President's interest in the program was based on his knowledge of recent intelligence as to progress in aeronautics being made by the Russians." A knowledgeable insider has testified to the "high quality of the national intelligence estimates in 1954," and these had reinforced for Eisenhower the concern expressed by his Science Advisory Committee when he met with it in March of that year. A month before seeing Hunsaker and Dryden, Eisenhower had appointed a technological capabilities panel under the direction of James R. Killian, Jr., president of MIT. Even before the TCP report was presented to the National Security Council in February 1955, Eisenhower was taking steps to implement the recommendations sure to be forthcoming: "get our military R and D program moving again with carefully established priorities better related to the existing threats to our security." One such step was to provide increased funding for the NACA.³⁷

With the Eisenhower administration's skepticism about R&D waning, there was no longer sufficient strength in Congress to hold down NACA budgets. The NACA got its supplemental in 1955, its increased budget in 1956, and annual increases thereafter for the remainder of its years.³⁸ The TCP report of 1955 set the pace and direction of American strategic policy for years to come: it led to the crash program to build an intercontinental ballistic missile, develop the U-2 spy plane, institute work on reconnaissance satellites, and generally augment military R&D across the board. The NACA was carried along on this tide.

In other ways as well, 1955 was a good year for the NACA. The Committee was still basking in the reflected glory of the Collier trophy awarded in 1954 to Richard Whitcomb of the Langley laboratory for discovery and verification of the area rule of aerodynamic flow, which established the relationship between the girth of a fuselage in transonic



This is the kind of expensive, highly technical research for which Chairman Hunsaker and Director Dryden requested funds from President Eisenhower: a wedge rake is being used to calibrate the Lewis laboratory's 2- by 2-foot supersonic tunnel at mach 3.5. (LeRC)

flight, and the appendages (e.g., wings) that, without application of the area rule, tended to upset the flow of air over the body. The principle had been known theoretically before Whitcomb “discovered” it, but he provided the engineering data that turned it into useful applications; specifically, he calculated the adjustments needed to get the air force’s F-102, first operational supersonic aircraft, through the sound barrier. Here was fundamental NACA research making an important and much publicized contribution to national defense.³⁹

Also in 1955, yet another Hoover Commission report on government organization appeared, and for the first time in more than thirty years of consistent opposition to the NACA form of organization, the former president brought himself to sign a report that praised the NACA and recommended its continuance intact. To hear this old critic of the NACA speak in glowing terms about the “splendid record” of the Committee and its “admirable” organization was enough to make one think that the NACA had converted its enemies at last and was secure as never before.⁴⁰

The budget was rising, the Committee was receiving awards for its achievement, and even old enemies were succumbing to the NACA’s charms. The question was, could the turnaround change the drift of events of the previous decade?



12

The End, 1956-1958

The fire that was to consume the NACA was laid throughout the 1950s, waiting for the match. It was fueled primarily by the Committee's peculiar organizational arrangement, one increasingly at odds with the Committee's responsibilities and with contemporary organizational theory. Warmed by misgivings about the Committee's conservatism, its ties to industry and the military services, and the apparent duplication of its work in other labs, and set in the budget-cutting and efficiency-seeking atmosphere of Washington in the Eisenhower years, the tinder grew more volatile. Sputnik provided the spark that set it off, and though it only smoldered for a while, soon the old agency was consumed in flames it was powerless to quench. From the ashes arose a new institution, the National Aeronautics and Space Administration, a bird of a different feather.

THE BALANCE OF POWER

At the annual meeting of the NACA in October 1956, Jerome Hunsaker announced that he was stepping down as chairman of the Committee. After a career of 43 years in aeronautics, he felt the new world was too much with him, that he was aging and set in his ways when the times called for young and imaginative leadership, that he was ill-equipped by temperament and training to cope with the new technologies of missiles, rockets, nuclear propulsion, even spaceflight. He agreed to remain on the Committee, but not in the chair which he had then held for 15 years.¹

In his place, and with his approval, the NACA chose James H. Doolittle. To the post Jimmy Doolittle brought unparalleled credentials acquired in one of the most remarkable careers in modern American history. Among his credits were an earned doctor of science degree from the Massachusetts Institute of Technology; a medley of aviation records, including the first one-day cross-country flight in 1922, the first blind landing by instruments, and the world's speed record for

airplanes; virtually every major aviation trophy and award that a pilot and engineer could win; a military career spanning two world wars and most ranks from aviation cadet to lieutenant general; a chestful of decorations topped by the Medal of Honor for leading the famous 1942 air raid on Tokyo; and latterly, a distinguished business career as a vice president and director of Shell Oil Company. In his spare time he was special assistant to the chief of staff of the air force, chairman of the President's Airport Commission, chairman of the Air Force Scientific Advisory Board, president of the Institute of Aeronautical Sciences, and president of the Air Force Association. Any one of his careers would have occupied and fulfilled most men, but Doolittle managed them all and continued in 1956 to bring to them a vitality and energy that belied his 60 years.²



John F. Victory swears in James H. Doolittle as the eighth and last chairman of the NACA, as outgoing chairman Jerome C. Hunsaker looks on with apparent delight. (ARC)

All Doolittle's credentials, however, could not change the fact that he stood the tradition of the NACA chairmanship on its head. Save only the first incumbent (General George P. Scriven, whose appointment reflected the military influence on the creation of the NACA), all the chairmen had been scientists, and all but one had been academics: Durand from Stanford, Walcott from the Smithsonian, Ames from Johns Hopkins, Bush from MIT and the Carnegie Institution, and Hunsaker from MIT. True, Hunsaker had careers in the military and industry that paralleled Doolittle's in breadth if not in depth, but as chairman of the NACA he was primarily an academic and an engineer. If Doolittle was anything, he was an academic last; first or second he was a businessman, second or first a military officer. He was the

personification of what Eisenhower was soon to label the military-industrial complex.

The NACA, by law and by tradition, had operated over the years to block control by any interest group. It had parried repeated suggestions that industry representatives sit on the Main Committee, until the circumstance of World War II forced this step. Now a businessman was chairman. Similarly, though military officers had by law the largest single bloc of representation on the NACA, the army and navy had always had equal numbers of representatives and the chairman had always been an impartial scientist or academic who could ensure that neither service came to dominate. Now a retired air force general was chairman.

Doolittle himself was a man of integrity whose long public service precluded suspicion of any conflict of interest. Still, he embodied the very forces that had been changing the NACA's fortunes from the golden years under Ames through the precarious and troubled times following World War II. Strangely, the leaders of the NACA seemed oblivious to the drift of events that his chairmanship represented. He was the logical and unanimous choice of a committee that had forgotten its past.

The same movement toward new blood and new ideas that brought Doolittle to the chairmanship could be seen in the NACA's program, as the Committee pursued the new technologies popping up all along the frontier of aeronautical progress. Early in 1957, for example, the Executive Committee approved a proposal to cooperate with the air force on a new research aircraft to succeed the X-15, even though the latter was more than two years away from its first flight. This was the beginning of NACA involvement in the program that led ultimately to the Dyna-Soar, a boost-glide vehicle capable of flying out of the atmosphere and into space.³

In less spectacular but equally important departures, the NACA turned greater attention in these years to the operating problems of aircraft, notably to noise reduction and crash research. It increased its program of propulsion research, opening up a new facility at Plum Brook, Ohio, to investigate rockets and to continue preliminary explorations of nuclear power for aircraft, an issue in which Dryden and Doolittle became deeply involved as consultants to the air force. In the expanding field of reentry aerodynamics brought forth by the flight of long-range missiles out of the earth's atmosphere, the Ames laboratory's H. Julian Allen contributed the blunt-body concept of vehicle design that won great approbation for the NACA in military circles, demonstrating that a theoretician could work successfully within the NACA if he didn't rub against the grain.⁴



Left, a 20° cone-cylinder is melted in a wind tunnel by the friction of air passing it at 6.9 times the speed of sound, much as a similarly shaped spacecraft would melt on reentering the earth's atmosphere. (LaRC) Right, H. Julian (Harvey) Allen stands beside the test section of the Ames 8- by 7-foot unitary plan wind tunnel, in which is mounted a test model of the blunt-body concept he pioneered to counteract this heating problem in reentry vehicles. (ARC)

Standing in the way of progress along this broad front of aeronautical research, with its new and exciting salients, were the same problems that had plagued the NACA since World War II: budget and personnel. Even with the increased funds it got from Eisenhower in 1956, the Committee still felt pressed for money in the ensuing years and regularly went back for more. Now, however, it encountered a recession in 1957 and still more belt-tightening throughout the federal government. Once again the NACA was in the double bind that had worried Lewis in earlier years and haunted Hunsaker in congressional testimony after World War II: should the Committee be a good soldier and accept the administration's austere line—running the risk of later congressional accusations that it had not done its duty in asking for what it needed to keep America aeronautically secure—or should it chomp at the bit in congressional hearings and run the risk of antagonizing Eisenhower and the Bureau of the Budget? The NACA chose the former course, but not without reluctance and misgiving.⁵

Notwithstanding the increased range and number of excepted positions the NACA won in the various pay-reform acts of the 1950s, the Committee sensed it was losing ground in the competition for personnel with a growing aircraft industry, swollen now with large-scale

orders for missiles and rockets. Beginning in 1955, inroads began even into the top ranks of NACA scientists and engineers, prompting Victory to predict in late 1956 that "leadership in scientific research in aeronautics will be lost" if the trend were not reversed.⁶

The NACA responded to these problems as it always had. It kept a low profile around Washington, cultivated its reputation for efficiency, and brought to the attention of the right people its continuing record of achievement. Richard Whitcomb's discovery of the area rule, for example, became the highlight of the 1955 annual report, in spite of the misgivings of some committee members that this emphasis smacked of self-serving demagoguery, and in spite of informed opinion in some aeronautical circles that the area rule was not all the NACA claimed for it.⁷

Mostly the NACA sought to keep its principal clients happy, sought even to expand its clientele. The army's request for membership on the Main Committee in 1957 split the NACA leadership along lines that reflected the new politics of the late 1950s. Hunsaker kept his eye on the aeronautics, telling Victory that "it is clear that Army representation could benefit the Army, but it is not so clear that it would benefit the NACA, unless the Army's own research were significant." Dryden wanted to remain "neutral on the subject," while admitting that "the possible advantages to NACA are those of additional logistic and moral support." But the issue was decided in an Executive Committee meeting at which chairman Doolittle agreed to inform the secretary of the army that "the NACA . . . is of the opinion that both the Army and the NACA would benefit from Army representation, the Army because it would be in closer contact with the activities of the NACA, and the NACA because it could anticipate the support of the Department of the Army as well as the Navy and the Air Force."⁸ In an understandable but dangerous way, the politics of institutional survival was once more piping the tune.

THE STATE OF THE NACA

The NACA in 1957 was not entirely what it seemed. It had become an enigmatic mixture of the intended and the unintended, of the obvious and the obscure, of substance and rhetoric, of unique research agency and traditional bureaucracy.

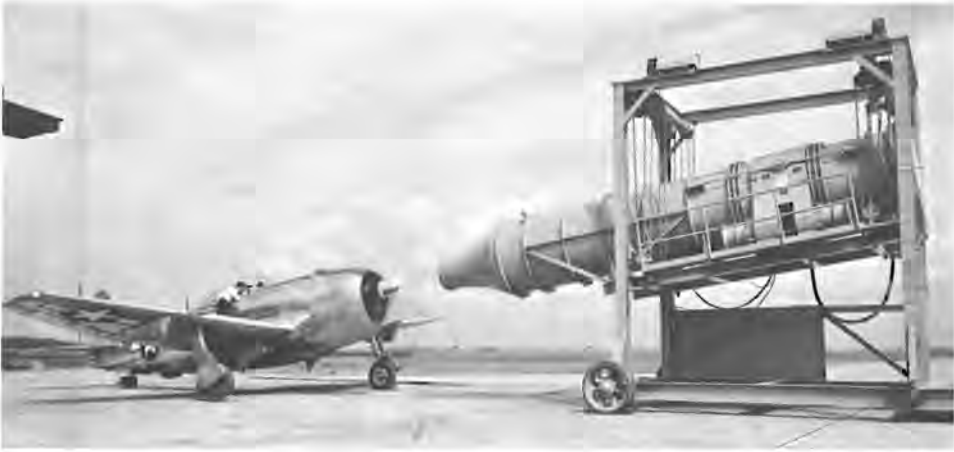
It was first of all a large organization in comparison to its modest beginnings. In 1915 it had consisted of twelve committeemen and a clerk in search of a place to hold meetings. In 1957, a staff of almost 8000 occupied three major laboratories and as many subsidiary facilities valued at \$300 million.⁹ Below the Main Committee, now grown to 17 members with two more planned, were four main technical commit-

tees and 24 technical subcommittees, having a total membership approaching 500. From the \$5000 with which the Committee conducted its first year of business, the budget had grown to \$75 million.

After abandoning in 1926 the advisory role implied by its name, the Committee had concentrated on conducting and coordinating aeronautical research. In 1957, as throughout its history, the NACA was torn between the fundamental research it preferred to do and the specific problem-solving it was called upon to do by the military and the industry. Since the agency's dramatic expansion during World War II, headquarters proved less able to control the details of research programs at the laboratories, freeing the staffs there to indulge their preference for fundamental research. At the same time, the NACA was becoming more of a service agency to its principal clients, drawn into problem-solving and bug-chasing. In the late 1950s, the Committee acknowledged that about half its work was in response to specific military requests; a smaller but significant proportion went to requests from the industry. Add to that the role of the industry and the military in determining which fundamental problems to undertake, and the percentage of the research program dictated by the NACA's clients is higher still. Between them, the military and the industry controlled 69 percent of the technical-committee memberships and 68 percent of the subcommittee memberships.¹⁰

The NACA was driven to being a service agency spending most of its time on problem-solving, not because the services and industry were blind to the need for fundamental research, but because it was not in their nature to look far into the future. Pressed by the need to get the next generation of fighter aircraft into operation or the next prototype into production, both the services and industry tended to focus on immediate problems, on the incremental advances in the state of the art, on refinement of the equipment at hand. Ideally, the NACA should have complemented these institutions by being the agency of deep thought and extended vision, operating above the fray and isolated from the distractions of day-to-day competition, responsible (as it claimed to be) for anticipating the research needs of tomorrow. But, tied to the necessity of ensuring its own survival, the NACA found it all too easy to link that survival to the good opinion of its clients. What those clients asked, the NACA did, even though their requests were too often for the specific, the immediate, the transient. Unwittingly and unfortunately, they dragged the NACA into an increasing concentration on the problems of the moment rather than the problems of the future.

That was the price paid. The advantage won was a genuinely good reputation and the sturdy support of its clients. The NACA's prestige was never as high as Victory tried to make it look by excerpting the bread-and-butter letters from industry and the services; all the NACA's



This portable cooling blower helps simulate flight conditions on the ground for untried engines at the Lewis laboratory, the kind of cleanup and testing into which the NACA was being increasingly drawn. (LeRC)

clients had grievances. But by the mid-1950s the NACA had recovered its reputation from its World War II slump and enjoyed real esteem in most aeronautical circles.

On Capitol Hill and within the executive branch, especially in the Bureau of the Budget, the NACA was widely respected as an efficient and dependable organization, meticulous in the way it spent its money and productive of truly cost-effective results. It came under constant suspicion, especially on the Hill, of duplicating work done at military research laboratories. At the Bureau of the Budget, the NACA's organizational structure was frequently faulted. Among the general public, save those associated with flying or flight, the NACA seems to have been little known or cared about.

The Committee's besetting problems were the same ones it had had since World War II: to meet the growing demands of industry and the services for specific research and still try to cover the entire frontier of aeronautical progress. As new technologies like missiles, rockets, and nuclear propulsion broadened that frontier, the budget restrictions of the 1950s made the necessary resources harder to come by. Ideally, the new facilities of the industry and the services should have alleviated the pressure on the NACA, but that ideal was not attained. As the services instituted their own advisory and coordinating committees—on which the NACA often served as guest, instead of the host it was accustomed to being—the NACA lost its power to control the course of events and to direct the agenda and the discussions. Similarly, the laboratories built by the services and the industries inevitably cut into

NACA territory and made the Committee appear less unique, more duplicative, less indispensable.

In spite of these political vulnerabilities, the NACA seems to have felt as secure of its institutional survival in 1957 as at any time in its history. When Sputnik was launched by the Soviet Union on 4 October of that year—the event that triggered the demise of the NACA—the Committee took little notice. At its annual meeting less than two weeks later, the subject never arose.¹¹



Two weeks before Sputnik, the NACA Executive Committee met at Wallops Island Station.

RECONSTITUTION

President Eisenhower was equally unmoved by *Sputnik 1* and just as deaf to the implications of the event. He felt that he had answered the Soviet technological threat when he examined the missile situation in 1954 and 1955 and instituted a crash program to develop an American intercontinental ballistic missile. He did not want, nor did he see any need, to upset America's economic stability by investing in an expensive space program. To indulge the fantasies of the space enthusiasts—"space cadets" was the contemporary sneer—would divert attention and resources from the more crucial missile program. Because much of the rationale behind his position was highly classified, he was at a disadvantage in public debate over the meaning of, and the appropriate response to, Sputnik. He and his staff adopted the unfortunate policy of discounting the Russian achievement as an attempt to draw the U.S. into "an outer space basketball game" of satellites, claiming that it did not worry the president "one iota."¹²

The political winds, however, were blowing in the opposite direction. Many public figures and opinion makers, including key members of Congress, saw Sputnik in an entirely different light. Most important, they viewed it as a threat to national security, for it demonstrated a

missile capability more sophisticated than previously estimated, a capability that for the first time since the War of 1812 posed a realistic threat to the protection provided by the Atlantic and Pacific oceans against foreign attack. Second, Sputnik manifested a general advance in Soviet education, science, and technology that was already worrying informed Americans. And third, the Soviet feat was widely viewed as a psychological victory in the cold war; it could lead unaligned or wavering nations to conclude that the Soviet Union really was the rising star with which the countries of the third world should ally their futures. These concerns motivated calls for a national crash program in space to catch and surpass the Russians. The space race was on.¹³

Hoping to stem this tide of public opinion, Eisenhower elevated his Science Advisory Committee to White House quarters and prestige, retitled it the President's Science Advisory Committee, and imported James R. Killian, Jr., from the presidency of MIT to chair it, anointing the 53-year-old engineer and administrator Special Assistant to the President for Science and Technology. To Killian and the rejuvenated PSAC, Eisenhower gave broad responsibilities for formulating advice on a wide range of questions involving national security, the first and most pressing being what to do about space.¹⁴

But these first steps, positive though they were, did not satisfy. *Sputnik 2* had gone aloft on 3 November, carrying a dog and more than 500 kilograms of scientific equipment. Even had the United States succeeded in launching its own satellite as scheduled the following month, it would have orbited less than two kilograms of payload. On 25 November Lyndon Johnson convened exhaustive hearings on the nation's missile and space program before his Preparedness Investigating Subcommittee of the Senate Armed Services Committee. The tenor of these hearings and the growing public concern over the issue soon made clear the political imperative for a major United States space program. The questions in 1957 were: Who would formulate it? Where would the program lodge?¹⁵

In this charged atmosphere, the NACA came alive to the significance of Sputnik and its portent for the Committee. Spaceflight was in many ways an extension of the atmospheric flight and missile research that had been the NACA's prime concern. If fundamental research was to be done on spaceflight, the NACA was the logical agency to do it. Soon enough the Committee realized that the opposite was true as well; much of its current research could easily be done by a new space agency, were such an institution to arise. Far from ensuring the Committee's continued growth into a new branch of technology, the prospect of spaceflight jeopardized the very existence of the NACA and shattered the calm assurance of the months preceding Sputnik. In self-defense the Committee would have to decide how to respond to the

challenge and where it would fit institutionally into the emerging controversy over developing a national space program.¹⁶

As it had been wont to do in any crisis throughout its 42 years, the NACA began by creating a committee, in this case a Special Committee on Space Technology. When Hunsaker refused the chairmanship, it was offered to H. Guyford Stever, then associate dean of engineering at MIT. Because of the press of other business, Stever could not take up this post immediately, but this mattered little to the NACA. The purpose of what came to be called the Stever committee was not to quickly formulate a policy for the NACA, but rather to bring together under the NACA umbrella all the scientists and engineers in the United States who might play a substantial role in the development and execution of a national space policy. The Stever committee was more political than technological, intended to coopt possible critics of the NACA and guarantee it the best available grip on the course of events. It was unlikely that the NACA would be left out of any truly significant development if its committee membership included all the individuals who would contribute to those developments.¹⁷

The Stever committee, however, had neither the opportunity nor the mandate to tell the NACA what to do next. On 18 December a meeting of key staff personnel from headquarters and all the laboratories debated the Committee's options; that night, chairman Doolittle hosted a still larger gathering of staff members that came to be called in NACA folklore the "Young Turks dinner." Here the younger engineers got a chance to say how they thought the NACA should respond to space. Opinion was divided, roughly along generational lines, between the young men who wanted the NACA to campaign for a broad new role in space and the old hands who preferred a more cautious expansion of the NACA's current activities. John Stack, the brilliant Langley engineer with two Collier trophies and an enormous ego in his corner, called Dryden an old fogey, or words to that effect. Though Stack was apparently voicing (however intemperately) the sentiments of the majority, he won little more than a debate-ending backlash from Dryden, who proceeded to "explain the approach that would be taken."¹⁸

The approach was a series of studies and papers in which the NACA made its formal claim to be selected as the agency that would conduct U.S. space research. First came "A National Research Program for Space Technology," a staff study completed on 14 January 1958, in which "the Soviet . . . bid for world supremacy" was characterized as "a most serious challenge to the United States and the Western world," calling for "an energetic program of research and development for the conquest of space." The study recommended "the pattern . . . already developed by the NACA and the military services"

and exemplified in the X-15 program, wherein "the scientific research [would] be the responsibility of a national civilian agency working in close cooperation with the applied research and development groups required for weapon-systems development by the military." This study was swallowed whole by the NACA Executive Committee two days later, reappearing in a "Resolution on the Subject of Space Flight," which became the basis of further staff action.¹⁹

On 10 February 1958 the staff published "A Program for Expansion of NACA Research in Space Flight Technology with Estimates of the Staff and Facilities Required," a remarkably prophetic document covering virtually every aspect of spaceflight from exotic propulsion technology to the mechanics of rendezvous in orbit, and concluding that the NACA should more than double its staff and operating budget over a two- to three-year period and should undertake a \$655 million construction program, including vast expansion of the existing laboratories and creation of a new laboratory. On the same day, the Committee published "NACA Research into Space," a catalogue of all NACA work over the years that could be construed as contributing to space flight. The jewel in this diadem, as in the other NACA papers on space, was the 1952 consideration of the Woods proposal to investigate the possibilities of spaceflight. Now the NACA was claiming that it "in 1952 initiated studies 'of the problems associated with unmanned and manned flight'" into space when, in fact, it had (on Dryden's recommendation) actually weasel-worded the resolution at the time, resolving that "a modest effort be devoted by the NACA to the definition and formulation of the problems associated with unmanned and manned flight" into space.²⁰ Once more the NACA was tarnishing a commendable record by claiming overmuch for itself.

By this time (February 1958) other hats were in the ring and Eisenhower had to choose one, or Lyndon Johnson and the Democratic Congress would do it for him. Chief contender, and in many ways the most logical choice, was the Department of Defense, and particularly the air force. For years, when it was unpopular and politically dangerous to do so, a group in the air force's Ballistic Missile Division (formerly the Western Development Division) of the Air Research and Development Command had been planning and advocating military space activities. A comparable group in the army, centered on Wernher von Braun's Development Operations Division of the army's Ballistic Missile Agency at Redstone Arsenal in Alabama, had similar plans and ambitions. Eisenhower opposed the choice of either, because he was reluctant to fuel the military-industrial complex that was becoming for him an increasing source of concern, and because the "missile mess" and the interservice rivalry at the Pentagon over roles and missions—not only in space but on earth as well—did not suggest to him that the

services could take on this new mission without further stimulating their counterproductive and exasperating struggle for position, prestige, and budget.²¹

In Congress there was some sentiment for entrusting America's space program to the Atomic Energy Commission, which appeared to be enormously successful in managing large-scale technology of both military and civilian dimensions. Sen. Clinton Anderson, chairman of the Joint Committee on Atomic Energy, led this crusade but never made much progress at the White House. Others suggested creation of an entirely new agency, perhaps modeled on the AEC, perhaps cut from whole cloth. The American Rocket Society and the Rocket and Satellite Research Panel, for example, joined in recommending a National Space Establishment independent of the military and free to pursue the scientific, commercial, and cultural aspects of space travel and exploration.²²

All these proposals had supporters and opponents, as did the NACA's bid. Many in the aviation community publicly endorsed the NACA as "the Logical Space Agency" and a "Spearhead of Progress." But some in the scientific community considered the NACA too small, too inexperienced, and above all too conservative to rise fully to the challenge of space. The Jet Propulsion Laboratory of the California Institute of Technology, for example, made just such an argument to Killian, but undermined the force of its criticism by suggesting that JPL should be "the national space laboratory."²³

The competition ended on 4 February 1958 when a PSAC panel that had been investigating the problem since December formally recommended that a new civilian agency be created around the nucleus of the NACA. Eisenhower quickly embraced this proposal and directed that legislation be drafted embodying the concepts in the PSAC presentation. Ideas were still vague at that point, and generalization was the order of the day. It was possible for all the participants to see in the proposed plan the acceptance of their own views; it was especially easy for the NACA to do so. Victory wrote to a former NACA member on 20 February: "Don't be surprised if you see some Congressman introducing legislation to change our name to National Advisory Committee for Astronautics, or Aeronautics and Astronautics."²⁴

This, however, was not to be. The legislation incorporating the administration plan would be drafted not by Congress but by the executive branch, specifically by a team composed of members from the PSAC, the NACA, the Rockefeller Commission on Government Organization, and the Bureau of the Budget. The scheme was to survey comprehensively the organic legislation of all comparable federal agencies, including the case law resulting from the legislation, in order to formulate a single organic act incorporating the best recent experience

on how to empower a new agency. Simplicity and power were the watchwords: the legislation should not encumber the new agency with needless complications and restrictions.

With that philosophy the NACA was in warm accord, but inevitably there arose the specific issue that would divide the Committee's representatives from the other drafters: would the new agency be a committee, or would it be organized hierarchically with a single head answerable to the president? To the former scheme Dryden, Doolittle, and the other NACA representative were firmly committed. To the latter, the BoB staff was equally committed. In fact, this had been the pet grievance of BoB for years, especially in the Government Organization Branch. In 1951, when the NACA was trying to have Dryden included in the Executive Pay Act, the only comment made by William Finan of Government Organization on the proposals was: "This looks like a good reorganization plan prospect to me." Now Finan was a key member of the team drafting the new legislation. Even Willis Shapley, constant defender of the NACA against BoB suggestions that the Committee be transferred to another agency like the Department of Commerce or Defense, was not averse to changing the organizational structure of the NACA if the opportunity arose. On the same executive pay issue in 1951, he wrote to his boss recommending that "we continue to raise with NACA the organizational question at every appropriate opportunity."²⁵

No opportunity in the previous decade had been so appropriate as the drafting of new legislation and the formation of a new agency in 1958. BoB spoke with one voice on this issue and most others in the executive branch concurred. Doolittle and Dryden went to the wall, for they feared the elimination of the one attribute of the NACA they considered most responsible for the Committee's success. So strongly did they feel on this issue—no doubt they were speaking as well for John Victory and all the rest of the Committee staff—that they overstated their case and unwittingly revealed the very myopia that had brought the NACA to this pass. Doolittle wrote to Killian on 24 March protesting that "we should not tear down something that is working perfectly in order to try out a derogation of the Board that both Hugh and I are convinced is unwise."²⁶ The NACA had real friends and admirers throughout Washington and the country, but few outside its own cloister would have claimed that the Committee system worked "perfectly." By embracing that conceit, the members of the NACA had deafened themselves over the years to the real misgivings about its organizational arrangement that friends like Shapley had been trying to express to them. Had they been more alive to the perceptions of others, they might have been better prepared in 1958 to counter the proposals of those who were determined to bring the NACA into line

with conventional wisdom about how to organize a government agency. As it was, the NACA protestations brought more heat than light to the debate and did nothing to dissuade the reformers. The space act drafted under Killian's general direction and approved by Eisenhower for submission to Congress provided for a National Aeronautics and Space Agency headed by an administrator appointed by the president and confirmed by the Senate. As a gesture to the tradition of collective leadership, the act provided for an advisory board—one that could advise, but need not consent. The NACA experiment in government organization was being abandoned.²⁷

FROM NACA TO NASA

The space act settled once and for all the organizational structure of the new space agency. It did not determine what the new agency would do. Clearly it would continue the aeronautical-research function of the NACA, but its role in space was specified nowhere in the act. Therein lay a new controversy that pitted the NACA and its friends in the Pentagon against the Congress and the president's staff. The outcome was of no one's choosing, least of all the NACA's, but it extinguished the old NACA and its traditions more thoroughly even than had the discarding of the committee system.

Nothing in the administration bill convinced the NACA that it could not operate as the new space agency much as it had operated in recent years: that is, as a research organization serving the industry and the military. Nor did Eisenhower give clear directions about what the new agency would do, how it would proceed, or what programs it would control, for the simple reason that neither he nor his staff had the answers to those questions. Rather, he directed the NACA and the Department of Defense to work out the issues between them.²⁸

While the NACA began the prescribed coordination with the Advanced Research Projects Agency (ARPA), a newly created branch of DoD initially assigned overall responsibility for space activities, it also took unilateral actions looking toward business pretty much as usual. It projected the addition of an 800-man Space Flight Research Center to its existing laboratories, but the latter "would not be greatly expanded." With the air force it planned and executed a joint agreement to develop a manned recoverable space vehicle on the pattern of the X-15 program: that is, a cooperative venture, with the air force in charge (and picking up the tab) while the NACA ran the technical and research aspects of the program. The X-15 program had become the NACA's model for a successful joint program and its first choice for conducting major projects in the future, including space projects.²⁹

To the extent that this agreement between the NACA and the air force reflected a willingness and an ability to coordinate the civilian and military requirements of space, it was surely welcome in Congress. But the agreement itself lacked the sweep and the enthusiasm that Lyndon Johnson for one—now chairman of the Senate Special Committee on Space and Astronautics—brought to his consideration of the administration space bill. He said that “seldom, if ever, [had] a Congress and an administration faced a more challenging task,” and that their actions could decide the future of the United States for the next century. He wanted nothing less than “to convert outer space into a blessing for humanity.” Alongside such cosmic visions, the NACA’s modest proposals looked half-hearted, even negative.³⁰

Johnson and his colleagues were also alive to the military potential of space, and they dreaded Armageddon as much as they sought the “millenium of peace.” Naturally, they wanted cooperation between the new space agency and the Department of Defense, to ensure that the U.S. would not be found wanting should space become a new arena for war; but they also wanted to keep the new agency from being dominated by the vast and voracious Department of Defense. So Johnson and his colleagues rewrote the administration bill, adding two provisions particularly displeasing to Eisenhower. First, the congressmen called for a civilian-military liaison committee to ensure regular and formal coordination between the civilian and the military space programs, and they prescribed a free exchange of information between the NASA and the DoD. Second, they added to the act language establishing a National Aeronautics and Space Council to be chaired by the president and to consist of heads of all agencies concerned with space: i.e., NASA, DoD, AEC, State Department, and such other agencies as the president deemed necessary. The purpose of the council was to ensure that the president would take a personal interest in the space program and that space matters would be examined in the highest councils of government, where the voice of the new space agency would be equal to those of the established giants. And the council replaced the advisory board that had been included in the administration bill as a sop to NACA sensibilities; Johnson considered the board too weak for the task at hand, a sad measure of the NACA’s reputation on the Hill.³¹

These organizational constraints the Congress could legislate, but it was powerless to infuse the new agency with the enthusiasm that dominated the special committees on space which both houses created to deal with the space act. The new administrator was to be chosen by the president with the consent of the Senate, and though Congress could not really say what it did want—a space cadet—it could say what it didn’t want—Hugh Dryden. He seemed the logical choice to head

the new agency, but his testimony before Congress in the spring and summer of 1958 ended any hopes he might have had for that post. His statements contained many of the right words, invoking visions of space stations and manned travel to the planets, but they lacked the enthusiasm and zeal so prevalent in Congress.³²

His most famous and most damaging gaffe illustrates the difficulty. Wernher von Braun, the dynamic and charismatic head of the army ballistic missile program at Redstone Arsenal, had suggested in earlier testimony before Congress that the United States should immediately begin a crash program with equipment already available to launch a man straight up into space and return him by parachute, just for the sake of doing it, for the sake of beating the Russians. When asked about this proposal, Dryden characterized it as a mere "stunt" like shooting a woman out of a cannon, devoid of scientific merit or technological substance. Of course he was right; but what he failed to grasp then—and what the Apollo program would demonstrate in only a few years—was that a stunt was just what the country wanted, a daring and dramatic demonstration of American technological superiority. The engaging and hyperbolic von Braun came away from the exchange looking bold and imaginative. The soft-spoken and correct Dryden came away looking timid and lackluster. So too did the NACA. Not only would a new agency be required, but a new leader as well.³³

Meanwhile, the executive branch of government, led by presidential science adviser Killian, was handling the NACA almost as roughly. It began by abrogating the joint NACA-USAF agreement to develop a manned recoverable space vehicle. Killian wanted ARPA to be the military space agency for the time being, and he did not want the NACA making separate agreements with the air force. In the long run ARPA became just as aggressive and demanding about the military role in space as Killian feared the air force would have been, but at least he could keep the number of players to a minimum. He wanted the NACA and ARPA to work out a division of labor as directed by Eisenhower; then he could adjudicate what they found irreconcilable.³⁴

At the outset, only two issues were clear. Reconnaissance satellites and other uses of space for military intelligence-gathering were surely an exclusively military function. Space science was a civilian function. For all other space activities envisioned at the time—meteorology, communications, lunar and planetary exploration, and manned spaceflight—both civilian and military programs could be envisioned.³⁵

The existence of a joint agreement on the manned recoverable satellite suggested that the NACA and its friends in the Pentagon, especially in the air force, would have been pleased to arrange joint projects in these gray areas, along the lines of the X-15 program. But Eisenhower would have none of that. He did not want to hand over to

any group in the Pentagon a large and potentially enormous new area of activity, especially as he seriously doubted the services' ability to handle their current missions. ARPA had been created in large part to eliminate the interservice rivalry over new technologies and the missions that went with them, and on the same day that Eisenhower sent the space act to Congress he forwarded a draft defense-reorganization act designed to clear up the "missile mess" and rationalize the development and employment of new technologies in the Pentagon.³⁶

Killian and the staff of the Bureau of the Budget had other reasons for disliking joint programs on the model of the X-15. Although they encouraged cooperation and coordination between NACA and the services on programs of common interest, they wanted each program to have a clearly identified lead agency with managerial responsibility and sole control of funding. The ultimatum to the NACA and the ARPA was to divide the programs between them along the lines of the evolving space act: programs "peculiar to or primarily associated with weapons systems or military operations" would go to ARPA, all others to the new civilian agency.³⁷

On this ground the NACA and ARPA debated and negotiated through the spring and summer. Finally, Killian had to step in. Every controversy he decided in favor of the civilian agency. NASA would control the development of launch vehicles, meteorology, and most important, manned spaceflight. Only in communications did the military make a case and win a minor concession: the civilian agency would run passive satellite communications (i.e., bouncing signals off a reflecting satellite) and the military would run active communications satellites, those capable of receiving and transmitting messages. The reconnaissance satellite went to the air force, the communications satellite to the army; with that, the ARPA was essentially out of the space program. But, in the few short months since its creation, ARPA had become wedded to space, and it fought to retain a role in space activities. This proved to be a harbinger of future military attempts to alter the division of roles between the new space agency and the Department of Defense.³⁸

For the time being, however, the debate was over. The National Aeronautics and Space Act was passed by Congress on 29 July 1958 and signed by President Eisenhower the same day. Within that month the basic division of labor between NASA and the military was determined. On 9 August Eisenhower nominated T. Keith Glennan, president of Case Western University, to head the new agency. At Glennan's request, Dryden accepted the post of deputy administrator. The two men were confirmed by the Senate on 15 August and sworn in at the White House four days later. The space act gave them less than three months to effect the transition from the NACA to NASA.³⁹

Many issues about the future of the new agency remained unresolved, but one thing was already clear: it would differ greatly from the NACA. It would operate under a new head unfamiliar with NACA traditions, and the staff would incorporate new personnel from outside the field of aeronautics. The new organizational structure would strengthen the head of the agency and reduce the advisory board to a powerless appendage outside the mainstream of agency activities. The addition of new groups—specifically the Vanguard staff of the Naval Research Laboratory and the Jet Propulsion Laboratory of the California Institute of Technology—would bring a new style to the laboratory work of the NACA, as would the new research facility to be built just outside Washington. NASA would be an operating organization conducting entire programs and missions, in contrast to the more limited research role performed by the NACA. The new agency would soon be contracting out up to 90 percent of its budget, in contrast to the minor contracting done by the NACA. With its far-reaching mission and the public attention being focused on space, the new agency would operate far more in the limelight, would move more often in the highest councils of government, and would command a far larger budget than its predecessor had. One wag represented the transition as:

NACA—NASA

But while changes from the old aeronautical-research agency to the new civilian space agency would obviously be drastic, there was no telling how much of the NACA influence would stay, how much would be swept away.

The NACA Executive Committee held its last meeting on 21 August 1958. On 30 September Chairman Doolittle sent the 44th and last annual report of the Committee to President Eisenhower. At close of business that day, the National Advisory Committee for Aeronautics ceased to exist.

CONCLUSION

If the NACA was so good, why was it laid to rest? First—was it so good? The evidence examined in this study does not support a conclusion one way or another. The NACA was the premier aeronautical-research organization in the country that came to lead the world in aeronautical development. The position the NACA held, however, does not necessarily establish its contribution, any more than position establishes the credit of the Guggenheim laboratories, or the military air branches, or the design and development teams of the aircraft manufacturers. More needs to be known about the nature of aeronautical

progress before the contribution of the NACA can be isolated and evaluated with confidence.⁴⁰

Still, some tentative conclusions can be drawn from the circumstantial evidence uncovered in this study. The men and women of the NACA were not as creative, innovative, and effective as they said or believed. Like other government employees competing for scarce funding to perform a job they believed in, they found it necessary to blow their own horns just to stay in existence. They read their own clippings and may have become victims of their own propaganda. Even so, they were better than is generally recognized. Letters of praise, congratulations, and appreciation fill their records and spill over into John Victory's private card file of kudos. Many of these, of course, were pro forma, even self-serving, submitted by customers and clients with a vested interest in the continued existence of the NACA. But many of the endorsements have the ring of sincerity too, and many are from individuals and institutions with no back to scratch. Furthermore, the thousands of copies of NACA reports sent out by the Committee every year were sought after, used, and cited by aeronautical engineers and designers around the world. The NACA's reputation in the world of aeronautics was usually secure, at times transcendent.

That it boasted overmuch suggests two conclusions about public institutions. First, organizations without a firm and continuing political base believe, rightly or wrongly, that they have to engage in selling themselves, often to a degree that is unbecoming, self-deceptive, and finally counterproductive. Second, people who stay with an agency all or most of their careers develop loyalty and experience, but they also get the institution's reputation confused with their own self-esteem. The result can be sentimentality and corporate narcissism.

The NACA enjoyed an enviable reputation for efficiency and economy, largely because of the fastidious and conscientious John Victory. "We were the most law-abiding organization, mind your own business type of organization, in the Federal Government,"⁴¹ he boasted with some reason, and though he offended many with his conceits and his compulsions, he pleased those in the Bureau of the Budget and Congress who worried over what return the taxpayer got on his dollar.

On balance, the NACA was a good agency—if not as good as it thought, at least as good as other agencies that outlived it. Why, then, was it eliminated? There are at least seven answers to that question, in roughly the following order of importance.

First, it was a committee. This peculiar organizational structure always rankled people who cared about organizational arrangements—the successive Hoover Commissions, the Brookings Institute, the Bureau of the Budget. But what to do about it? The two most popular suggestions were to merge it with the Department of Commerce or the

military establishment, but this always seemed to entail favoring either commercial or military aviation to the detriment of the other. So the NACA remained an independent committee not because there was much liking for that structure, but because its critics failed to come up with a compelling alternative. *Sputnik* changed all that, providing an ideal opportunity to remodel the agency in a more conventional and hierarchical pattern. This was the solution that the Committee's critics had missed over the years, because they disliked its independence almost as much as its committee form. To leave the agency independent while eliminating the committee structure was to eliminate the main irritant without taking away the autonomy that the NACA insisted it needed.

Sputnik pointed up another problem closely related to organizational structure: size. Committee management of the NACA might have been allowable in the 1920s and 1930s when budgets were never more than a few millions and the staff never topped 500, all housed in a single laboratory and a small headquarters. Since World War II, however, the NACA had been a large and expensive organization spread across the country, employing thousands and spending as much as \$100 million in a single year, far more than in its first 25 years combined. Gone was the simplicity and ease of operation that characterized the early years when a close-knit organization could operate out of George Lewis's hip pocket. In the 1950s the NACA was a large, complex, expensive enterprise, requiring the most modern of management techniques. A committee did not fit that requirement.

Third, during World War II the aviation industry and the aviation branches of the military services had grown so large and powerful that they began to encroach on the NACA's domain and compromise its claims to be unique and indispensable. This intrusion was largely unavoidable, because no clear dividing line exists between fundamental research, development, and testing, the areas claimed respectively by the NACA, industry, and the services. The NACA had set up an artificial division in order to stake out for itself a research field that it could monopolize without antagonizing any of its potential clients. The intrusion of the services and the industry into the NACA's domain after World War II was also the result of jet propulsion and the discovery after the war of other German advances that cast doubt on the NACA's ability to anticipate the future course of aeronautical development and keep the United States in the forefront.

A fourth cause of the NACA's demise was its conservatism. Committees are conservative by nature, especially when one seeks of them unanimity as the NACA chairmen often did. Decisions become still more conservative when made from a precarious political base where a bold step in the wrong direction can be fatal. Over the years the NACA

became increasingly a service agency, responding not so much to its own considered judgment about the future course of aeronautics as to the day-to-day demands of industry and the services, not to vision but to routine. For every X-15 program there were a dozen others that were pedestrian and unexceptional.

Another shortcoming of decisions by committee is that they tend to endorse those projects that have sponsors on the committee and overlook those that do not. This tendency accounts for a number of skeletons in the NACA closet, some of which contributed to the Committee's demise. Failure to discover jet propulsion was the most famous and damaging of these, because it came to the attention of Congress and because it upset Hap Arnold so. But other shortcomings tempered the praise the industry and the services gave to the NACA. The Committee stayed too long with airships and seaplanes, for example; it came too late to structures and helicopters.

By 1956 the NACA had also lost the Progressive purity that distinguished its beginning. It was an article of faith in the early years that representatives of industry should not sit on NACA committees or subcommittees lest they exert undue and self-serving influence on research policy. But over the years, as industry grew more powerful, its representatives slowly won memberships and even chairmanships, first on the subcommittees, then on the main technical committees, finally on the Main Committee. However scrupulous these men may have been, their presence nurtured the impression in some circles that the NACA was a captive of the military-industrial complex.

Finally, aviation was no longer the infant technology it had been when the NACA was formed. Surely research was still needed, but with the industry and the military services engaging in so much of their own, the need for a separate agency was less obvious than at the outset. In many ways the NACA had achieved what its founders set out to do: contribute to the establishment of a thriving technology in the United States, a technology that could now survive without a government agency devoted exclusively to its nurture. Thus, in a most significant way, the NACA was laid to rest because it had accomplished what it set out to do.

Bibliographic Essay

NACA RECORDS

In 1972 and 1973 an attempt was made to bring all the records of the National Advisory Committee for Aeronautics under one roof. It failed. Some of the files were still actively in use by NASA to continue research begun by the NACA. Some had already been retired to federal archives and records centers around the country, inextricably mingled into NASA records with which they had become interfiled. Some remained at the former NACA laboratories, now NASA research centers, as part of the permanent station inventory.

The most complete guide to these scattered records is the 1973 "Special Study on the Records of the National Advisory Committee for Aeronautics," NN-572-13, prepared by William H. Cunliffe and Herman G. Goldbeck, then of the records appraisal staff at the National Archives. This 90-page typescript describes in considerable detail 3967 cubic feet of records at the Washington National Records Center in Suitland, Maryland. It also accounts, in much less detail, for another 1265 cubic feet of records either retained by former NACA research laboratories and stations or stored in their local federal archives and records centers. At the time the Special Study was prepared, it was expected that all these records would be permanently accessioned by the National Archives. To date, only the files at the Washington National Records Center and a portion of those at the San Francisco Federal Archives and Records Center have been. Except for a few classified files, these are now open to all researchers; permission from NASA is required to see the classified ones, or those at NASA centers.

All NACA records in the custody of the National Archives and Records Service, whether or not title to them has actually passed from NASA to NARS, are accessioned into Record Group 255, Records of the National Aeronautics and Space Administration. When a group of records is retired, the archives and records center to which it goes assigns it an alphanumeric accession number. All accession numbers for NACA records are in the same form: i.e., 57 A 415, indicating the 415th group of records accessioned by that records center in fiscal year 1957.

Each accession has a "Transmittal of Government Records" form prepared by the NACA or NASA, identifying the office retiring the records and describing the contents of the one-cubic-foot records center boxes used to transfer and store the documents. The accuracy and completeness of these descriptions vary considerably from office to office, and within the same office over time. Too often they are brief, inaccurate, or unclear. Still, they are in many cases the only guide available.

Washington National Records Center

The seventy accessions at the Washington National Records Center constitute the largest and most important single collection of NACA records. Most of these originated at NACA headquarters. Some are from the Langley laboratory in Hampton, Virginia, and its former subsidiary Wallops Island Research Station (now part of Goddard Space Flight Center). Title to all of these records is now permanently vested in the National Archives.

The Cunliffe and Goldbeck special study of these records divides them into five categories: Correspondence Files, Publication Files, Reference Collection, Organizational Records, and Topical Files.

The 235 cubic feet of correspondence files are really the general files of the NACA headquarters. In addition to correspondence, they comprise subject files, biographies, clippings, budget material, research program information, and report files. All the material is filed according to one of three systems. Guides to these systems may be found in 63 A 29 (31), i.e., Record Group 255, accession 63 A 29, box 31.

The publications files contain 680 cubic feet of documentation on the NACA's publications (see appendix F). Besides copies of NACA reports, the files contain documents related to the distribution and editing of the reports, as well as Langley laboratory files of research authorizations under which the reports at the laboratory were prepared.

The reference collection is essentially the NACA headquarters library. In its 1426 cubic feet are reports, studies, papers, journal articles, and translations from military, academic, and industrial sources around the world. Some are classified according to an alphanumeric code; others have simply a sequential "N" number, indicating the order of their receipt by the NACA library. NASA's Langley Research Center has a complete shelf list and numeric index to this collection. The 180 drawers of 3x5 cards mentioned in the special study as being at NASA Headquarters have since been transferred to the NASA Scientific and Technical Information Facility in Linthicum Heights, Md.

The 160 cubic feet of organizational records contain material on the activities of various NACA committees and subcommittees, reports and memoranda from field laboratories and stations, biographies of key personnel, and lists of visitors to NACA headquarters and laboratories.

The topical files contain 169 cubic feet of information on patents and inventions, legal and fiscal matters, security, and Project Vanguard. Finally there are two boxes of photographs, three boxes of slides, and 23 cubic feet of miscellaneous records ranging from personnel policies through laboratory-site selection.

Using the special study and the Transmittal of Government Records forms as guides to these nearly 4000 cubic feet of records, I selected 718 boxes for examination. I looked for records that promised to tell most about how NACA operated as opposed to what it did: i.e., the procedure instead of the product. Especially did I choose boxes that seemed to have material on policy, organization, administration, research procedures, committee composition, personnel recruiting and management, and relations with other agencies and institutions. Of the 718 selected, I examined 480. After sampling some accessions, I found the materials were not what I had expected and warranted no further attention. In this way I was able to delete 178 boxes from my list. Also, 64 boxes were not available for research because they had been destroyed or were missing, either misplaced within the records center or charged out to NASA and not returned. All these now appear to be irrecoverable. In the course of my research I added to my list 4 boxes that had not appeared to be interesting on the inventories but which continued important sets of files found in other boxes.

All 480 boxes were examined in Stack 3 of the Washington National Records Center, where most of them were stored. This relieved the Center staff of the necessity of carting them to the research room. Some of the boxes required only a few moments' examination to show they had no material worth closer scrutiny. Most required much more time. The very best ones took two or more days to examine. Of those, I brought 11 back to my office on special loan from the National Archives to examine in detail and make extensive photostatic copies.

A few peculiarities of these files warrant mention. John Victory, whose personality infects them, was awed and inspired by the great men who served on the NACA. In filing documents, he often put into biography files materials that might better, or more

reasonably, have gone elsewhere. If an important man was author or addressee of or interested party to a document, his file would probably contain the document, mixed indiscriminately with letters of appointment, travel vouchers, and regrets that he could not attend this or that meeting.

Victory began a history of the NACA in the late 1940s. In the early 1950s he was assisted by Ruth Walrad, for a while the NACA historian. After that his daughter Betty helped him. Scattered throughout the files at WNRC are out-slips indicating that documents and even whole folders have been removed, most often by Betty Victory. I have not tracked down all these removals, but I believe that most of them ended in a collection of NACA headquarters papers separately donated to the National Archives and now retained by the Modern Military Branch in the Main Building in Washington, D.C. (See National Archives.)

Except for these removals by the Victories, the files appear remarkably complete. They contain many copies of most documents, especially the important ones. Even before the modern riot of photocopying, Victory ensured that numerous carbons were made and that extra copies were always available, through retyping if necessary. Cross-referencing is common in the files. Often the face of a carbon copy will contain directions to the complete files on the subject. There are considerable marginalia and, in the later years, there are buck slips, though never as many as the historian would like.

Some items I expected to find either are missing from the files or escaped my attention or my sampling. Information on the NACA staff is especially hard to come by. The Committee was traditionally opposed to organization charts and, lacking these, it is difficult to recreate the hierarchy over the years. I found no telephone directories, and the biography files on the staff are scattered and irregular. Information on facilities at Langley laboratory is quite complete, much less so for the other laboratories and stations. Controversy within the organization was seldom committed to paper. There are clues that the NACA had its share, but it seems that such unpleasantness was resolved orally—behind closed committee doors, in the privacy of John Victory's office, or over drinks at the Cosmos Club. I have found only one instance in which an NACA committee submitted a minority report. On paper, at least, all else was harmony and unanimity.

Following is a summary of the most useful material found in these records. It is by no means a thorough survey of the collection, but rather a description of what was most helpful to me in preparing this study.

Probably the single most useful accession is 57 A 415. Its 80 cubic feet of general-correspondence files, covering the years 1915 to 1942, document virtually every facet of NACA activity before World War II. These files follow meticulously the alphanumeric "Index to Files of Correspondence Division," dated 26 September 1942. This makes them doubly useful, for judicious comparison of the index and the retirement inventory enables the searcher to go directly to the box and folder containing information on any subject in the index. These files, by no means a complete record, are by far the most comprehensive single accession. A sampling of the kind of information I extracted from this accession gives an idea of its usefulness.

Boxes 3 through 5 reveal how aeronautical problems were selected for research in the early years, and how research authorizations were originated, approved, and monitored. Box 13 has folders on "Commercial Testing, General, 1929-1940," through which it is possible to trace the evolution of NACA policy on testing and refining prototypes for the aircraft industry. Box 14 has candid and confidential information on the campaign by Frank Tichenor in the early 1930s to abolish the NACA. It also contains copies of trip reports by NACA staff members who had visited industry plants. Boxes 16 and 17 contain folders on "Estimates of Appropriations, 1927-1943," one of the most complex and elusive subjects in the NACA's administrative history. Box 22

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has documentation through 1933 on "Policy and Procedures," revealing how George Lewis sought by personal involvement to control the Langley laboratory's research program. Boxes 64 and 65 contain unique material on the background of the Air Commerce Act of 1926, including the important roles played by John Victory and the NACA. Box 66 contains correspondence with John J. Ide, the Committee's European representative. The letters to Ide from Victory and Lewis are especially useful, for the latter two often tried to summarize for Ide what they considered the most important news in U.S. aviation and aeronautics. Boxes 75 and 76 contain copies of Victory's semiannual reports to the NACA; these are the most consistent and comprehensive periodic summaries of the Committee's administration and organization, better even than the NACA's annual reports to Congress.

In 1942 the filing system used in accession 57 A 415 was replaced by a far more elaborate Dewey decimal system that attempted to code all the information with which the NACA dealt. It had eight classes, of which three (000, 100, 300) were "abstract"; four (400, 500, 600, 700) were "concrete"; and one (200) was mixed, dealing mostly with personnel. Each of the classes would include hyphenated abstractions. Thus, category 600 was "Flight"; 662 was "Flight Instruments" (still concrete); but "Flight Characteristics" (an abstract) was -532. Category 300 was "Administration"; "Coordination with Universities" was 370.112; but "Classification of Firms by Commodities" was -073. The system was so complex it was unworkable. Repeated attempts to modify it failed. In February 1952 it was scrapped altogether.

Records filed under this system are in the following accessions:

<u>Accessions</u>	<u>Boxes</u>	<u>Codes</u>
60 A 635	29-39	113 through 119
62 A 35	1-77	011 through 376.8
62 A 174	1-23	400 through 577
62 A 441	1-29	600 through 617
63 A 29	1-31	618 through 852.1
64 A 186	1-8	033 through 829
59 A 2112	10-37	100 through 112

Taken together, these accessions continue the general files of the NACA begun with 57 A 415. Several guides to the filing system exist, none entirely dependable. The 1 May 1944 "NACA Filing System: Index to 'Concrete' and 'Abstract' Subjects," running to 110 pages, may be found in 63 A 29 (31). Perhaps more helpful is the 10-page "Index to the Old Files: 1943 Filing System, revised 26 Oct. 1945" to be found in National Archives, Record Group 255, Entry 11, Box 1.

Compared with the Dewey decimal filing system used by the NACA between 1942 and 1952, the alphanumeric system of the Committee's final six years is a model of clarity and simplicity. A guide to it appears in an untitled 6-page typescript dated 11 March 1952. Copies may be found in 63 A 29 (31) and as an appendix to the Cunliffe and Goldbeck special study. The system had three lettered categories. The "A" category contained the Committee's operating files: i.e., documentation on conferences, committees, visits, comments on reports, security, films, etc. The "B" category covered concrete and tangible subjects like complete aircraft, airframe components, propulsion systems, fuels, materials, equipment, and instruments. The "C" category covered abstract or intangible subjects like fluid mechanics, aerodynamic characteristics, stability and control, heat transfer, aircraft loads, structural properties and stresses, and operating problems. These files are contained in the following accessions:

63 A 101	1-24	A2-32, B1-B10, C1-C10
63 A 250	1-31	C1-C12
63 A 398	1-33	B1-B2
63 A 5036	1-23	B3-B14
64 A 614	1-13	A1-A28, B1
65 A 228	1-38	A1-A2
65 A 539	1-51	A3-A11
65 A 953	1-38	A12-A34
65 A 1125	1-22	B2-C112

Other accessions, though less comprehensive, were almost equally informative. Accession 62 A 35, filed mostly in a Dewey decimal system, continues 57 A 415 through 1952. Box 40 has excellent material on Committee reorganizations and on the NACA's role in the creation of the National Science Foundation. Box 41 contains useful material on the important Unitary Wind Tunnel Plan and on the post-World War II Mead committee hearings, for which the NACA gathered and tabulated much formerly scattered information about its organization and activities. Boxes 44 through 49 contain material on the short-lived but important Research and Development Board of the Department of Defense. Boxes 54 through 56 contain reports by NACA staff members after they attended professional conferences, a mine of information on the aircraft industry and the scientific and engineering professions that serve it. Box 77 lists all research authorizations at the three major NACA laboratories.

Accessions 57 A 807 (1-64) and 61 A 195 (20-64) hold complete files on research authorizations. The first is a Langley laboratory accession, the second is from headquarters. Some RAs require a single folder; others fill more than one box. Through them the whole NACA research process can be followed from idea through final published report. A note of caution: the Special File folders are not the treasure troves described in the special study; rather, they are gathering places for miscellaneous correspondence regarding the authorizations.

Accession 54 A 581 records, with photographs, the construction at Langley laboratory between 1929 and 1951. It offers a unique perspective on what complex and magnificent machines the wind tunnels were, and how easily the NACA engineers could have become enamored of them. Accession 55 A 344 (R25-R32, R34, R38, R40-R47) shows how reports were circulated within the NACA, commented upon, published, and distributed. Accession 56 A 635 (1-4) has more of the same.

Boxes 10 through 39 of accession 59 A 2112 are the files on the technical committees. Generally these are arranged in separate folders on Organization, Minutes, Notices [of meetings], Reports, and General. The Organization folders are the most revealing. Interspersed in these records are some characteristically rich biography files of prominent committee members. Boxes 5 through 13 of accession 55 A 312 contain biography files on members of the NACA technical committees. These show clearly that aircraft-manufacturing firms were actively seeking NACA membership for their employees.

Among the best fiscal records are those in accession 64 A 125 (17-40). Box 17 is especially useful for its summary of construction at Langley laboratory. In box 23 are copies of all Treasury Department warrants, the only sure and complete source of information on moneys received by the NACA from Congress or other branches of the federal government. Box 35 contains excellent summaries of NACA finances year by year, many first collected for presentation to the Mead committee in 1946. Accession 64 A 518 (8-13) also has useful budget information.

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The following list of all the boxes I examined at the Washington National Records Center may help future researchers to reexamine the material I saw or perhaps look for new evidence:

54 A 581	(1-16)
55 A 312	(1-7)
*55 A 291	(4-12)
*55 A 344	(R24-R32, R34, R38, R40-R47)
56 A 437	(15, 23, 27, 46-48, 59)
56 A 635	(1-10)
57 A 415	(1-80)
57 A 807	(3-9, 12-20)
58 A 411	(14-20)
58 A 454	(1-9), (75, 81)
59 A 2112	(2-39)
60 A 635	(1-13, 23-29)
61 A 195	(1-17, 20-28, 57-64)
62 A 35	(1-16, 18-77)
62 A 129	(1-14)
62 A 174	(8, 9, 13-20)
62 A 441	(1-29)
63 A 29	(1-31)
63 A 101	(1-2, 10-15)
64 A 125	(16-31, 33-40)
64 A 518	(8-16)
64 A 614	(1, 5-7)
64 A 929	(4)
65 A 228	(36-38)
65 A 539	(44-48)
65 A 953	(1-2, 6-7, 31, 33-34, 36-38, 68-69)
65 A 1135	(6, 9-11)

Those with an asterisk are Langley files; all others are from NACA headquarters.

As this book goes to press, the NACA records at the Washington National Records Center are being catalogued and reboxed. Researchers will not in the future find the records cited in this study in the locations indicated here. The records will, however, be arranged more logically and more conveniently, and a concordance will be available to translate the citations given here to the new system of boxing. Unfortunately some of the records cited in this study, considered to be of insufficient historical value to warrant permanent retention, will go to other repositories such as the history archives at NASA Headquarters and Langley Research Center or to the collection at the National Air and Space Museum; some few will be destroyed.

National Archives

The main building of the National Archives in Washington, D.C., houses two important collections that supplement the holdings of the Washington National Records Center. The Modern Military Branch holds 60 cubic feet of NACA records in 191 1/3-cubic-foot archives boxes. The exact origin of this holding is unknown, but most of it is believed to be files collected by John Victory in the preparation of his

history of the NACA. These are supplemented by the files of Walter Bonney, NACA director of public relations from 1949 through 1958. They are described in National Archives Preliminary Inventory NM-86, for Record Group 255, covering textual records of the National Advisory Committee for Aeronautics. A more detailed guide to the Victory portion of this collection is a 46-page typescript inventory entitled "Files in Historian's Office (as of January 16, 1953)." Presumably, these were the files put together by Ruth Walrad, NACA historian from 1950 to 1952. She was working closely with Victory and he apparently retained these files when she left.

This collection, though uneven, is the best single source of NACA documentation except for the 4000 feet at the Washington National Records Center. Furthermore, it must be used to supplement research at WNRC, for many of the folders removed from those files seem to have found their way here. Not counting the Bonney material, this collection appears to constitute what John Victory felt was the most important documentation of the NACA's history.

Photographs are scattered throughout the NACA records, but by far the most comprehensive and the most useful collection is that in the Photographic Branch of the National Archives. This collection has been divided into five series:

The RF series (on research facilities) has about 5000 items in 23 archive boxes totaling 8.28 cubic feet. These are photographs of wind tunnels, towing tanks, laboratories, shops, offices, hangars, test stands, etc.

The RA series (on research activities) shows NACA employees at work, mostly on technical jobs like building models or setting up tests in wind tunnels. It fills 14 boxes.

The PA series records European and American aviation from 1903 through 1950. Included are photographs of important events, airplanes, and people. The 3000 items fill 14 boxes, 4.9 cubic feet.

The P series, one of the most useful in the collection, has photographs of all the airplanes with which the NACA dealt: i.e., virtually every American plane from 1915 through 1958. A card catalogue provides easy access to this collection.

The GF series is the general files, containing photographs of NACA conferences, meetings, committee members, and ceremonies.

Most NACA photographs are numbered. The NASA research centers that were once NACA laboratories maintain active files of these old photographs, and usually can reproduce them from the original negatives quickly and at reasonable cost.

Langley Research Center

Records of the Langley Memorial Aeronautical Laboratory include the files of the Wallops Island facility, created in 1944 as a test site for Langley work in rocket research. Most of these records have been retired to the Washington National Records Center. The few exceptions are worth noting.

Several attempts have been made at Langley to prepare histories of the NACA and of the Langley lab. Documents collected for one of these attempts, stored in 9 oversize boxes in the Center historical archives, are described in some detail in a 15-page typescript inventory entitled "Materials Re Langley History."

As mentioned earlier, the Langley Research Center has a complete card file to the old NACA reference library. Cards are filed by subject, author, title, and—for NACA reports and research authorizations—by number. This catalogue is probably the most complete guide to public aeronautical information for the period 1915 through 1958.

The Langley Research Center historical archives include many NACA documents not yet retired to the National Archives.

Ames Research Center

The NACA records retired from the Ames laboratory are in two groups at the San Francisco Federal Archives and Records Center in San Bruno, California. The first group, records retired in or before fiscal year 1960, have all been permanently accessioned by the Archives Branch of the Records Center and are listed in the addendum to the "Special Study." The second group consists of material retired by the Ames Research Center since 1960, in which NACA records are interspersed with NASA records. These are maintained by the General Records Branch of the SFFARC.

Using the Records Transmittal forms for the accessions listed in the "Special Study," I selected 33 boxes of records to examine. On arriving at the Records Center, I learned that these records had been transferred to archives boxes, renumbered, and inventoried. The following are the records I examined, showing both the old and the new box numbers:

<u>Accession</u>	<u>Ames Box Numbers</u>	<u>Archives Box Numbers</u>
55 A 1015	V359-V361	1104-1116
56 A 193	V422-V425, V427-V428	428-456
57 A 256	51638-39, 51641-43	505-538
58 A 296	30567, 30573-77	850-984
58 A 329	20651-53	457-503
59 A 117	55341-42	1028-1033
59 A 628	1338, 1340-42, 1347, 1349, 1368	558-673
59 A 753	56871	1117-1129

Not surprisingly, these records are far more technical than those of the NACA's headquarters. What is surprising is the extent to which this is true. These records testify to the success of NACA headquarters in insulating the laboratories from administrative and political responsibilities, leaving them free to pursue aeronautical research. The interlaboratory correspondence in these files is mostly with Langley laboratory because of the similarity of the work conducted there. Correspondence with Lewis laboratory is comparatively slight, though not insignificant.

The NACA records in the General Records Branch are still stored in records-center boxes in which they were retired. No inventory of them has been made. The only guide is the Records Transmittal Form, on which the dates of the records almost always appear. Using these forms, I selected and examined the following boxes:

63 A 224	(1-2)
61 A 565	(1-6)
60 A 437	(V6424)
61 A 303	(V7201, V7207)
63 A 277	(V6493)
66 A 301	(V1659, V1675, V1678)
66 A 906	(V2250)

These were mostly "General Files" of the laboratory, unremarkable and containing few surprises. One important accession I did not examine—largely a duplicate of a file in Washington—is 62 A 621, containing the memoranda of Edwin P. Hartman, NACA's

western coordination officer from 1940 through 1958. His papers are an invaluable guide to the west coast aircraft industry.

Lewis Research Center

The NACA records of the Lewis laboratory are stored in three different locations. The four boxes in accession 57 A 332, stored at the Federal Archives and Records Center in Chicago, contain lectures, speeches, talks, and broadcasts made by NACA (mostly Lewis) personnel between 1944 and 1954. They are filed alphabetically by author. Accession 73 A 20 is stored at the new Federal Archives and Records Center in Dayton, Ohio. In its six boxes are speeches and technical papers by Lewis personnel between 1951 and 1959, filed chronologically by year and alphabetically within each year group.

The remaining NACA papers from Lewis are stored in Lewis Research Center's Plum Brook Station, located on Lake Erie near Sandusky, Ohio. There they are stored with the 7500 cubic feet of records maintained by Lewis. Shelf lists kept by the Records Management Office provide a guide to this material. The boxes whose numbers are listed in the addendum to the "Special Study" contain the bulk of the NACA records.

High Speed Flight Station and Western Coordinating Office

The records of the High Speed Flight Station and the Western Coordinating Office are stored in 10 accessions in the Federal Archives and Records Center in Laguna Niquel, California. The three accessions of WCO records, totaling 8 cubic feet, are largely duplicated in the files of the Ames Research Center and NACA headquarters. Most of the records of the High Speed Flight Station are detailed test data and published research results available elsewhere. The 124 cubic feet of material in accession 62 A 729 are administrative and organizational records of the station. These records are described in Richard P. Hallion, *On the Frontier: Flight Research at Dryden, 1946-1981* (NASA SP-4303; in press).

NASA Headquarters History Office

The History Office in NASA Headquarters holds two small collections of NACA files. One filing cabinet of uncertain origin contains a strange mixture of papers, some of which seem to be holdovers of the NACA history project of the early 1950s. To these have been added published and unpublished papers related to the NACA's later history, including some materials gathered by Walter Bonney. These files have an interesting photograph collection and draft chapters of the Victory-Walrad history of the NACA.

The documents gathered in preparation for the present study were collected by Walter Bonney between 1971 and 1975 and by the author between 1975 and 1978. They now fill most of two filing cabinets, about 15 cubic feet. When the project is completed, they will be boxed as a single collection and retired to the Washington National Records Center in a single accession. They include NACA documents, copies

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of documents from other agencies, note cards, transcripts of interviews, drafts of outlines and the narrative manuscript, and comments by readers before publication. People interviewed by Bonney in researching the history of the NACA were:

Ira H. Abbott	Sandwich, NH	28 Oct. 1971
John V. Becker	Hampton, VA	27 March 1973
Steven E. Belsley	Moffett Field, CA	24 Sept. 1974
T. Melvin Butler	Hampton, VA	29 March 1973
Smith J. DeFrance	Moffett Field, CA	27 March 1973
J. R. Dempsey	[Everett, MA]	1 Nov. 1971
John E. Duberg	Hampton, VA	28 March 1973
Ira A. Eaker	Washington, DC	11 Feb. 1974
Edward I. Garrick	Hampton, VA	27 March 1973
Aubrey Harris	Moffett Field, CA	23 Sept. 1974
Leonard S. Hobbs	Hartford, CT	27 Oct. 1971
Manley Hood	Moffett Field, CA	23 Sept. 1974
Richard E. Horner	Waseca, MN	3 May 1972
Jerome C. Hunsaker	Boston, MA	2 Nov. 1971 (notes only)
R. T. Jones	Moffett Field, CA	24 Sept. 1974
S. Paul Johnston	Bozman, MD	19 Oct. 1971
Arthur Kantrowitz	Averett, MA	1 Nov. 1971
Grover Loening	Washington, DC	15 Nov. 1971
Laurence K. Loftin	Hampton, VA	28 March 1973
Axel T. Mattson	Hampton, VA	29 March 1973
Mark R. Nichols	Hampton, VA	29 March 1973
Irving W. Pinkel	Cleveland, OH	22 Sept. 1973
Russell G. Robinson	Moffett Field, CA	24 Sept. 1974
L. Eugene Root	Moffett Field, CA	25 Sept. 1974
Robert C. Seamans	Washington, DC	23 Feb. 1973
Igor Sikorsky	[Stratford, CT]	26 Oct. 1971
Abe Silverstein	Cleveland, OH	21 Oct. 1972
	Cleveland, OH	20 Sept. 1973
Hartley A. Soulé	Hampton, VA	28 March 1973
Clarence A. Syvertson	Moffett Field, CA	25 Sept. 1974
Floyd L. Thompson	Hampton, VA	27 March 1973
Richard T. Whitcomb	Hampton, VA	27 March 1973
Charles Zimmerman	Hampton, VA	30 March 1973

OTHER ARCHIVAL SOURCES

U.S. Air Force Academy, Victory Papers

In 1961 John Victory retired to Colorado Springs, Colorado. There he planned to work at the U.S. Air Force Academy, writing his history of the NACA. He deposited some 24 boxes of his papers with the Academy's Special Collections Branch and began working with them. Soon, however, he soured on the project and abandoned it. He left the papers at the library but never offered them to the academy. The boxes were closed and stored in a basement while attempts to get a proffer, first from Victory and then from his widow, proved unavailing.

In March 1977 I visited Mrs. Victory, then 86, and her daughter Betty, in Tucson, Arizona. She gave me an enlightening interview, a proffer that opened up her late husband's papers, and three more boxes of his papers that she still had around the house. These I delivered to the Air Force Academy, where I was then able to view all 27 boxes.

This collection consists of the personal files Victory kept in his NACA office and at home. By far the richest are boxes 1 through 3, the correspondence files. These leave the reader with a certain respect for the loyalty and singlemindedness with which Victory strove to advance the NACA, and an accompanying distaste for the pomp and circumstance he came to value so highly. These files clearly show what a turning point World War II was for Victory and the NACA. After the war Victory spent most of his time traveling, vacationing, making speeches, associating with "important people," and arranging inspections and celebrations. His greatest direct contribution to the NACA during these years was his tireless campaign to obtain higher salary scales for the Committee's scientists and technicians. This last is documented in box 21, which also contains what appears to be an early outline of his history of the NACA.

The 36 feet of records in this collection are described in a 36-page manuscript record (MS 20) prepared by the Special Collections Branch of the USAF Academy Library. Included are a biographical sketch of Victory, narrative descriptions of the 12 series into which the collection has been divided, and a folder-by-folder inventory.

Also available is the transcript of three revealing interviews of Victory, conducted by Alfred F. Hurley in 1962 while preparing his biography of Billy Mitchell.

Johns Hopkins University, Dryden Papers

The papers of Hugh L. Dryden are gathered in the Milton S. Eisenhower Library at Johns Hopkins University. Consisting of 85 linear feet of materials in 196 archives boxes, these records document Dryden's life from his precocious boyhood writings to his activities as Deputy Administrator of NASA, the post he held at the time of his death in 1965. They are described in *The Hugh L. Dryden Papers, 1898-1965: A Preliminary Catalogue of the Basic Collection*, compiled and edited by Richard K. Smith (Baltimore, 1974). The collection is weak on NACA records and adds little to the Dryden material in the NASA History Office.

Smithsonian Institution

The papers of Jerome C. Hunsaker are collected in the National Air and Space Museum. Walter Bonney examined the entire collection in 1972 and 1973, and inventoried those items relating to the history of the NACA in a series of typescript descriptions now included in the records of this study.

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The papers of Charles D. Walcott are in the Smithsonian archives, Record Unit 45, Walcott correspondence.

National Archives, BoB Records

The records of the Bureau of the Budget, Record Group 51 in the National Archives, are a rich and unique source of information on the executive branch of the federal government. Since 1922, this central and comparatively impartial agency has reviewed and administered the preparation and presentation of the president's budget, first as part of the Treasury Department and since 1939 as part of the Executive Office of the President. The federal government runs on money, and this is where the executive branch determines who gets what.

The files of the Bureau of the Budget are, as one might expect, remarkably orderly and complete. They are described in R. Michael Reynolds, compiler, "Series-Title Inventory of the Records of the Office of Management and Budget," a 15-page typescript prepared in 1975. Using this guide and the advice of the staff of the Legislative, Judicial, and Administrative Branch of the National Archives, I selected and examined records on the NACA from the following series:

- 21.1 General Subject Files, 1921-1938
- 39.27 General Records of the Directors, 1939-1946
- 39.1 Legislative History Files, 76th-79th Cong., 1939-46
- 47.1 Legislative History Files, 80th-82d Cong., 1947-52
- 53.2 Legislative History Files, 83d-86th Cong., 1953-60
- 47.1a Legislative History Files, Public Laws, 80th Cong., 1947-48
- 47.1b Legislative History Files, Public Laws, 81st Cong., 1949-50
- 47.1c Legislative History Files, Public Laws, 82d Cong., 1951-52
- 53.2a Legislative History Files, Public Laws, 83d Cong., 1953-54
- 39.21a Estimates and Budgetary Administration Records
- 39.32 Division of Administration Management, Government Organization Branch (Boxes 22,160)
- 47.3 General Records of the Director, 1947-1960
- 52.1 General Records of the Director, 1947-1960
- 51.18a Subject Files of Independent Agencies Assigned to the Military Division, 1953-1960
- 52.6 Office of Management and Organization, Government Organization Branch (Boxes 23, 27)

The most useful kind of document in these files is the internal memorandum. Typed on blue paper, so that they are easy to find in the files, these memoranda are gems of clarity, candor, and conciseness. In them, staff members summarize for their superiors or for colleagues in other branches of the bureau the essential history and issues of a given subject. The director of the Bureau had to meet regularly with the heads of all branches of the federal executive. To do so competently, he needed a quick study of each branch's special interests and problems. These memos were the vehicles for that information.

These files contain so much useful information that attempting a summary is futile. A few general comments will suggest the range of the material. The legislative history files trace laws and proposed laws from first suggestion as far as they go, either into law or failure. The General Records of the Director usually offer perspective on

policy at the highest level of an agency. The General Subject Files are mines of information on what work an agency performed and how it related to other branches of government. The NACA's budget was handled by the military division of BoB, and its activities were always judged in that context. The Estimates files reveal the conflict between agency requests and BoB concessions, though never as clearly as the historian might hope.

PUBLISHED WORKS

Primary Works

The publications of the NACA are the best primary source on Committee activities and achievements. The *Annual Report*, published in 44 volumes from 1915 through 1958, provides a brief outline of Committee membership, policy, activities, facilities, and budget, along with a summary of the state of aeronautical research. Bound with each *Annual Report* are the *Technical Reports* published in that year.

The Committee's other reports are described in appendix G. They are inventoried in *Index of NACA Technical Publications, 1915-1949* (Washington: NACA, 1949) and in supplementary volumes that carried the index through 1958. Eugene B. Jackson and Ruth L. Jackson, *Author Index to Index of NACA Technical Publications, 1915-1949* (Washington: NACA, 1951) may be used as a companion to the 1949 index.

Prints of the annual NACA appropriations hearings are the best congressional documentation of the NACA. These hearings were held before the Independent Offices Appropriations Subcommittee (variously titled) of the House Committee on Appropriations. After 1950 there were some revealing authorization hearings as well. The single most informative congressional publication is the Mead committee hearings following World War II: Senate Special Committee Investigating the National Defense Program, *Investigation of the National Defense Program*, Hearings on S. Res. 55, 79/2, 1946, Part 33. Here the NACA summarized and defended its entire record in bidding for a position in the postwar scheme of things. Uncharacteristically, it came under close scrutiny and severe criticism.

Secondary Works

The history of the NACA is a part of the broader history of aeronautical research, which is in turn a branch of aviation history. I do not pretend to have mastered, nor even read, the vast literature on this topic. My sampling of it suggests that it is more vast than helpful. A few works, however, warrant special mention either as being particularly good or as having influenced my own thinking on the NACA. Most of these are cited in the notes; some appear here for the first time or are repeated for emphasis.

No satisfactory up-to-date bibliography of aviation exists. Peter Fearson, "Aviation Past and Present," *Journal of Transport History* 4 (Feb. 1977), 47-54, is a masterful review article on the major works on aeronautical history over several decades. Eugene S. Ferguson, *Bibliography of the History of Technology* (Cambridge, Mass.: Society for the History of Technology and MIT Press, 1968), pp. 240-43, lists the principal bibliographic tools and a sampling of the histories in the field.

John D. Anderson, Jr., *Introduction to Flight: Its Engineering and History* (New York: McGraw-Hill, 1978), while not as strong on history as its title suggests, is nevertheless a conscious and commendable attempt to explain the state of the art, with some historical asides on how it got there. *Exploring in Aeronautics: An Introduction to Aeronautical Sciences*, NASA EP-89 (Washington: NASA, 1971), presents similar material in simpler form with fewer equations. J. H. Stevens, *The Shape of the Aeroplane* (London:

Hutchinson and Co., Ltd., 1953) is more successful in tracing the evolution of aeronautical technology, but views it from a decidedly British perspective. Nationalistic bias is a principal weakness of nearly all aviation literature.

By far the best work in its field is Ronald Miller and David Sawers, *The Technical Development of Modern Aviation* (New York: Praeger, 1970), an outgrowth of the classic study by John Jewkes, David Sawers, and Richard Stillerman, *The Sources of Invention* (New York: St. Martin's Press, 1959). Miller and Sawers' study is rich in its perceptions of the technical progress in aviation but, by focusing on commercial success as the yardstick of progress, it subordinates technological innovation to the dictates of the marketplace. Oliver Stewart's *Aviation: The Creative Ideas* (New York: Praeger, 1966) attempts to focus more directly on technological concepts, regardless of their commercial acceptance, but it suffers from the author's disproportionate familiarity with British aviation and from an apparent inability to weigh the contributions of his friends and countrymen impartially. J. L. Naylor and E. Ower, *Aviation: Its Technical Development* (Philadelphia: Dufour Editions, 1965)—the British counterpart of Miller and Sawers—escapes economic determinism and presents the British story knowingly, but its topical arrangement makes it difficult to trace the historical evolution of aviation as a whole. Charles H. Gibbs-Smith, *The Aeroplane: An Historical Survey of Its Origins and Development* (London: Her Majesty's Stationery Office, 1960) is better on the history but concentrates overmuch on the early period, devoting half the narrative to the period before World War I. *Research and Development Contributions to Aviation Progress* (2 vols.; Washington: Department of the Air Force, 1972) attempts to identify and trace the impact of the major inventions and innovations in aeronautical technology. It is a stimulating and thoughtful analysis, but it serves the purposes of its institutional authors (the Department of Defense, NASA, and the Department of Transportation) too well to escape suspicion.

Four model studies of specialized topics in aeronautics are worthy of special mention. Robert Schlaifer, *Development of Aircraft Engines* and S. D. Heron, *Development of Aviation Fuels* (bound together with common subtitle, *Two Studies of Relations between Government and Business*) (Boston: Division of Research, Graduate School of Business Administration, Harvard University, 1950) are thoughtful and informed studies replete with historical insights. Schlaifer's is the more detailed and scholarly of the two, but it relies of necessity on received opinions from unidentified sources. Heron writes from personal experience. Peter W. Brooks, *The Modern Airliner: Its Origins and Development* (London: Putnam, 1969) is a classic in the field and deserves the praise it has received. C. Fayette Taylor, "Aircraft Propulsion: A Review of the Evolution of Aircraft Power Plants," *Annual Report of the Board of Regents of the Smithsonian Institution, 1962* (Washington: Smithsonian Institution, 1963), pp. 245-99, an insider's version, should be compared with the less technical but more analytical treatment by Schlaifer.

A. Hunter Dupree, *Science in the Federal Government: A History of Policies and Activities to 1940* (Cambridge, Mass.: Belknap Press of Harvard University Press, 1957) forces a large and unwieldy topic into pleasantly digestible form. John B. Rae, *Climb to Greatness: The American Aircraft Industry, 1920-1960* (Cambridge, Mass.: MIT Press, 1968) is the best work to date on a badly neglected subject. Nick A. Komons, *Bonfires to Beacons: Federal Civil Aviation Policy under the Air Commerce Act, 1926-1938* (Washington: Federal Aviation Administration, 1978) is the most helpful of the four volumes in the FAA history, untangling as it does the complex story of the Air Commerce Act of 1926. Irving Brinton Holley, Jr., *Buying Aircraft: Materiel Procurement for the Army Air Forces, United States Army in World War II, Special Studies* (Washington: Office of the Chief of Military History, Department of the Army, 1964) delivers far more than its title promises. It provides the best explanation of army aircraft procurement policies from inception through the end of World War II, and it elucidates in remarkable detail the complex interactions between technology, military operations, the government bu-

reaucracy, and the aircraft manufacturing industry. Edward W. Constant's *The Turbojet Revolution* (Baltimore: Johns Hopkins University Press, 1980) addresses that important topic from the perspective of paradigms of technological change but fails to explain why U.S. jet development lagged behind that of Germany and Great Britain.

The best book on the NACA is George W. Gray, *Frontiers of Flight: The Story of NACA Research* (New York: Alfred A. Knopf, 1948). Gray, a professional writer widely respected for his ability to translate complex technical topics into clear, simple prose, was hired by the Committee on a short-term contract to record NACA contributions in World War II. The project stretched out over a number of years and grew to encompass all the Committee's technical achievements up to the time of publication. The Committee staff provided Gray with the material; he provided the words and music. The result is a sympathetic, straightforward, topical report stronger on clarity and technical accuracy than on analysis and interpretation. Still, it is as fine a summary of the NACA's claims for itself as is likely to be prepared.

A more historical, and even more sympathetic, summary of the NACA record is that of Jerome C. Hunsaker, "Forty Years of Aeronautical Research," first published in the Smithsonian annual report for 1955 and reprinted in the *Forty-Fourth Annual Report of the National Advisory Committee for Aeronautics, 1958* (Washington: NACA, 1959), pp. 3-27. Written by Walter T. Bonney, the NACA public affairs officer, on the occasion of Hunsaker's retirement as chairman of the NACA, this essay sings the Committee's praises and ignores its problems and shortcomings. The companion piece, James H. Doolittle, "The Following Years, 1955-1958," on pages 29-31 of the NACA annual report for 1958, completes the story in the same laudatory tone.

A more critical review of the Committee's history may be found in Arthur L. Levine, "United States Aeronautical Research Policy, 1915-1958: A Study of the Major Policy Decisions of the National Advisory Committee for Aeronautics," unpublished Ph.D. dissertation, Columbia, 1963. I am indebted to Dr. Levine for many good ideas. His dissertation, however, should be used together with Ira H. Abbott, "A Review and Commentary of a Thesis by Arthur L. Levine Entitled 'United States Aeronautical Research Policy, 1915-1958: A Study of the Major Policy Decisions of the National Advisory Committee for Aeronautics' dated 1963," NASA History Office HHN-35, 1964. Abbott is one of the old NACA hands but—unlike many of his engineering colleagues—he writes a clear, sometimes eloquent, prose; he understands history; and he is familiar with how and why headquarters operated. His defense of the NACA is informed and persuasive; it also reveals more about the Committee than he intended.

Two general histories of the NACA begun by insiders were left unfinished. From 1949 until his death in 1974, John Victory worked on a history of the Committee. In the early 1950s he was joined by Ruth Walrad, then serving as NACA historian. Between them they drafted several chapters, copies of which are in the NASA History Office and in Victory's papers at the U.S. Air Force Academy. The drafts, apparently by Walrad, do not begin to tap the wealth of information in Victory's mind and in the extensive notes he compiled over the years.

Walter T. Bonney's "So Much, So Quietly . . . : A History of The National Advisory Committee for Aeronautics, 1915-1958" was the product of nearly four years of research, including interviews with many former NACA colleagues. Bonney outlined this manuscript in considerable detail but completed drafting only two of a projected 33 chapters before his death in 1975. The outline and draft chapters make it possible to project the book he had in mind, and his extensive research data suggest how he planned to document his case.

The literature on the laboratories is not as satisfactory as that on the Committee as a whole. The best of it is Richard P. Hallion, *On the Frontier: Flight Research at Dryden, 1946-1981*, NASA SP-4303 (Washington, NASA, in press), prepared by the leading authority on the history of high-speed flight. Several publications record the history of

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Langley, mother laboratory to all the other NACA research centers, without providing the full interpretive history it deserves. David A. Anderton, *Sixty Years of Aeronautical Research*, NASA EP-145 (Washington: NASA, 1978) is a profusely illustrated summary of highlights in Langley's history. Michael David Keller, "From Kitty Hawk to Muroc: A History of the NACA Langley Laboratory, 1917-1947," NASA History Office HHM-15, 1969, is a well-researched and well-documented, but uncritical, narrative based on Keller's earlier "Fifty Years of Flight Research: A Chronology of the Langley Research Center, 1917-1966," NASA History Office HHN-65, 1966. Two old NACA hands made preliminary sketches of Langley histories: Milton Ames, "Report on the History of Langley Research Center, 1917-1967," NASA History Office HHM-25, 1972, and Hartley Soulé, "Outline History of Langley Research Center, 1915-1958," HHN-40, 1966.

Edwin P. Hartman was for years the head of NACA's Western Coordination Office, and his reports on the west coast aircraft manufacturers are models of clarity and comprehension. His *Adventures in Research: A History of Ames Research Center, 1940-1965*, NASA SP-4302 (Washington: NASA, 1970) is an insider's appreciative memoir, rich in detail, illustrations, anecdotes, and technical understanding. Its shortcomings in documentation and analysis will be redressed by Elizabeth A. Muenger's forthcoming history of Ames Research Center, 1940-1970. B. R. Luczak, "A Management and Procedural Analysis of the National Advisory Committee for Aeronautics," unpublished paper submitted to the Stanford University Graduate School of Business Administration, 1950, is strong in describing day-to-day workings of the Ames laboratory but falls far short of what its title promises.

Joseph A. Shortal, *A New Dimension: Wallops Island Flight Test Range: The First Fifteen Years*, NASA Reference Publication 1028 (Washington: NASA, 1978) is an exhaustive catalog of technical activities at Wallops by one of the center's veteran engineers. No one has undertaken a history of Lewis laboratory, but John D. Holmfeld's unpublished manuscript, "The Site Selection for the NACA Engine Research Laboratory: A Meeting of Science and Politics" ([Cleveland,] 1967), is a useful introduction.

NOTES

CHAPTER I

1. On the scientific accomplishments of the Wright Brothers, see George W. Lewis, "The Contributions of the Wright Brothers to Aeronautical Science and Engineering," *U.S. Air Services*, May 1938, pp. 13-15. For a succinct, informed, and candid account of the contributions of the Wrights and Langley, see Charles H. Gibbs-Smith, *The Aeroplane: An Historical Survey of Its Origins and Development* (London: Science Museum, 1960), pp. 26-28, 222-34. For an interpretation sympathetic to Langley, see J. Gordon Vaeth, *Langley: Man of Science and Flight* (New York: Ronald Press, 1966); the Wright version is in Fred C. Kelly, *The Wright Brothers: A Biography Authorized by Orville Wright* (New York: Harcourt, Brace, 1943).
2. Gibbs-Smith, *The Aeroplane*, p. 59. The characterizations of Langley and the Wrights are from Mark Sullivan, *Our Times, 1900-1925* (6 vols; New York: Charles Scribner's Sons, 1926-1935 [1971]), 1: 566, 568.
3. Walter T. Bonney, *The Heritage of Kitty Hawk* (New York: Norton, 1962), chap. 9. On the paucity of other aeronautical research in the United States, see *Aeronautics: First Annual Report of the National Advisory Committee for Aeronautics, 1915* (Washington: NACA, 1916), pp. 12-13. [Annual reports of the NACA will be cited hereafter in the form *AR 1915*.]
4. A. Lawrence Rotch, "Aerial Engineering," *Aero Club of America Bulletin* 1 (Aug. 1912): 10; Jerome C. Hunsaker, "Europe's Facilities for Aeronautical Research—I," *Flying*, Apr. 1914, pp. 75, 93, and "Europe's Facilities for Aeronautical Research—II," *ibid.*, May 1914, pp. 108-09.
5. *Aeronautics: Report of the Advisory Committee for Aeronautics for the Year 1909-1910* (London: HMSO, 1910), pp. 4-5.
6. Gibbs-Smith, *The Aeroplane*, pp. 59-81.
7. Announcement of the "First Annual Banquet of the Aeronautical Society," (1911). For a copy of this document and others relating to the navy's role in the early efforts to establish an aeronautical laboratory, I am indebted to Lee M. Pearson, who scoured the archives of the Naval Air Systems Command.
8. Jerome C. Hunsaker and Lester D. Gardner, "Background and Incorporation of the Institute of the Aeronautical Sciences," undated typescript, 8 pp., "the first chapter of a history of the I.A.S." Unless otherwise indicated, this document and all other unpublished materials cited in the notes are among the materials collected for the present study. They are retained in the NASA History Office Archives, NASA Headquarters, Washington, D.C. See the bibliographic essay, pp. 305-320.
9. Chief, Bureau of Construction and Repair, to Secretary of the Navy, "Relative to Proposed Establishment of an Aeronautical Laboratory in Washington," 20 Apr. 1911. On the bureau politics within the navy that lay behind this dispute, see Lee M. Pearson, "The Role of the U.S. Navy in Establishing a National Aeronautical Research Agency," typescript of address before the History of Science Society, New York, 28 Dec. 1956. Hunsaker believed Pearson overstated the importance of interbureau competition and missed the significance of the scientific community; Hunsaker did, however, admit the plausibility of a basic tension between science and technology suggested by Pearson. Hunsaker to Pearson, 29 Nov. 1956. Hugh L. Dryden confirmed for Hunsaker at least part of Pearson's position, "that Naval officers played a predominant role in the Pre-NACA days and in its formation." Dryden to Hunsaker, 17 Aug. 1956.

The argument about the similarity of aerodynamics and hydrodynamics had merit. One of the most important papers ever published in aerodynamics, Ludwig Prandtl's "Über Flüssigkeitsbewegung bei sehr pleiner Reibung," was based on research on the flow of water, not air. (Originally published in the *Proceedings of the Third International Mathematical Congress, Heidelberg, 1904* [Leipzig: Teubner, 1905], the paper was republished by the NACA in 1928 as TM-452, "Motion of Fluids with Very Little Viscosity.")

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10. Sec. of the navy to sec. of war, 18 May 1911, quoted in Bonney, "So Much, So Quietly . . .," unpublished draft of history of the NACA, n.d., p. 2d-13.
11. Archibald D. Turnbull and Clifford L. Lord, *History of United States Naval Aviation* (New Haven: Yale Univ. Press, 1949), pp. 16-17.
12. A[lbert] F. Zahm, "On the Need for an Aeronautical Laboratory in America," *Aero Club of America Bulletin*, Feb. 1912, p. 35.
13. Zahm, "Uses of an Aeronautical Laboratory," *ibid.*, Mar. 1912, p. 15.
14. Rotch, "Aerial Engineering," *ibid.*, Aug. 1912, pp. 9-10.
15. Richard C. Maclaurin, "The Sore Need of Aviation," *ibid.*, p. 7.
16. W. I[rving] Chambers, "Remarks on Some Developments in Aviation," *ibid.*, May 1912, p. 28.
17. Chambers's "Report on Aviation" filled pp. 155-69 of the secretary's *Annual Report*.
18. Arthur S. Link, *Woodrow Wilson and the Progressive Era, 1910-1917*, The New American Nation Series (New York and Evanston: Harper and Row, 1954), p. 22.
19. Meyer to the president, 16 Dec. 1912. The membership of the commission is given in Rudolph Forster to Meyer, 20 Dec. 1912: in addition to Woodward, Chambers, and Zahm, it consisted of Charles D. Walcott, secretary of the Smithsonian Institution; S. W. Stratton, director of the Bureau of Standards; William J. Humphreys of the Weather Bureau; James Allen and Samuel Reber of the army; David W. Taylor of the navy; M. B. Sellers of the Aeronautical Society; Henry A. Wise Wood of the Aero Club of America; Bion J. Arnold of the Aero Club, Chicago; W. F. Durand of Stanford University; Richard Maclaurin of the Massachusetts Institute of Technology; Charles M. Manly, Langley's pilot; Harold M. Sewall; Herbert Parsons; Frederick H. Smith; and Frank West Rollins. Biographical information on the members appears in Bonney, "So Much, So Quietly . . .," pp. 2d-25, 26. The government members were from institutions exactly parallel to those represented on the British Advisory Committee for Aeronautics, the National Bureau of Standards being the counterpart of the National Physical Laboratory and the Smithsonian representing the Royal Society of London. The National Academy of Sciences is perhaps more properly the counterpart of the Royal Society, but the Academy was moribund at the time and the Smithsonian was the real institutional head of American science.
20. Paul G. Dembling to John F. Victory, "Legislative Reasons for Section 9, 35 Stat. 1027 (of 4 March 1909)," 28 Nov. 1951. The pertinent section reads:

That hereafter no part of the public moneys, or of any appropriation heretofore or hereafter made by Congress, shall be used for the payment of compensation or expenses of any commission, council, board, or other similar body, or any members thereof, or for expenses in connection with any work or the results of any work or action of any commission, council, board, or other similar body, unless the creation of the same shall be or shall have been authorized by law; nor shall there be employed by detail, hereafter or heretofore made, or otherwise [sic] personal services from any executive department or other government establishment in connection with any such commission, council, board, or other similar body.

Walter Bonney believed that this law was additionally prompted by presidential commissions that too thoroughly investigated congressional misconduct. "So Much, So Quietly . . .," pp. 2d-26.

21. The best account of the legislation concerning the Woodward commission and the laboratory it tried to establish is in Richard P. Hallion, "To Study the Problems of Flight: The Creation of the National Advisory Committee for Aeronautics, 1911-1915," unpublished typescript, 1976, pp. 6-10. Even this admirable account, however, leaves some unanswered questions. The assistant secretary of the navy wrote to Chambers that "the bill has been passed by the Senate and assurance has been received that it will be passed by the House of Representatives on January 19, 1913." (Beekman Winthrop to Chambers, 17 Jan. 1913.) The 17th was the day on which the House bill was reported out favorably by the Committee on Naval Affairs, but the day *before* the Senate voted on its bill. (House Committee on Naval Affairs, *Aerodynamical Laboratory*, 62d Cong., 3d sess. (hereafter 62/3), 1913, H. Rept. 1343; and *Congressional Record*, 62/3, 1913, vol. 49, pt. 2: 1258, 1396, 1479, 1481, 1695, 1725, 1786.) The Senate bill was not, as Dr. Hallion states, introduced by Representative Hobson on 20 Jan.; rather, it was referred on that date by the Senate to the House Committee on Appropriations. What was to become the House version of the bill was introduced by

- Hobson on 13 Jan. and referred to the Committee on Naval Affairs. This seems to have been the rub, for Representative Mann later objected to this bill because it had come through the Committee on Naval Affairs; apparently he wanted it to come by normal channels from the Senate through the House Appropriations Committee. (U.S. Congress, *Congressional Record*, 62/3, 1913, 49, pt. 3: 2507-09.) In any event, the bill failed of passage in the House on 19 Jan., despite Winthrop's optimism. Still, his opinion that "Congressional sentiment favors an early report from the Commission" no doubt influenced Chambers's recommendation that meetings begin even without congressional sanction.
22. "Digest of the Minutes of the Meeting of the Aerodynamical Laboratory Commission," apparently prepared by Zahm shortly after the last meeting on 5 Feb.; report of the drafting subcommittee to Chairman Woodward, 24 Jan., 5 pp., unsigned copy, typescript with handwritten changes.
 23. Taylor reported these events to William F. Durand in a letter of 8 Feb. 1913.
 24. See n. 51.
 25. Taylor to Durand, 13 Feb. 1913.
 26. Maclaurin to Senator W. Murray Crane, 14 Feb. 1913. See also n. 15.
 27. Taylor to Durand, 8 Feb. 1913.
 28. Hallion, "To Study the Problems of Flight," p. 8; U.S. Congress, *Congressional Record*, 62/3, 1913, 49, pt. 3: 2682, 2763.
 29. Draft, "Report of the Aerodynamical Laboratory Commission," 12 Feb. 1913.
 30. Bonney, "So Much, So Quietly . . .," pp. 2d-31 through 33.
 31. *Army and Navy Register* (22 Feb. 1913), p. 235.
 32. U.S. Congress, *Congressional Record*, 62/3, 1913, 49, pt. 3: 2507-09.
 33. *Aerial Age*, Mar. 1913. p. 5.
 34. Taylor to Durand, 8 Feb. 1913.
 35. Meyer to Senator George Peabody Wetmore, 11 Feb. 1913; asst. secy. of war to chairman, Senate Committee on the Library, 12 Feb. 1913; Charles D. Walcott to Wetmore, 12 Feb. 1913; Maclaurin to Wetmore, 27 Feb. 1913.
 36. Hallion, "To Study the Problems of Flight," p. 9; U.S. Congress, *Congressional Record*, 63/1, 1913, 50, pt. 2: 81, 89, 194. See also Alexander Graham Bell, "Home Notes" for 20 Feb. 1913, 5 pp., handwritten ms. Bell here records an interview with Chambers in which the latter enlisted his support in getting the rider attached to the Sundry Civil Bill. Bell noted that he and other regents of the Smithsonian were reluctant to request funds of Congress. Without the endorsement of all the regents who were members of Congress (which Chambers did not have) there was little likelihood of passage.
 37. Ellis L. Yochelson, "Charles Doolittle Walcott, 1850-1927: A Biographical Memoir," National Academy of Sciences *Biographical Memoirs*, vol. 39 (New York and London: Columbia University Press, 1967), pp. 471-540. A. Hunter Dupree says Walcott was chosen by his predecessor as chief of the Geological Survey because he was the "assistant with the hardest exterior for political abuse." *Science in the Federal Government: A History of Policies and Activities to 1940* (Cambridge: Belknap Press of Harvard University Press, 1957), p. 217.
 38. This account of the circumstances leading up to the reopening of the Langley laboratory derives largely from "Advisory Committee on the Langley Aerodynamical Laboratory," Smithsonian pub. 2222 (Washington, 17 July 1913), *Smithsonian Miscellaneous Collections*, vol. 62, no. 1, pp. 1-5. The latter report was apparently prepared by Albert Zahm, recorder of the Advisory Committee of the Langley Aerodynamical Laboratory. The actual mechanism used was that Walcott proposed the laboratory to the Smithsonian Board of Regents at its regular meeting on 13 Feb. 1913. The board then appointed a committee consisting of George Gray, Alexander Graham Bell, and John Dalzell to study the proposal and consider using part of the Smithsonian's Hodgkins Fund. The committee reported to the board at a special meeting on 1 May, where its recommendations were approved and in fact enlarged upon.
 39. Walcott to Wilson, 8 May, and Wilson to Walcott, 9 May 1913, both reprinted in the "Minutes of First Meeting of the Advisory Committee of the Langley Aerodynamical Laboratory," 23 May 1913.
 40. The term *Bureau of Aeronautics* appeared in the original Board of Regents authorization, but not in the official publication "Advisory Committee on the Langley Aerodynamical Laboratory," which appeared the following summer. Still, even that formal document stated that

the Board of Regents had authorized the secretary "to add, as means are provided, other laboratories and agencies; [and] to group them into a bureau organization."

41. The army and navy each requested two chairs on the committee, because "of the magnitude of their aeronautical interests." The resulting composition was Chambers and Naval Constructor H.C. Richardson from the navy, Brig. Gen. George P. Scriven and Maj. Edgar Russel from the army, Stratton from NBS, W.J. Humphreys of the Weather Bureau, Walcott, and four members at large: Glenn H. Curtiss, John Hays Hammond, Orville Wright, and Zahm. At the time, Zahm was attached to the Smithsonian Institution; the other three were from private life. Cornelius Vanderbilt and Harold F. McCormick had declined to serve. "Minutes of First Meeting of the Advisory Committee of the Langley Aerodynamical Laboratory, May 23, 1913."
42. Subcommittees on the following topics were organized and chairmen appointed:
1. Collection and correlation of aeronautical information (Zahm)
 2. Publication and dissemination of aeronautical information (Zahm)
 3. Aeronautical meteorology (Humphreys)
 4. Comparative tests and standardization of instruments, motors, and propellers; tests of the tensile, compressive, and bending strengths, and elasticity, weight, etc., of various materials used in aeronautical construction and determination of aeronautical constants (Stratton)
 5. Hydro-mechanic experiments in relation to aeronautics (Richardson)
 6. Naval air craft (*sic*) design (Chambers)
 7. Military air craft design (Russel)
 8. Field experiments with naval air craft (Chambers)
 9. Field experiments with military air craft (Scriven)
 10. Air craft communication (John Hays Hammond)
 11. Experimental air craft factory (Richardson)
 12. Laboratory buildings and equipment (Walcott)
 13. Air craft appliances (Scriven)
 14. Natural flight (No chairman)
 15. Mathematical principles of aeronautics (No chairman) ("Minutes," pp. 9-10.)

At the second meeting, in June, the titles of committees 6, 7, and 11 were altered slightly and a committee on applied aerodynamics (Zahm) was added. Note the similarity of this committee structure to that of the early NACA, as set forth in appendix B.

43. In Apr. 1913 Richard C. Maclaurin of MIT had asked the secretary of the navy to detail Junior Naval Constructor Jerome C. Hunsaker to MIT for three years to prepare a course of instruction and conduct research in aeronautics. Chambers, who was privy to this request, recommended approval, in spite of his earlier disagreement with Maclaurin on the Woodward commission and his continuing suspicion that Maclaurin was engaged in empire-building in Cambridge. When the proposal was approved in June, Maclaurin asked further that Hunsaker be sent to Europe that summer so that he could bring to his post in the fall an up-to-date familiarity with the best aeronautical research and instruction going on there. Chambers brought this plan to Walcott's attention, and they decided to send Zahm as well, perhaps so that MIT would not get an undue advantage over the advisory committee in currency and expertise. Maclaurin to sec. of the navy, 22 Apr. 1913; 2d endorsement by Chambers, 6 May 1913; Josephus Daniels to Mac Lauren [*sic*], 12 June 1913; Maclaurin to Daniels, 14 June 1913; Hallion, "To Study the Problems of Flight," p. 13.

Both published reports of their trip: Zahm, "Report of European Aeronautical Laboratories," 27 July 1914, reprinted in Zahm, *Aeronautical Papers* (2 vols.; Notre Dame, Ind.: Univ. of Notre Dame Press, 1950), 1: 319-42; and Hunsaker, "Europe's Facilities for Aeronautical Research."

44. Hallion, "To Study the Problems of Flight," pp. 14-15.
45. House Committee on Appropriations, Subcommittee in Charge of the Sundry Civil Appropriation Bill of 1915, hearings, 63d Cong., 2d sess., 1914, pp. 419-29. (Congress and session will hereafter be cited in the form 63/2.)
46. Walcott to George E. Downey, 16 Mar. 1914; Downey to Walcott, 17 Mar. 1914.
47. This was the real beginning of what came to be called the Wright-Langley controversy, though—as Orville Wright wrote to Smithsonian Sec. Charles G. Abbot on 28 Sept. 1928—it was really "a 'Walcott-Wright' or a 'Smithsonian-Wright' but not a 'Langley-Wright' controversy." (See note 1.) With his accustomed brevity and clarity, Hunsaker summarized the con-

troverly in a letter to C.G. Grey in 1943, the year after Abbot finally published an account of the whole affair acceptable to Orville Wright:

More precisely, you should refer to the Wright-Smithsonian argument. There has never been any argument with Langley, but a very hot patent fight between [Glenn] Curtiss and Wright in which Curtiss cited Langley's work as prior art in an effort to break the Wright patent. The Smithsonian evidently was maneuvered into aiding Curtiss, possibly through sentimental regard for Langley as their former head. This aid came to nothing as the suit was dropped, but the fat has been in the fire ever since so far as Orville Wright was concerned. Our friends [Griffith] Brewer and Zahm were fairly diligent in feeding the flames. At long last, Brewer has won out, in the form of Dr. Abbot's handsome retraction. Orville is satisfied and no real harm is done to Langley, whose merits as a pioneer Orville freely acknowledges.

Langley's friends claimed too much for the possibilities of a vehicle they did not understand, and the Smithsonian officials were too eager to accept such views. Hunsaker to Grey, 31 Mar. 1943, in National Archives and Records Service, Washington National Records Center, Record Group 255, Records of the National Advisory Committee for Aeronautics, accession 57 A 415, box 79, folder 74-5. (Hereafter, all such entries will be in the form 57 A 415 (79), 74-5.)

48. See "Documentary History of the National Advisory Committee for Aeronautics," unpublished ms., p. 1-16, which reproduces the appropriate "Extract from Proceedings of the Board of Regents of the Smithsonian Institution," for 10 Dec. 1914; Walcott's memorandum to the committee on the Langley laboratory, dated 30 Jan. 1915; and the minutes of the meeting of that committee held on the same day in Senator Stone's office at the Capitol. Members of the committee were Alexander Graham Bell, Senator William J. Stone, Congressman Ernest W. Roberts, John B. Henderson, Jr., and Walcott. Walcott's memorandum, slightly modified, served as a memorial to accompany the proposed resolution.
49. On 29 Jan. 1915 Senator Tillman introduced two identical Senate Joint Resolutions, S.J.R. 229 for referral to the Committee on Naval Affairs and S.J.R. 230 for referral to the Committee on Military Affairs. Roberts introduced House Joint Resolution 413 on 1 Feb. 1915; it was referred to the Committee on Naval Affairs. U.S. Congress, *Congressional Record*, 63/3, 1915, 52, pt. 3: 2656, 2827.
50. H.J. Resolution 413 is reprinted in appendix H.
51. *Aeronautics: Report of the Advisory Committee for Aeronautics for the Year 1909-1910*, p. 5. The British further provided that their advisory committee was "also to determine the problems which the experimental branch should attack, and discuss their solutions and their application to practical questions." In the American legislation, this was rendered as "to determine the problems which should be experimentally attacked and to discuss their solution and their application to practical questions." The British explicitly stated that "the construction and use of dirigibles and aeroplanes having regard mainly to their employment in war" were duties for the Admiralty and the War Office, whereas the American wording studiously avoided those troubled waters altogether.
52. Roosevelt to L.P. Padgett, 12 Feb. 1915. This letter is reproduced in appendix H.
53. Walcott's testimony is reprinted in "Documentary History of the National Advisory Committee for Aeronautics," pp. 64 ff. The original is in House Committee on Naval Affairs, *Hearings on Estimates Submitted by the Secretary of the Navy*, 1916 (3 vols.; Washington, 1916), 2: 1799-1813.
54. U.S. Congress, *Congressional Record*, 63/3, 1915, 52, pt. 4: 4165.
55. According to the House Manual (73/2, H. Doc. 413, sec. 397), joint resolutions "are used for what may be called incidental, unusual, or inferior purposes of legislation. . . ." Quoted in Laurence F. Schmeckebier and Roy B. Eastin, *Government Publications and Their Use* (rev. ed.; Washington: Brookings Institution, 1961), p. 193n. Although, as Mark Twain once described it, "Congress was expiring, and was passing bill after bill as if they were gasps and each likely to be its last" (with William Dudley Warner, *The Gilded Age; A Tale of Today* [Hartford: American Publishing Co., 1873; New York: New American Library, 1969]), p. 392), the advisory committee resolution was just the sort of minor bill that could get lost in the shuffle. As it happened, the House version did come up for a vote in the evening session the day before the 63d Congress expired, but by then the measure had already passed as a rider on the Naval Appropriations Bill. Neither Senate resolution reached the floor.

NOTES

56. Dupree, *Science in the Federal Government*, p. 217. Although Dupree thinks that NACA was created by a "trick" and that the appropriation-bill rider was a devious method "of winning congressional approval," he does not look upon it as "wanton political immorality." He maintains:

Legislating scientific bureaus into existence was a technically difficult problem with which the machinery of Congress could not cope directly. Most of the people's representatives in the late nineteenth century had little background for science or appreciation of its results. Indeed, 1865 to 1900 was not a great period for legislation on any subject. Hence the appropriation-bill rider allowed a small number of congressmen, adequately coached by experts, to legislate in the interests of science. Theirs was a constructive achievement, their circumventions detouring ignorance and lethargy, not the rights of a vigilant people. (p. 291)

While Dupree thinks that "the Progressive Era [saw] a wider appreciation of the use of science in the public interest," the creation of the NACA seems to conform more to his description of the late nineteenth century, the period when Walcott learned the ways of Washington politics.

57. U.S. Congress, *Congressional Record*, 63/3, 1915, 52, pt. 5, pp. 4600-26, 4694-4716, 4869, 4839, 5209-16. The Naval Appropriations Bill for 1916, H.R. 20975, was called up on 25 Feb. 1915. The NACA amendments were agreed to without debate, most floor discussion being devoted to personnel policies and submarines. The conference committee adopted the House version calling for five private members for the NACA, as opposed to three in the Senate version. The conference report (S. Doc. 966, H. Rept. 1500) was presented in both houses on 2 Mar. The NACA amendment was never mentioned on the floor of either house. The bill passed and was signed into law by President Wilson on 3 Mar. 1915. See appendix A.

CHAPTER 2

1. Chairman's opening remarks, "Public Session of Executive Committee of National Advisory Committee for Aeronautics Held at Smithsonian Institution, June 8, 1916," typescript, p. 1. Walcott's solution was "that we should learn from Europe."
2. "Minutes of Meeting of National Advisory Committee for Aeronautics held in the War Department at Washington, D.C., April 23, 1915"; Scriven to The Advisory Committee for Aeronautics, 16 Apr. 1915.
3. Minutes, 23 Apr. 1915; the quoted sections are from the "Rules and Regulations for the National Advisory Committee for Aeronautics" sent to Wilson for his approval on 23 Apr. (see appendix A, p. 405); the draft prepared by Walcott is enclosed in Walcott to Richardson, 8 Apr. 1915; the Walcott quote is from a letter to W. F. Durand, 30 Oct. 1918.
4. Minutes, 23 Apr. 1915.
5. Like much else in the early NACA, the concept of subcommittees had appeared earlier in the Smithsonian's Advisory Committee for Aeronautics. Scriven's objection was stated in his letter to Walcott of 17 Apr. 1915, National Archives and Records Service, Washington National Records Center, Record Group 255, Records of the National Aeronautics and Space Administration, Accession 57 A 415, box 1, folder 1-1 (hereafter such citations will be abbreviated 57 A 415 (1), 1-1); Walcott to Wilson, 28 Apr. 1915; Wilson to Scriven, 7 June 1915. (See appendix A, pp. 406-407.)
6. *First Annual Report of the National Advisory Committee for Aeronautics, 1915* (Washington, 1916), pp. 18 and 19 (hereafter such citations will be given as *AR 1915*). On the survey of aeronautical activities, see the correspondence in 57 A 415 (18), 20-1, 1915.
7. Biographical information on Victory is derived from a set of note cards on "Important Facts" that he prepared when being considered for the Wright Brothers trophy, from his nomination for the Career Civil Service Award of the National Civil Service League, dated 30 Aug. 1955, and from an interview with Victory's widow, Marie F. Victory, Tucson, Arizona, 21 Mar. 1977. Victory was born on 23 Jan. 1892, and described himself as standing 5 feet 9½ inches tall when he married in 1917, two years after joining the NACA. He himself was no doubt the source of the following information in his Career Service Award nomination:

He has worked continuously since age 11. At age 16, orphaned and homeless, he studied stenography at a night school. Promoted to stenographer at age 18 he was assigned to record proceedings of Navy courts martial, courts of inquiry, etc. Seeking highest proficiency at shorthand reporting he developed speed of 230 words per minute, bought the Success Shorthand School and made it a night school for training of shorthand reporters. While working at the Navy Yard he took annual leave to record Congressional Committee hearings during rush periods, Army courts martial and, while still running the school, became a convention reporter, substitute court reporter, and temporary night secretary to a U.S. Senator.

8. A copy of Daniels's letter of 17 Sept. 1915 accompanied Scriven's to secy., NACA, 2 Oct. 1915.
9. Scriven's proposal for a laboratory was endorsed by the Executive Committee on 14 Oct. 1915 and by the Main Committee at a special meeting the following day. Minutes, 14 and 15 Oct. 1915. At the latter meeting the \$85,000 figure was approved. The figure \$53,580 was provided for the record by Walcott to the House Committee on Naval Affairs after he testified before that body on 21 Feb. 1916. House Committee on Naval Affairs, *Hearings on Estimates Submitted by the Secretary of the Navy, 1916*, 64/1, 1916, 3 vols., 2: 1799-1813.
After the start of fiscal year 1918 on 1 July 1917, the comptroller of the treasury had ruled that NACA's organic legislation would be interpreted to mean that the funding of \$5000 a year for five years would apply to the fiscal years 1915 through 1919: i.e., the Committee could spend its first \$5000 during the first four months of its existence and begin the second \$5000 with the start of the new fiscal year. John Victory considered this one of his first and most cherished bureaucratic victories. George E. Downey, comptroller, to chairman, NACA, 5 Aug. 1916.
10. Daniels to the president, 30 Nov. 1915 (retyped copy incorrectly subscribed George P. Scriven).
11. Wilson to Daniels, 2 Dec. 1915.
12. Minutes, 10 Feb. and 9 Mar. 1916; diary of Walcott, 1916 box 16, Charles D. Walcott Collection, Manuscript Collection, Smithsonian Institution, Washington, D.C.; Public Law 241, 64/1, 29 Aug. 1916; minutes, 9 Oct. 1916.
13. *AR 1916*, pp. 12-15; "Subcommittees of Executive Committee of the National Advisory Committee for Aeronautics," 23 Nov. 1916, typescript. See appendix B.
14. For an illustration of the "silliness" that went on, see NACA minutes, p. 3, for 9 Sept. 1915, when the members of the Executive Committee listened as Dr. O.W. Owen of Detroit "described at length his idea of how an aeroplane could be sustained in the air by the principle of sympathetic vibration set up by seven bells of various sizes, which received sound waves from large musical tops rotated by a thirty-horsepower engine."
15. Minutes, 13 July 1916, p. 1. J.J.K., "Definition of a Right-Hand Engine," typescript, 23 July 1943, cites the following NACA Technical Reports as giving definitions: #15 (1917), #25 (1918), #91 (1920), #157 (1922), #240 (1926), and #474 (1933). The complete file is in 57 A 415 (63), 49-7. Victory interview, Colorado Springs, Colo., Oct. 1962, by Alfred F. Hurley, pp. 3-6.
16. Minutes, 2 Feb. 1916, p. 3. Walcott to J.H. Towers, 10 Feb. 1917.
17. On DeKlyn, see minutes, 23 Nov. 1916. Otto Praeger, second assistant postmaster general and the public official most closely linked to the development of the U.S. air mail, attended the annual meeting of the full Committee on 5 Oct. 1916. In succeeding years the Committee worked closely with Praeger and publicly supported the establishment of an aerial mail service. See, for example, *AR 1921*, pp. 23-24.

At the Executive Committee meeting on 11 Nov. 1915, "it was recorded as the sense of the meeting that commercial publishers should not be allowed to print scientific reports which are the property of the committee, until after their official publication by the committee." Minutes, p. 3.

18. Major contracts for 1916 and 1917 were:

Massachusetts Institute of Technology.....	\$800
Columbia.....	1500
Cornell.....	1000
Smithsonian Institution.....	3000
Stanford.....	4000

Durand's contract, the one listed under Stanford, was renewed in subsequent years.

In striking contrast to NACA behavior in this case, Josephus Daniels refused to fund much work by Naval Consulting Board members for just this reason. David K. Allison to author, 7 Aug. 1980. Durand's work under this contract is brilliantly described and analyzed in Walter G. Vincenti, "The Air-Propeller Tests of W.F. Durand and E.P. Lesley: A Case Study in Technological Methodology," *Technology and Culture* 20 (Oct. 1979): 712-51.

19. Unless otherwise indicated, the discussion on pp. 34-37 is based on the transcript of the "Public Session of Executive Committee of National Advisory Committee for Aeronautics Held at Smithsonian Institution, June 8, 1916," typescript, 58 pp. Walcott's remarks are on p. 1.
20. *Ibid.*, pp. 14-16. Coffin gave some examples of the kind of expertise that the automobile industry had fostered. "No magneto should carry a gear directly on its shaft," he reported. "We learned that in racing cars in 1906." He was even more emphatic on wiring. "The wiring in the average aeroplane is a joke," he told them. "You would not think of building a five hundred dollar garage without the underwriters passing on the wiring installation, yet you will spend ten thousand dollars on an aeroplane, and risk your life in it, and not give a damn as to the wiring." That last observation evoked the only laughter noted in the transcript of the meeting (p. 16).
21. *Ibid.*, pp. 16-28.
22. *Ibid.*, pp. 30-32.
23. *Ibid.*, pp. 10-11, 24-26, 34, 38, 50.
24. John F. Victory, "A Half Century of Aeronautical Research," address delivered at Norwich University, Northfield, Vt., 30 Apr. 1956.
25. Transcript of public session, 8 June 1916, p. 47.
26. *Ibid.*, p. 52. Henry Souther, the speaker, went on to say:
 Incorporated in that committee should be three classes of men, or four, perhaps: Manufacturers of planes, as such; manufacturers of the improvements that go into those planes; the users of the combination, that is, the entire airship, meaning principally the Army and the Navy fliers; and any other neutrals that we could find.
27. The application for the basic Wright patent was filed 23 Mar. 1903, granted 22 May 1906. Marvin W. McFarland, ed., *The Papers of Wilbur and Orville Wright* (2 vols.; McGraw-Hill, 1953), 2: 1228. On the patent dispute in general, see Fred C. Kelly, *The Wright Brothers: A Biography Authorized by Orville Wright* (New York: Harcourt, Brace and Company, 1943), chaps. 17 and 18; Howard Mingos, "Birth of an Industry," in *The History of the American Aircraft Industry: An Anthology*, ed. by G.R. Simonson (Cambridge: MIT Press, 1968), pp. 23-69; and the "Memorandum Regarding Patent Situation in the Early Months of 1917," incorporated in the minutes of the special meeting of the NACA Executive Committee, 27 Sept. 1917. For a detailed treatment see John F. Victory and Howard Mingos, "Patents and Problems," a 104-page typescript dated 1949, located in National Archives, record group 255, Records of the National Aeronautic and Space Administration, entry 2, box 1, unlabeled folder. (Hereafter NARS, RG 255, 2(1), unlabeled folder.)
28. Minutes of meeting of Executive Committee, 11 Jan. 1917, quoted in "Important Events in Early History of National Advisory Committee for Aeronautics," typescript prepared for Victory, 5 Dec. 1929. The letters from Roosevelt and Ingraham are cited in "A Brief Historical Review Outlining the Origin and Operations of the Manufacturers Aircraft Association, Inc. Following its Organization at Instigation of the Government, 1917," typescript, 11 pp., 24 Sept. 1935.
29. "Important Events in Early History"; minutes of special meeting of the Executive Committee, 3 Feb. 1917. Outsiders at the meeting were Howard E. Coffin of the Naval Consulting Board; E.F. Hagar, president of Wright-Martin; and Frederick P. Fish, counsel of Wright-Martin. In defense of their policies, Hagar and Fish maintained that "the required license fee of ten thousand dollars a year is equitable, and that any manufacturer who can not afford to pay it is not in a position to help in the development of the industry along scientific lines; in other words, that a manufacturer with a limited amount of capital invested in his business can not possibly make airplanes successfully in the present advancing state of the art." It was just this philosophy that was to anger critics of the cross-licensing agreement that resulted from these negotiations.

30. The automobile industry cross-licensing agreement was brought up at the 3 Feb. meeting, probably by Howard Coffin. John Victory later recalled that Coffin proposed this as a model at the June 1916 meeting with engine manufacturers, but I find no mention of it in the transcript of that meeting. Minutes of meeting of the Executive Committee, 3 Feb. 1917; Victory interview, Colorado Springs, Colo., Oct. 1962, by Alfred F. Hurley, p. 3-11. See also, "Patent Solution—Manufacturers Aircraft Association, Incorporated," *Aviation*, 1 Aug. 1917, p. 43.
31. Walcott to the president, 5 Feb. 1917.
32. Naval Act, 1918, Public Law 391, 64/2, 4 Mar. 1917. The members of the Subcommittee on Patents were Walcott (chairman), Samuel W. Stratton, John H. Towers, and S.D. Waldon of the Signal Corps.
33. Minutes of "Joint Meeting of the National Advisory Committee for Aeronautics and Aircraft-Manufacturers Association," 22 Mar. 1917. Walcott also discussed other problems facing the industry, but, as he had said in his 5 Feb. letter to the president, all of these could be resolved once the patent impasse was broken.
- Walcott explained why so many planes were needed for training: "European experience shows that it takes at least nine months to produce a properly trained advanced military aviator and that it costs approximately one and a half machines in wear and tear and breakage for each finished aviator. The breakages are most often made by the men who fail to qualify."
34. The outline of the plan is derived from the "Report of Subcommittee on Patents of National Advisory Committee for Aeronautics on the Present Aeronautic Patent Situation with a Suggested Plan for Its Solution," 23 Mar. 1917. This report explains how the Curtiss company came to be included in the settlement:
- In reviewing the records of the Army and Navy Departments as to planes purchased during the eight years prior to our recent heavy appropriations for Aerial Defense it was brought out that four men in four different factories supplied all of those planes and apparently contributed most in the development and reduction to practice of the aviation art. These named in the order of their appearance on the records are Wright, Curtiss, [W. Starling] Burgess and [Glenn L.] Martin. By a strange coincidence Curtiss and Burgess joined hands and later the Wright and Martin interests came together. While there are other aircraft patents, it was found that these two combinations owned and controlled what might be considered the two dominating groups of patents.
- The members concluded that "it is not within the province of this Committee to attempt to determine the value of one patent against another or the validity of any patent" and that "the relative contributions to the establishment of the aircraft industry as between Wright and Martin on the one hand and Curtiss and Burgess on the other hand may be said to offset each other, and that the recognition of each should be in the same total amount." The NACA might help with a settlement, but it was not going to invite trouble by comparing the merits of one patent against another.
35. Walcott to secretary of war, 24 Mar. 1917. At the 2 Feb. 1917 meeting, the Wright-Martin representatives had asked for \$2,000,000 in return for selling the patent outright, but they had agreed to accept \$1,000,000 "for the use of the Wright patent." Minutes of the Executive Committee meeting, 2 Feb. 1917.
36. Mingos, "Birth of an Industry," pp. 27-29.
37. See minutes of the meetings of the Subcommittee on Patents, 18 June, 10 July, 12 July 1917; minutes of meetings of the Executive Committee, 14 June and 12 July 1917; "Report of Subcommittee on Patents of the National Advisory Committee for Aeronautics," 18 June 1917; and W.F. Durand, "Memorandum Regarding Proposed Arrangements between Members of the Aircraft Manufacturers Association in Cases Where a Design Originated by One Manufacturer Is Placed by the Government with Another Manufacturer for Production," 23 June 1917. The need for the NACA's aid in resolving the controversy was manifested in a letter of S.D. Waldon to Walcott, 9 June 1917. Said Waldon:

It is becoming clear to me that unless the National Advisory Committee for Aeronautics takes hold there will be no cross licensing agreement or settlement of the patent situation. I know that most of the manufacturers, who were continually raising the question of right litigation at the time I was doing some special work for you and for General Squier and who repeatedly stated that settlement of the

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patent question was the most important thing that could be accomplished to help the industry, are now the ones most strongly inclined toward inaction instead of action

I would . . . recommend that the matter of getting the thing done be withdrawn from the Aircraft Manufacturers Association and undertaken by the National Advisory Committee for Aeronautics. [57 A 415 (67), 51-7, June 1917]

38. The most thorough discussion of the cross-licensing agreement appears in the minutes of the meeting of the Subcommittee on Patents on 10 July 1917. Minor revisions were made the following day, after the plan was presented to a meeting of the Aircraft Manufacturers Association, and on the 12th, when it was presented to the NACA Executive Committee. A good summary of how the agreement was finally reached appears in "Patent Solution," *Aviation*, 1 Aug. 1917, p. 43.
39. Durand to secretary of the navy, 27 July 1917; Josephus Daniels to Durand, 2 Aug. 1917; minutes of the Executive Committee meeting, 7 Aug. 1917. Of course the NACA had not really saved that \$1,000,000 for the government; the \$2,000,000 in royalties that would go to Wright-Martin and Curtiss-Burgess would come from higher selling prices for all aircraft. Since the government was to be the principal customer, it would bear the lion's share of this increased cost.
40. Frederick W. Barker to the president, 14 Aug. 1917; Rudolph Forster, executive clerk, the White House, to Newton D. Baker, 17 Aug. 1917; F.D. Keppel, secretary's office, War Department, to Gen. Squier, 17 Aug. 1917; S.S. Hanks, Capt., Signal Corps, Ofc. of the Chief Signal Officer, to NACA, 22 Aug. 1917; Durand to Barker, 17 Aug. 1917; Barker to Durand, 20 Aug. and 22 Aug. 1917; Durand to Barker, 25 Aug. 1917; Barker to Durand, 29 Aug. 1917.
41. Durand to Barker, 30 Aug. 1917; and Thomas A. Hill to Durand, 31 Aug. 1917. Hill advised Durand that the Aeronautical Society of America did not want to examine the NACA's records on the cross-licensing negotiations unless it could "secure a transcript and submit it to the advice of proper counsel." Durand to John H. Towers, 1 Sept. 1917, in 57 A 415 (67), 51-7, 9/17; Durand to Walcott, 4 Sept. 1917, 59 A 2112 (10), 17-3 Durand, July-December 1917; minutes of Executive Committee meeting, 13 Sept. 1917; "A Brief Historical Review Outlining the Origin and Operations of the Manufacturers Aircraft Association," p. 3, citing 31 Opinions Attorney General 166. The term "hymn of hate" is Howard Mingos's description of the criticism in "Birth of an Industry," p. 34.
42. "A Brief Historical Review Outlining the Origin and Operations of the Manufacturers Aircraft Association"; Mingos, "Birth of an Industry."
43. Years later George W. Lewis, the NACA's director of aeronautical research, revealed how sensitive this issue still was within the Committee when he advised the new chairman, Vannevar Bush: "the Committee tries to keep away from the 'patent problem' as much as possible." Lewis to Bush, 9 Jan. 1939, 57 A 415 (67), 51-7, 1935-. This last file is the major collection of NACA material on the cross-licensing agreement.
44. "Functions of National Advisory Committee for Aeronautics and Its Co-operation with the War Department," undated typescript under cover letter, R.P. Day to chief clerk, Ofc. of Chief Signal Officer, War Dept., 27 Oct. 1917; L.C. Stearns, report "On Inventions Handled by the National Advisory Committee for Aeronautics," 13 Apr. 1918; *AR 1918*, pp. 29-30. The NACA, which had begun as an aeronautical-inventions board for the War Dept., was soon performing the same service for other government agencies.
45. Minutes of special meeting of the Executive Committee 4 Apr. 1917. The minutes of the Executive Committee meeting of 11 Feb. 1927 state that the recommendation of an Aircraft Production Board flowed directly from a survey of the U.S. aeronautical industry initiated by Walcott, but the minutes of the 10 Apr. 1917 meeting contain no mention of such a survey. Perhaps this recommendation was confused with those generated by the tour of aircraft manufacturing facilities initiated by Walcott in Nov. 1917. (See note 47.) See also "Functions of National Advisory Committee for Aeronautics and its Cooperation with the War Department" and the annual reports for 1917 and 1918 for further examples of the NACA's war-time advisory work.
46. On Durand's trip, see "American Airplanes in World War I: Recollections of W.F. Durand," signed typescript, 19 Sept. 1941.
47. Quoted in *The Outlook*, 16 Jan. 1918, p. 87. In declaring Ames to be "unquestionably expert" in aeronautical matters, *The Outlook* editors repeated the credentials cited in the *Atlantic*

- Monthly*, that Ames had led a scientific delegation to Europe the previous summer. On Ames's European trip, see Joseph S. Ames, "The American Scientific Mission to France and England," *The Johns Hopkins Alumni Magazine* 6 (Nov. 1917–June 1918): 1–10. The trips to Dayton, Detroit, and Buffalo that prompted these remarks by Ames were initiated by Walcott and took place in Nov. 1917. *AR 1917*, p. 23.
48. *The Outlook*, 16 Jan. 1918, p. 87.
 49. Minutes of Executive Committee meetings, 1 Jan. and 24 Jan. 1918; Ames to Durand, 31 Jan. 1918, 57 A 415 (9), 2–11, 1918.
 50. Alice M. Quinlan, "World War I Aeronautical Research: A Comparison of the National Advisory Committee for Aeronautics and the National Research Council," NASA History Office HHN-135, 1974.
 51. On American organization for aeronautical research in World War I, see *ibid.*; also Robert G. Hilldale, "History of Development of Aircraft Production during the War of 1917," part V, "Organization," chap. 4, "Advisory and Co-operative Agencies," Air Services Historical Monograph, 1919, in National Archives, Record Group 18, Records of the Army Air Forces, entry 107, box 1; I.B. Holley, Jr., *Ideas and Weapons: Exploitation of the Aerial Weapon by the United States during World War I: A Study in the Relationship of Technological Advance, Military Doctrine, and the Development of Weapons* (New Haven: Yale University Press, 1953; Hamden, Conn.: Archon Books, 1971), esp. chap. 6; and A. Hunter Dupree, *Science in the Federal Government: A History of Policies and Activities to 1940* (Cambridge: The Belknap Press of Harvard University Press, 1957), chap. 16. On the movement to create a cabinet-level department of aeronautics, see minutes of the Executive Committee meeting, 26 May 1917, and Victory to Walcott, 5 Aug. 1918. Prophetic of what was to follow the World War, Victory advised Walcott that, though the present movement seemed bound to fail, "Dr. Ames and Dr. Stratton think that either a department of aeronautics or an air ministry, to accomplish the same result, is reasonably sure to come in time."
 52. The following comparison of the National Research Council and the NACA is based almost entirely on Quinlan, "World War I Aeronautical Research."
 53. *Ibid.*, p. 23.
 54. *AR 1917*, pp. 31–32.
 55. *AR 1917*, p. 12; *AR 1918*, p. 10. The 1917 amendment had other provisions as well; see app. A for the full text.
 56. Minutes of Executive Committee meetings 10 Jan. 1918, 23 Feb. 1918, and 8 Aug. 1918; *AR 1918*, pp. 24–25. The main source of information at this time was the Research Information Committee of the National Research Council. The chairman of that committee was also a member of the NACA, as was the head of the Department of Technical Information of the Bureau of Aircraft Production. The overlapping of memberships in the wartime aeronautical agencies was positively incestuous.
 57. Among those hired during the war were John H. DeKlyn, technical assistant, and Leigh H. Griffith, staff engineer. The Committee also employed George de Bothezat for a while before relinquishing him to the army. Minutes of Executive Committee meetings 11 Jan. 1917, 24 Jan., 25 May, 8 June, and 27 June 1918. For more on de Bothezat, see chap. 4.
 58. Minutes of Executive Committee meetings, 27 June 1918 and 23 Feb. 1918.
 59. Holley, *Ideas and Weapons*, p. 111.
 60. Robert A. Millikan to George Ellery Hale, 31 July 1918, and E.B. Wilson to Hale, 25 Apr. 1917, both quoted in Quinlan, "World War I Aeronautical Research," pp. 27, 10.
 61. Ames to Durand, 10 Aug. 1918.
 62. Victory to Durand, 31 Aug. 1918.
 63. Griffith to Executive Committee, National Advisory Committee for Aeronautics, 4 Sept. 1918. This letter was marked SECRET.

CHAPTER 3

1. On the condition of the American aircraft industry after World War I, see Howard Mingos, "Birth of an Industry," in *The History of the American Aircraft Industry: An Anthology*, ed. by G.R. Simonson (Cambridge: M.I.T. Press, 1968), esp. pp. 45–65; and Irving Brinton Holley, Jr.,

Buying Aircraft: Matériel Procurement for the Army Air Forces, United States Army in World War II, Special Studies (Washington: Office of the Chief of Military History, Department of the Army, 1964), chap. 2. Statistics in this and the following paragraph are from John B. Rae, *Climb to Greatness: The American Aircraft Industry, 1920-1960* (Cambridge: M.I.T. Press 1968), chap. 1.

2. Letter from S.S. Bradley, 14 Oct. 1918, cited in Executive Committee meeting minutes, 30 Oct. 1918. The quotation is from A. Hunter Dupree, *Science in the Federal Government: A History of Policies and Activities to 1940* (Cambridge: The Belknap Press of Harvard University Press, 1957), p. 337. Walcott reported the congressional sentiment in the minutes of the Executive Committee meeting on 14 Dec. 1918, and again in a letter to John D. Ryan, 1 Feb. 1919, in 57 A 415 (10), 11-9, 1919-1927. Military opinion of course found expression in the Committee itself and in the "Memorandum Report of the Committee on Invention and Research to the Chairman of the Board on Organization, Division of Military Aeronautics, War Department," dated 30 Nov. 1918. This report by Captains Adelbert Ames and Robert McNath and Prof. W.C. Sabine (who resigned from the NACA on the same date) recommended "that the Air Service look to the National Advisory Committee for Aeronautics for the solution of problems relating to scientific and technical research other than military, also for the commercial development of aeronautics, the continual output by universities and technical schools of scientifically and technically trained specialists, and the reference to research laboratories connected with industrial institutions of special aeronautical problems."
3. *AR 1918*, p. 27. The joint body formed in 1918, called the Special Interdepartmental Conference on Aerial Navigation, chose Walcott as chairman and appointed a subcommittee on aerial legislation. The activities of the conference were terminated by the transfer of some of its military members before the subcommittee got much beyond recommending establishment of a joint board to consist of representatives of all the government agencies involved in aviation. This notion of a joint board was to be the seed of later NACA ideas.

This chapter, whose specific focus is the place of NACA in the federal management of aviation, devotes little attention to parallel developments in state and international regulation of civil aviation. These developments, important in their own right, had considerable influence on the final form of national aviation legislation. See Donald R. Whitnah, *Safer Skyyways: Federal Control of Aviation, 1926-1960* (Ames: Iowa State University Press, 1966), esp. pp. 24-25; and Oliver James Lessitzyn, *International Air Transport and National Policy*, Studies in American Foreign Relations, ed. by Percy W. Bidwell, no. 3 (New York: Council on Foreign Relations, 1942), esp. chap. 15.

The struggle for passage of civil aviation legislation deserves its own monograph. The best secondary accounts are Nick A. Komons, *Bonfires to Beacons: Federal Civil Aviation Policy under the Air Commerce Act, 1926-1938* (Washington: U.S. Department of Transportation, Federal Aviation Administration, 1978); Laurence F. Schmeckebier, *The Aeronautics Branch, Department of Commerce: Its History, Activities, and Organization*, Institute for Government Research of the Brookings Institution, Service Monographs of the United States Government, No. 61 (Washington: Brookings Institution, 1930); and John F. Victory and Ruth Walrad, "Shaping a National Aviation Policy," typescript, 62 pp., chap. 7 of Victory's projected history of the NACA.

4. Minutes of Executive Committee meeting, 21 Feb. 1919; Walcott to the president, 21 Feb. 1919; U.S. Congress, House, *Regulation of Civil Aerial Navigation* . . . , H. Doc. 1828, 65/3, 26 Feb. 1919.
5. Minutes of Executive Committee meeting, 7 Mar., 24 Apr., and 25 Nov. 1919; and 57 A 415 (65), 50-7, Jan.-June 1920.
6. Ames to Walcott, 11 Dec. 1919, enclosing "Extracts from Report of Captain H.C. Mustin, U.S.N., to the Secretary of the Navy, on the Subject of Aviation Organization in Great Britain, France, and Italy." On Ames's search for information, see, for example, Ames to William Knight, 2 Dec. 1919, in 57 A 415 (66), 51-6G, 1919-1920. Ames may well have been particularly impressed by Mustin's evaluation because of its emphasis on the question of aeronautical research. It should be noted that the Crowell commission of which Mustin was a member generally endorsed the British model.
7. Special Committee on Organization of Governmental Activities in Aeronautics, "Memorandum," undated [ca. 11 Feb. 1920]. This memorandum was requested by the Executive Committee at its meeting on 29 Jan. 1920. Minutes.

8. The NACA files contain three copies of this draft bill, two marked received on 12 Feb. and one on 15 Feb. One of the 12 Feb. drafts is further identified as the "preliminary report of Special Committee on Reorganization of Governmental Activities in Aeronautics, Submitted Feb. 12, 1920," and it provided for a "Bureau of Air Service." The other 12 Feb. draft provides for creation of a "Bureau of Aviation." The two 12 Feb. drafts differed, in that the one creating a Bureau of Air Service dealt with the entire structure of government organization for aviation, and the one creating a Bureau of Aviation dealt more narrowly with organization of the new bureau within the Department of Commerce. The former draft was the basis of the 15 Feb. draft.
9. The Hicks bill was H.R. 14137, 66/2; the Kahn bill, H.R. 14061. At the time, Victory wrote to Ames: "Dr. Walcott says this is the last revised bill of the number that have been drawn up. He says the principles are the same as those enunciated by the Committee as worked over by Admiral Taylor and Captain Craven, and Dr. Walcott with Mr. Hicks. The latest Kahn bill has apparently been embodied as a whole for the regulation of air navigation." Victory to Ames, n.d., received for filing 21 May 1920. The Kahn bill parallels the draft creating a "Bureau of Air Service."
10. *AR 1920*, p. 11.
11. *AR 1920*, pp. 14-15.
12. Compare sections 3 through 6 of H.R. 14137 with the sections quoted above. The quote is from *AR 1920*, p. 54. See also minutes of Exec. Com. meetings, 11 June, 28 June, and 28 July 1921. Ames later said "it is thought that the proposed revision of the Hicks Bill giving certain additional functions to the Committee is a better method of handling the situation than the establishment of a second committee as contemplated in the original Hicks Bill." Ames to Thurman H. Bane, 12 July 1920.
13. Bane to Ames, 8 July 1920; Hayford to Ames, 4 Nov. 1920.
14. *AR 1920*, pp. 54-56, reprinted in full in appendix H. At the annual meeting of the NACA on 7 Oct. 1920, it was reported that "the Hicks Bill as modified was broader in scope than the Kahn Bill, and would in all probability encounter sufficient opposition to prevent its passage at the next session of Congress; and that for this reason the Executive Committee had decided to urge the enactment of the modified Kahn Bill." No mention was made of the distinction later drawn for President Harding by Walcott: "the difference between the Kahn Bill and the Hicks Bill is that the Hicks Bill, in addition to providing for the regulation of air navigation as contemplated in the Kahn Bill, also provides that the coordination of plans, estimates, and programs in aeronautical matters shall be considered by the National Advisory Committee for Aeronautics." Walcott to the president, 23 Mar. 1921.
15. Walcott wrote to Hicks 16 Apr. 1921:

Both the Kahn bill and your bill were thoroughly studied and considered by the Advisory Committee last summer during my absence in the west. I understand that the sections of your bill that I have mentioned were not included in the Kahn bill on account of the objections of the military members of the Committee, but they were left in your bill and incorporated in the Annual Report of the Advisory Committee in order that the Committee could express its approval of your bill, the first choice being given to the Kahn bill on account of its being more favorably considered by the military members of the Committee.

16. Walcott and Victory were surely advocates of the expanded role for the NACA. In his 16 Apr. 1921 letter to Congressman Hicks, Walcott said of the controversial sections of the bill: "From my personal point of view these . . . sections . . . will give just what is needed to thoroughly coordinate all Government activities in aviation." Victory was even more explicit, in the draft of a statement he apparently prepared for Captain Moffett for the information of Assistant Secretary of the Navy Roosevelt:

The committee is a well organized and efficient agency of the Government, which has functioned well in the past under the limitations of its organic act. It is the logical agency for the consideration of any special question regarding aeronautics, and affecting the general interests or the activities of more than one department of the Government. If the recommendations contained in its national aviation policy are carried into effect, there will be no need for the establishment of a new board of aeronautic control.

In other words, the NACA could handle all coordination of all aeronautical activities throughout all the government.

NOTES

17. Minutes of special meeting of the Executive Committee, 4 Apr. 1921.
18. Minutes of meetings of the Subcommittee on Federal Regulation of Air Navigation, 5, 6, and 7 Apr. 1921. Members of the subcommittee were Charles D. Walcott (chairman); Charles T. Menoher and Walter G. Kilner of the War Department; David W. Taylor and Kenneth Whiting of the Navy Department; E.C. Zoll and C.I. Stanton of the Post Office Department; Samuel W. Stratton and E.T. Chamberlain of the Department of Commerce; F.H. Russel, Glenn L. Martin, and Sidney D. Waldon from private life; and John F. Victory (secretary). Waldon missed the first two meetings, Zoll the second. Ames attended the second meeting, Lewis the last three.
19. Minutes of the third meeting of Subcommittee on Federal Regulation of Air Navigation, 7 Apr. 1921, pp. 7, 8.
20. Minutes of fourth meeting of Subcommittee on Regulation of Air Navigation, 8 Apr. 1921. At the close of this meeting, George Lewis was appointed chairman of a sub-subcommittee to draft appendixes to the report.
21. Walcott's version of these events appears in the minutes of the Executive Committee meeting, 14 Apr. 1921. See also 57 A 415 (65), 50-7, Jan.-June 1921. The full text of the majority report is in *AR 1921*, pp. 13-21. The report was published with the president's accompanying recommendation in U.S. Congress, House, H. Doc. 17, 67/1, 19 Apr. 1921.
22. For example, when the Subcommittee on Federal Regulation of Air Navigation was discussing inclusion of a statement on a separate air service, one of the government members asked for a definition of *United Air Service*. Gen. Menoher replied that "United Air Service is a term applied to a proposed Department of the Air, coordinate with other departments of the Government, under a Secretary of Air, independent of the Army and Navy." Minutes of fourth meeting, 8 Apr. 1921, p. 5. Actually this definition describes a mixture of a department of air and an independent air force.
23. Minutes of semiannual meeting, National Advisory Committee for Aeronautics, 21 Apr. 1921.
24. On the public controversy, see the documents presented by Ames in the minutes of the Executive Committee meeting, 12 May 1921, and the correspondence quoted in *Aviation*, 2 and 9 May 1921, pp. 552-58, 588-90.
25. Lester Gardner revealed this industry suspicion when he said in an editorial in the 9 May 1921 issue of *Aviation* that "it is only natural that officials in existing departments will not as a rule recommend the unification of government aviation."
26. H.R. 201, introduced by Kahn on 11 Apr. 1921 and H.R. 271 introduced by Hicks on the same day, were substantially the same: both were modified Kahn bills of the second session of the 66th Congress of 1920, which the NACA had endorsed in its annual report of 1920. The Committee now chose to rally behind the new Hicks bill. This legislation was described as "stop-gap" in a memo from Gen. Menoher, chief of the Army Air Service, to the adjutant general of the army, 16 May 1921. Ames's comments on H.R. 271 are in the minutes of the Executive Committee meeting, 9 June 1921.
27. An editorial in the *Army and Navy Journal* for 25 June 1921 said that in both services, Borah's bill (S.J.R. 77) "was generally credited to the advocates of the united air service plan with the idea of keeping it alive in the face of the general opposition to uniting the air services manifested in Congress, and particularly in the Senate." There is no satisfactory secondary treatment of the British experience. The reasoning behind the change in the pre-World War I system is presented in Great Britain, Air Ministry, Committee on Education and Research in Aeronautics, *Report*, presented to Parliament 12 Dec. 1919 (London, 1920). The results can be traced in *Aeronautics: Report of the Advisory Committee for Aeronautics for the Year 1919-20* (London, 1921), and *Aeronautics: Report of the Aeronautical Research Committee for the Year 1920-21* (London, 1921).
C.R. Finch Noyes's pessimistic letter of 4 May 1921 to L.Y. Spears reported that "400,000 pounds of last year's money was transferred from the Research Vote of the Air Ministry to the Maintenance Vote so that, where they might have obtained 400,000 pounds worth of sound research, the same money was spent in maintaining a number of useless, idle, overpaid, very often hard-drinking young men." Such a picture no doubt had a chilling effect on the NACA. Writing in a similar vein to William D. Tipton on 30 Apr. 1921, C.G. Grey, concluded: "Personally I have never been able to discover a solitary argument in favor of having a separate Air Force."
28. Paper prepared for William A. Moffett by John F. Victory, 21 June 1921.

29. Walcott to Roosevelt, 4 June 1921.
30. Lewis to Ames, 21 July 1921, and minutes of Executive Committee meeting, 28 July 1921; "Draft of the Bill submitted to Secretary Hoover by Mr. Howard Coffin, for the regulation of Air Navigation through the establishment of a Bureau in the Department of Commerce, being a modification of the Bill H.R. 271," 8-page typescript received in the NACA files 22 July 1921. Senator James W. Wadsworth introduced S. 2448 on 24 Aug. 1921; Congressman Hicks introduced H.R. 9184 on 17 Nov. 1921.

On NACA opposition to the changes in these bills, see Ames to Maj. G.C. Marshall, Jr., 29 Aug. 1921, and Victory to Walcott, 12 Aug. 1921.

A confidential "Progress Report on the Aeronautic Situation," prepared for the National Aircraft Underwriters Association and dated 10 Nov. 1921, said of the Wadsworth bill:

So far as I can ascertain this is a product of the commercial aviation interests. It goes as far in ignoring the National Advisory Committee for Aeronautics as the Hicks Bill went in endeavoring to concentrate regulatory work in the hands of the Committee. This Wadsworth Bill is now subscribed to by the National Aircraft Underwriters Association, The Manufacturers Aircraft Association, Ltd., and such manufacturers as The Curtiss Company. On the other hand the Bill is criticized for being so loosely drawn as to give too broad powers without limitation, for lacking essential definitions, for permitting duplication of the work of existing agencies, for involving law enforcement, policing, etc. beyond the proper scope of such an agency, and in general for preparing the way for a future Department of Aviation under the control of interests rather disassociated from the best interests of the Government.

31. Representing the NACA at the 8 Dec. meeting were Ames, Moffett, Patrick, Marvin, Lewis, and Victory; representing the opposition were Howard Coffin, Samuel S. Bradley, and F.H. Russell. Lewis and Victory got Sen. Wadsworth to introduce S. 2815 on 12 Dec. and Hicks to introduce H.R. 9407 on 9 Dec. Minutes of Executive Committee meeting, 26 Jan. 1922. Lewis's observation was in a letter to John J. Ide, 13 Dec. 1922. Victory earned a Bachelor of Law degree in 1923, a Master of Law degree the following year. His thesis, dated 15 Apr. 1924, is entitled "The Relation of Law to Aviation." Victory's role is exemplified by his action following hearings before the Senate Commerce Committee on the newly revised bill. He sent out 169 copies of the hearings to "various individuals identified with the development of aviation, including aero clubs, air boards, and manufacturers." Victory to Coffin, 23 Jan. 1921. A copy of his mailing list is attached to his letter to W.D. Tipton, 23 Jan. 1921.
32. The legal dispute over S. 2815 is beyond the scope of this study. It will suffice here to record Victory's view of the matter. On 16 Jan. 1922 he wrote to Wesley L. Jones, chairman of the Senate Commerce Committee:

Informal legal advice had been obtained from Government attorneys as to the constitutionality of Sections 8 and 15 of the pending measure. The question involves new principles in the law, on which good lawyers are frankly hesitant to express definite and positive views. In the light of the legal advice obtained, and after discussion with aviation authorities, I am of the opinion that no substantial change is necessary or desirable in the wording of the bill. The constitutional objections raised to Sections 8 and 15 as written in the bill are not conclusive or convincing. As these sections embody provisions which, in the opinion of those most concerned with aviation at the present time, will greatly aid the general development of aviation, it is urged that these sections be retained in the bill without substantial change.

The following day Victory wrote to Howard Coffin: "I really believe that the pending Wadsworth Bill has an excellent chance of passage at this session, in substantially its present form." That, however, was not to be. The bill was greatly modified in committee and a new version was introduced on 25 Jan. as S. 3076. Victory mentioned "objectionable changes" in a letter to C.M. Keys on 31 Jan., but added that "many compromises were necessary" and "it would not be good strategy to agitate senators over any present objectionable features." The same day he wrote to Ames that "strategy and politics have had their influence." See also Victory to S.S. Bradley, 14 Feb. 1922.

33. Victory wrote to Coffin on 16 Feb. 1922 that Winslow "has not been impressed with the importance of the measure," and Winslow himself wrote to Secretary of the Navy Edwin Denby the previous day reporting that he had "instituted a study of the question only to find

out that the field had not been thoroughly surveyed, and that no bill which has come into our hands has been sufficiently comprehensive to meet what we regard as the best interests of Government."

On the midwestern opponents of the legislation, S.S. Bradley wrote to Lewis on 16 Jan. 1922 that "four or five members of the [Chicago Air] Board had been informed, or came to the conclusion, that the Wadsworth-Hicks Bill had been drafted by a group of 'Eastern Manufacturers owning patents for the purpose of completing their strangle hold upon the aeronautical situation.'" In a letter of 22 July 1922, David W. Taylor asked Edward A. Deeds of Dayton, Ohio, about "renewal of agitation for the establishment of a Department of Aeronautics, to combine the Army and Navy Air Services and other aeronautical activities of the Government, and involving the dissolution of the National Advisory Committee for Aeronautics." To Taylor it seemed "that this agitation is centered in Dayton."

On the Lamb draft of new legislation, see Victory to Walcott, 1 Aug. 1922.

34. Winslow's bill was actually drafted by Frederic P. Lee of the House Legislative Drafting Service. See Lee to Victory, 6 Nov. 1922 and Herbert Hoover to Samuel S. Bradley, 10 Aug. 1922 (War Department copy). Lee properly referred to this measure as the Civil Aeronautics Bill, but in a letter of 20 Dec. 1922 to Winslow, Victory called it the Civil Aeronautics Act of 1923, the first time one of these bills took the short title that was to appear in the final act of 1926. The observation that the Winslow bill had merit is from the minutes of the special meeting of the Executive Committee, 20 Dec. 1923. Adm. Moffett expressed similar sentiments in a letter to Winslow, 22 Dec. 1923. See also the NACA "Synopsis of Civil Aeronautics Act of 1923," dated 19 Dec. 1922.
 35. Victory called the provision a joker; see his typescript "A Joker in the Winslow Bill, H.R. 13715," 29 Jan. 1923, and his letter to Stratton of 3 Feb. 1923, where he refers to "a number of jokers." Ames to Winslow, 2 Feb. 1923.
 36. Orville Wright wrote to Victory on 7 Feb. 1923:

I am decidedly of the opinion that the provision for a Civil Aeronautics Consulting Board, composed entirely of persons who are financially interested in the manufacture or use of aircraft, would not be to the best interests of the public—and as I understand it the bill is designed for the public welfare, and not merely for the welfare of people engaged in aeronautics for a livelihood.

It is but right that the industry should be in a position to place its views before the Secretary (of Commerce); but on the other hand it is quite as, or even more, important that the view of the general public be also expressed. It would be very difficult for a board constituted as provided for in the bill, however conscientious its members, to give unbiased advice.
- Victory, "One Bad Feature in the Winslow Bill, H.R. 13715," 30 Jan. 1923, a tempering of his "One Joker. . ." draft of the previous day.
37. Victory to Stratton, 23 Jan. 1923; W.A. Ross to Lewis, 15 Jan. 1923.
 38. At the conference on 6 Feb. 1923, Victory represented the NACA; Lt. Van Zant the army; Comdr. Cecil the navy; Coleman, Tinker, Robinson, Martin, and Hartney the N.A.A.; and Bradley and Bell the Aeronautical Chamber of Commerce. "Conference on Winslow Bill (H.E.H[artney].)," received in the NACA files 10 Feb. 1923. Winslow did not hold hearings on his own bill in the 67th Congress; minutes of Executive Committee meeting, 6 Apr. 1923. Victory's comments on H.R. 3243 are in a letter to Edward P. Warner, 7 Jan. 1924.
 39. Victory reported the pressure on the congressmen in a letter to Stratton 26 Jan. 1924. His characterization of the offending provision in the Winslow bill appeared in a letter to C.A. Tinker, 8 Feb. 1924. Coffin's telegram from Darien, Ga., dated 31 Mar. 1924, is in 57 A 415 (67), 51-7, 1920-1924.
 40. As early as Feb. 1923, Victory concluded that the offending portions of the Winslow bill were inserted to "undermine the Advisory Committee and lay a foundation for its abolition as the first obstruction to be overcome to establish a separate Air Service." Victory to John F. Hayford, 13 Feb. 1923. On the opposition of commercial aviators to the bill, see Ralph W. Cram to Lewis, 14 Mar. 1924. Cram, vice president of the National Aeronautic Association, enclosed in this letter a circular prepared by E.B. Heath, in which ironically the operators sided with the NACA in opposing the Civil Aeronautics Consulting Board. Wrote Heath:

All the members of the board are aircraft manufacturers, designers, and engineers. Of course the designers and engineers are in the employ of the Aircraft

Manufacturers Association, and should there be any operators they would also be under the control of the aircraft manufacturers, or they could not operate. Again the little fellow would have no show.

The NACA official was George W. Lewis, describing a visit by J.V. Martin in a letter to Jerome C. Hunsaker, 11 Apr. 1924. In the same letter, Lewis reported:

In the meantime the Daugherty investigating committee and the oil investigation committee have taken up the aircraft scandal and it looks as though they are stealing most of the thunder. . . . Just to keep things moving the House Naval Committee started hearings on a separate air service There is so much behind this that it is really dangerous to put it all in a letter, but the action at the time was rather dramatic.

41. See Joint Committee on Reorganization of the Administrative Branch of the Government, *Reorganization of the Executive Departments*, H. Rept. 937, 68/1, to accompany H.R. 9629, 1924. Victory reported to the annual meeting of the NACA on 16 Oct. 1924 that the joint committee had not heard a representative of the NACA before making its report. Walcott to the president, 25 Nov. 1924. *AR 1924*, p. iii. H.R. 9629 died in committee. *Congressional Record*, 68/1, Vol. 65, Pt. 10, p. 10414.
42. On the events leading up to the creation of the Lampert committee, see I.B. Holley, Jr., *Buying Aircraft: Materiel Procurement for the Army Air Forces*, United States Army in World War II, Special Studies (Washington: Off. of the Chief of Military History, Dept. of the Army, 1964), pp. 43-46. At the 12 June 1924 meeting of the NACA Executive Committee, Gen. Mason M. Patrick reported that James V. Martin—the same enemy of the NACA who had earlier waved his finger at Lewis and expressed an ambition to put the NACA out of business—had been retained by the Lampert committee as a witness with a monthly pay of \$300. Victory wrote to Walcott on 8 Aug. 1924 that "great pressure is being brought to bear to have the [Lampert] committee recommend a united air service." The committee's hearings were published as hearings before the Select Committee on *Inquiry into Operations of the United States Air Service*, 68th Cong. 1924-1925, 6 vols. The committee's report is H. Rept. 1653, 68/2, 14 Dec. 1925. Victory's comment about the sensationalism in the hearings is in a letter to Ames, 25 Feb. 1925.
43. *Congressional Record*, 68/2, Vol. 66, Pt. 6, pp. 9, 15; Victory to Frank E. Herbert, 19 Mar. 1925.
44. Archibald D. Turnbull and Clifford L. Lord, *History of United States Naval Aviation* (New Haven: Yale University Press, 1949), pp. 223-25, 249-51, and Alfred E. Hurley, *Billy Mitchell: Crusader for Airpower* (Bloomington: Indiana University Press, 1975), chap. 6. Victory's comment about the Mitchell "publicity stampede" is in a letter to Walcott, 9 Sept. 1925. I.B. Holley suggests that Coolidge appointed the Morrow board in response to requests from the secretaries of war and the navy to help answer the expected conclusions of the Lampert committee investigation. *Buying Aircraft*, p. 46.
45. Victory to Walcott, 9 Sept. 1925.
46. This change in posture can be traced through the NACA's annual reports. In *AR 1921*, the Committee claimed it had two roles: (1) research and (2) "consideration of special problems" that may be referred to it by any government agency (pp. 9-10). In *AR 1924*, the second part had been limited to "consideration of special problems in aeronautics" (p. 57). In *AR 1926*, it would claim only that it was "the governmental agency that supervises and conducts scientific research in aeronautics" (p. 66).
47. *Aircraft: Hearings before the President's Aircraft Board* (4 vols.; Washington, 1925), 1: 347-48; minutes of the third meeting of Subcommittee on Federal Regulation of Air Navigation, 7 Apr. 1921, p. 8.
48. The report of the Morrow board was *Aircraft in National Defense*, S. Doc. 18, 69/1, 30 Nov. 1925. Victory's comment on it appeared in a letter to H.L. Millsbaugh, 5 Jan. 1926. He was perhaps less pleased with the letter that Dwight Morrow wrote to Ames on 22 Dec. 1925. Said Morrow:

May I not express my thanks to you for the part you contributed to our testimony. Looking back over it, it is interesting to note that the aviation work of the Post Office Department and of the Advisory Committee on [sic] Aeronautics practically escaped all criticism. With your experience you may feel that you have done something wrong if no one has been throwing rocks at you. (From a copy of the letter in 57 A 415 (43), 25-42.)

After three months of intensive study of American aviation, Morrow still did not know the correct title of the NACA!

49. In commenting on the legislation that was introduced in the first session of the 69th Congress, Ames said:

A careful examination of the bill . . . discloses the desirability of a number of changes, some of which were included in former bills on this subject. In view, however, of the failure of all previous efforts to enact similar legislation, our Committee is loath to recommend changes at this time from the text of the bill as introduced . . . , which may have the effect of jeopardizing or delaying passage of the bill at this session of Congress.

In a similar vein, Howard Coffin wired Lewis on 18 Feb.:

It is my opinion that a start on commercial aviation legislation in its simplest form must be made STOP Any law now enacted will be improved by amendment as future experience points way STOP The important thing is to get on with the job without striving for too much perfection in our first efforts in this line.

Lewis replied: "For once we all agree as to the advisability of restricting Federal legislation affecting aerial navigation to interstate flying and that the bill be passed in the simplest possible form." Undated letter, received for filing 20 Feb. 1926.

50. Senator Hiram Bingham introduced S. 41 on 8 Dec. 1925. Congressman James S. Parker introduced an identical bill, H.R. 4772, on 10 Dec. 1925. In amended form these bills became Public Law 254, 69/1, on 20 May 1926. The army legislation was P.L. 422, 69/1, 24 June 1926; the navy's was P.L. 446, 69/1 2 July 1926. The Kelly Act, P.L. 359, 68/2, had been approved 2 Feb. 1925.

The only hitch in S. 41 as first introduced was that it called for the transfer of the NACA to the Dept. of Commerce, a provision reportedly insisted on by Secretary Hoover, who apparently took up the position of his subordinates in the Department of Commerce. After considerable behind-the-scenes politicking, that provision was removed from the bill. See Victory to Durand, 18 Dec. 1925. Hoover's belief that the NACA should be transferred to the Department of Commerce would return more than once to haunt the Committee.

CHAPTER 4

1. For example, at the special meeting of the Main Committee on 15 Oct. 1915, Prof. John F. Hayford, director of the College of Engineering at Northwestern University, outlined what he thought the policy and functions of the NACA should be, but the ensuing discussion got little beyond details. Minutes, pp. 3-4. Hayford expanded on these suggestions in a letter to Durand 28 Apr. 1917. The policy he proposed was adopted by the Executive Committee on 7 Aug. of that year and by the full NACA the following October. However, this policy never received the formal endorsement of publication in an annual report, and the Committee seems to have been little affected by its provisions.
2. See p. 48; and Ames to Durand, 10 Aug. 1918; Victory to Durand 31 Aug. 1918.
3. See minutes of the NACA meeting, 10 Oct. 1918. In *AR 1918* the Committee attempted to define the "Functions of the Committee," but these were directed more toward the NACA's place in the federal scheme of things than to a research program and a staff to administer it. Instead of establishing an organization and procedure for the NACA as a whole, each of the existing subcommittees prepared a statement of its function, organization, and program. See Victory to Walcott, 11 Sept. 1918. This preliminary to defining functions for the NACA produced nothing further until the spring budget crunch. See minutes of Executive Committee meeting, 23 Sept. 1918. On activities in the spring of 1919, see minutes of Exec. Com. meeting, 7 Mar. 1919.
4. Appendix B; minutes of the NACA meeting, 20 Apr. 1916, p. 3; Ames to Durand, 10 Aug. 1918.
5. Once more Leigh M. Griffith provided good advice to the Executive Committee (see chapter 2, note 63). His memorandum of 8 Apr. 1919 suggested that the technical committees then being formed be restricted in number, limited in membership, and administered by secretaries who would be salaried staff of the NACA, to prevent unnecessary meetings and bothering committee members with routine business. This is very nearly the policy finally settled upon

by the NACA, but it is not clear that Griffith's suggestion was responsible. Rather, the Committee seems to have fallen into the pattern he suggested.

6. For a detailed glimpse into the history and early workings of the Office of Aeronautical Intelligence, see L.C. Stearns to Ames, 3 Apr. 1919. Staff member J.H. De Klyn had referred to the NACA in 1917 as "a clearinghouse for scientific knowledge." See De Klyn, "Suggestions for Compilation of an Aeronautical Handbook to be Published by the National [Advisory] Committee for Aeronautics" (ca. 19 Jan. 1917), in 57 A 415 (44), 27-1. On the efforts to make the holdings of the Office of Aeronautical Intelligence complete, see 57 A 415 (46), 32-5, 1919.
7. The first representative of the NACA in Europe was William Knight, who had suggested the idea to the Committee in a letter dated 26 Mar. 1919, while he was still a first lieutenant in the Air Service. On 27 May 1919, Knight was appointed technical assistant and transferred to the Paris office of the Committee. At first the Committee was pleased with Knight's work and resisted efforts by the military services to eliminate his post. Part of the protest was just a case of military attaches jealously guarding their own territory, as when the assistant chief of the Air Service in the American Expeditionary Force asked Knight concerning the relationship between the NACA and the services, "Did you ever hear of a child's supporting his parents?" (Reported in Knight to NACA, 2 July 1919 in 57 A 415 (66), 51-6.) But soon it became apparent that Knight was simply not the man for the job. On 14 Dec. 1920, Maj. Benjamin D. Foulois wrote to B. Gen. M. Churchill: "Mr. Knight, as a former Air Service officer, was under my command during the war, and on duty in Paris. He is an excellent technical man, but I would never recommend his employment for any position where tact, diplomacy or good business judgement is required." (NA RG 255, Series 3, box 24, loose papers at front of box.) Lewis reminded Ames, 26 May 1922, that "Mr. Knight invited difficulties by interchanging European information among different European countries." (NA RG 255, entry 3, box 1, Joseph S. Ames, 1915-1924)

On the early years of the Paris Office, see 57 A 415 (66), 51-6G, 1919-1920. On Knight, see minutes of Executive Committee meetings, 4 Apr., 20 May, 20 June, and 12 Sept. 1920, and the minutes of the NACA meeting, 7 Oct. 1920. The characterization of the NACA European representative as a fifth wheel was reported in John J. Ide to Lewis, 15 Mar. 1923, in 57 A 415 (66), 51-6G, 1921-1923.

8. Minutes of Executive Committee meetings 14 Apr., 21 Apr., and 14 May 1921. The kind words about Ide were from Edward Warner, reported back to Ide in Lewis's letter of 21 Aug. 1922 in 57 A 415 (66), 51-6G, 1921-1923. Lewis told Ide as early as Dec. 1921 that "we all feel that you have been successful in handling the Paris Office and personally I wish to congratulate you especially in view of the relations Mr. Knight had created." Lewis to Ide, 13 Dec. 1921, in 57 A 415 (66), 51-6G, 1921-1923.

Ames reported to Lewis from Paris on 20 June 1923 that "Hunsaker says Ide is the only man in Paris who has 'contacts,' and he is right. The attaches don't amount to much." (NA RG 255, entry 3, box 12, Hunsaker, 1916-1935)

9. See *AR 1926* for details on how the NACA planned to execute its responsibilities under this section of the Army Air Corps Act of 1926.
10. Minutes, NACA meeting, 15 Oct. 1915.
11. At least two academics were considered for the post of director of aeronautical research during the war, Prof. L.V. King of McGill University, Montreal, and "Dr. H.W. Bridgeman" of Harvard (probably P.W. Bridgman, the Harvard physicist and subsequent Nobel laureate). The Committee came very close to hiring King, but he declined at the last moment. See 57 A 415 (10), 9-2; minutes, Executive Committee meeting, 23 Mar. 1918. Before settling on Lewis, the Committee offered the post of executive officer to Dr. Cary T. Hutchinson, a physicist by training but an engineer by experience. He too declined. Minutes, Executive Committee meeting, 17 Feb. 1919.
12. See the biographical memoir reprinted from the *Year Book of the American Philosophical Society*, 1948, pp. 269-78. See also *AR 1918*, pp. 25-26; NA RG 255, Series 3, box 28, "George W. Lewis"; William F. Durand to H.C. Dickinson, 8 Aug. 1917 in 59 A 2112 (10), 17-3 Durand, July-Dec. 1917; C.D. Walcott to Clarke Thomson [ca. 3 June 1919]; S.W. Stratton to Local Draft Board #2, Swarthmore, Pa., 26 Sept. 1918; Victory to Adm. Land, 2 Aug. 1934, enclosing "Biographical information with regard to Dr. Lewis"; Ames to Executive Committee, 10 Sept. 1919; Lewis to Robert P. Lesley, 9 July 1923; and minutes of Executive Committee

meetings, 9 Oct. and 25 Nov. 1919. The NACA regulations were amended in 1919 to accommodate the new position of executive officer; see appendix A.

13. See appendix C, esp. table C-2. Note that funds for "General Purposes" never decreased during these years. Lewis nominally took over the budget duties from Victory, who had been performing them unofficially from the outset, officially since July 1918. Minutes, Executive Committee meeting, 30 July 1918.
14. See pp. 265-266 and appendix C, esp. table C-1. In these early years the NACA budget usually passed with ease. For example, Lewis wrote to Redmond D. Stephens on 16 Apr. 1924: "Our hearings before the House Appropriations Committee were most satisfactory, and the only comment made on the Committee's item was in the House, which comment was favorable." 64 A 518 (8), 1925.
15. The Bureau of the Budget was created by the Budget and Accounting Act of 1921 (42 Stat. 20). The philosophy behind it was similar in many respects to that behind the creation of the NACA. At a meeting of government executives on 29 June 1921 to inaugurate the new budget system, President Harding spoke of the "necessity of driving at the loose, unscientific expenditures of government." His first budget director, Gen. Charles G. Dawes, called his audience "business men, a part of the business administration . . . which for the first time commences functioning under a president of a business corporation who is also the President of the United States." (Transcript, pp. 1, 3)
16. Meetings of Executive Committee, 31 Aug. 1922 and 10 Jan., 19 Jan., and 6 Apr. 1923.
17. Ames reported to the Executive Committee meeting of 20 Sept. 1924 that "General Lord, Director of the Bureau of the Budget . . . disapproved the practice of this Committee in recommending to Congress in its annual reports increased appropriations for the Army and Navy Air Services, as being outside the functions of the Committee." (Minutes) Lewis wrote to the chairman and secretary of the Executive Committee on 9 June 1920:

The Committee's appropriation for the fiscal year 1921 is \$200,000, as compared with \$175,000 for the current fiscal year. However, during the current fiscal year the Committee has found it necessary to secure outside financial assistance, to the extent of \$11,000 in order to carry through its research work.

Unless the program of essential aeronautical research work which the Committee has recommended be seriously curtailed, the appropriation for the fiscal year 1921 will be insufficient, and it will be necessary for the Committee to consider the question of securing additional funds. (64 A 518 (8), 1921)
- See appendix C, esp. table C-5. At the Executive Committee meeting on 25 June 1925, George K. Burgess reported that, at a luncheon at the Bureau of Standards, the director of the Bureau of the Budget cited the NACA as "an example of true cooperation with a high degree of efficiency unexcelled in the Government service."
18. See appendix C, esp. table C-1.
19. At least three attempts have been made to write a history of the NACA's Langley Memorial Aeronautical Laboratory. By far the most comprehensive is Michael David Keller, "From Kitty Hawk to Muroc: A History of the NACA Langley Laboratory, 1917-1947," NASA History Office HHM-15 (1969), an expansion of his earlier "Fifty Years of Flight Research: A Chronology of the Langley Research Center, 1917-1966," HHN-65. The best technical treatment is Hartley A. Soule, "Synopsis of the History of the Langley Research Center, 1915-1939," HHN-40, by a veteran NACA engineer. John Victory and Ruth Walrad drafted a chapter on "The Langley Laboratory" for their projected history of the NACA.
20. John Victory was the source of a delightful anecdote and a serious misunderstanding about the role of the navy in the selection of Langley Field. He told two different interviewers on occasions nearly twenty years apart that the navy wanted a research field near the water and the army wanted one inland, and neither agency wanted their interest to come to the attention of local land speculators. So the navy representatives conducted their site surveys disguised as fishermen while the army representatives conducted theirs disguised as hunters. More misleading than this harmless bit of apocrypha is Victory's assertion that the navy backed out of the Langley site after some progress had been made. It is true that the notion of a joint site was discussed with navy representatives present, but H.C. Richardson quickly squelched any expectations the NACA may have had about navy participation. Writing to Walcott on 4 Dec. 1916, Richardson said:

I note in the revision of the Second Annual Report that you make certain references as to the flying field selected by the Army, and the possibility of joint

occupation by the Army, Navy and this committee. The statements made are not specific, but are broad in general, except that from this report the inference may be drawn that the Navy Department has approved this site as suited to its own purposes; also that the Navy Department has committed itself to this joint occupation.

While I agreed with the committee in its general report as to the desirability of co-operation in this work, I do not feel that my action should be interpreted as indicative that the Navy Department does commit itself to this plan, for, as a matter of fact, I very much doubt that the Department does so want to commit itself, as the Department has a special commission now investigating this particular subject by authority of Congress, and would naturally, therefore, not want to commit itself to any project which might conflict with the findings of that commission.

I, of course, do not know whether you have received any assurances direct from the Navy Department as to its attitude, but submit these comments in order that you may not misunderstand my position in the matter.

- I know of no other assurances received by the NACA from the Navy Department. The Helm board, to which Richardson referred, made no definite recommendations as to sites, but its successor chose Norfolk for its air base. Aeronautical research for the navy was conducted at Philadelphia. Victory's comments are in the transcript of his interview with Alfred F. Hurley, Oct. 1962, pp. 3-7—3-8, and in the transcript of his interview with John L. Robson, 23 Aug. 1944, cited in Robert I. Curtis, John Mitchell, and Martin Copp, *Langley Field, The Early Years, 1916-1946* (Langley AFB, Va.: Office of History, 4500th Air Base Wing, 1977), p. 11. See also Turnbull and Lord, *Naval Aviation*, pp. 74-78.
21. Minutes of Exec. Com. meetings, 9 Oct. and 9 and 23 Nov. 1916.
 22. [Historical Division, Headquarters, Tactical Air Command, U.S. Air Force,] *50th Anniversary: Langley Air Force Base, Virginia* (n.p.; n.d.); Curtiss, Mitchell, and Copp, *Langley Field, The Early Years*, pp. 14-17; Maurer Maurer, "McCook Field, 1917-1927," *Ohio Historical Quarterly* 67 (1958): 21-34; John Victory to Orville Wright, 20 Sept. 1945, in 62 A 35 (15), 170.2 (semi-official) (1); and "Report of the Sub-Committee on a Site for Experimental Work and Proving Ground for Aeronautics," 21 Nov. 1916. The quote about the bottleneck is attributed by Victory to Gen. George O. Squier.
 23. Sgt. James Cunningham, quoted in Curtiss, Mitchell, and Copp, *Langley Field, The Early Years*, p. 13.
 24. See Keller, "From Kitty Hawk to Muroc," pp. II-16—II-23.
 25. Victory to sec. of the NACA, 5 Oct. 1918; Lewis to Ames, 9 Apr. 1925, in NA RG 255, entry 3, box 2.
 26. John H. DeKlyn to Ames, 9 July 1919, enclosing memorandums by himself and Edward P. Warner, in 57 A 415 (20), 21-2, 1916-1921.
 27. Victory, "Memorandum Regarding Use of Langley Field by National Advisory Committee for Aeronautics," 27 Sept. 1919.
 28. *AR 1919*, pp. 13-14.
 29. Ames wrote to Samuel Stratton on 29 Jan. 1921 pointing out some of the shortcomings of Bolling Field. Across the top of his memo he wrote: "Not for discussion with Gen. Mitchell." Keller believes that, within two months of Ames's memo, the decision was made. "From Kitty Hawk to Muroc," pp. II-26—II-27.
 30. Curtiss, Mitchell, and Copp, *Langley Field, The Early Years*, p. 13; *AR 1920*, pp. 8-9; transcript of speech by Lewis to staff, Langley Memorial Aeronautical Laboratory (hereafter LMAL), 4 Oct. 1938, in 57 A 415 (44), 29-1.
 31. DeKlyn, hired by the Committee as a technical assistant in 1916, took up his duties at Langley Field shortly after NACA construction was authorized. Victory's chastisement appears in his letter to DeKlyn of 7 May 1919. In that year DeKlyn was earning \$3500 a year, Victory, \$3300. Minutes of Executive Committee meeting, 1 Apr. 1920.
 32. Victory to Lewis, 12 Feb. 1920.
 33. Lewis to LMAL, 31 Oct. 1922. On the more successful relations between Victory and Griffith, see Victory to Griffith, 11 Mar. 1920, Griffith to Victory, 13 Mar. 1920, and Victory to Griffith, 22 Mar. 1920. Even before taking over at Langley, Griffith had given considerable thought to how the laboratory should be organized and administered. See, for example, his memorandum to the NACA (ca. 3 Aug. 1918) in 57 A 415 (10), 9-2.

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34. Keller, "From Kitty Hawk to Muroc," pp. II-23—III-7. On the research policy, see appendix F and pp. 103–106 below; on the NACA camp, see p. 121. Both Lewis and Griffith came from backgrounds in engine work, and both were introduced to government service by William F. Durand. They collaborated on the Roots supercharger, both before and after Lewis joined the NACA, and they stayed in touch long after Griffith left the Committee. Of their early collaboration, see, for example, Griffith to Lewis, 2 July, 31 July, 11 Oct., 27 Oct. 1919 and 6 Jan. 1920, and Lewis to Griffith, 11 Oct. 1919.

On the organizational scheme at Langley, see Victory to LMAL, 8 May 1923; Griffith to Victory, 10 May and 12 May 1923; Griffith to Lewis, 4 Oct. 1923; Lewis to LMAL, 6 Oct. 1923.

35. Victory to LMAL, 20 Oct. 1924.
 36. Griffith to Victory, 22 Oct. 1924.
 37. As early as 1920, shortly before Warner left his position as chief physicist at Langley to return to MIT, he and Griffith asked whether they had to adhere to one of Victory's directives since it had been signed by only an "Assistant Secretary." This correspondence and the 1925 exchange between Griffith and Victory are in 57 A 415 (22), 21-24, 1921-1933. Most of the same material, plus Griffith's final comment on the evidence of Victory's ignorance, is in the "Langley Historical Material" collected by Milton B. Ames for a history of the laboratory, box 4, under "Miscellaneous Correspondence." This folder is marked: "Local NACA Hqts—Langley color" and "Note: Strict discipline req'd."
 38. For example, Warner left in June 1920 to return to MIT and physicist David L. Bacon left in 1924 to take a job with industry. Warner was the most prolific author the Committee had; in a letter to Ames dated 27 Sept. 1924, Lewis called Bacon's departure a "severe loss to the Committee," one that Lewis did not know how to remedy. On the departure of promising young staff members, see the correspondence between Lewis and Griffith in NA RG 255, Series 3, "George W. Lewis," especially in 1919. See also Leigh M. Griffith, "Report of the Engineer-in-Charge of the Langley Memorial Aeronautical Laboratory to the Executive Committee of the National Advisory Committee for Aeronautics," 31 Dec. 1925, pp. 4-7, 17.

Victory was no more officious with the Langley staff than he was with his own in Washington. In 1918, for example, he issued the following "Memorandum for all Employees":

It has been . . . observed that certain employees are abusing the privilege of 15-minute recesses, morning and afternoon and are staying out from twenty to twenty-five minutes. There is no need for confusion on this point as a bugle is blown at the beginning and end of each recess. (62 A 129 (11), "24 Hours of Duty 1918-1951.")

One Langley employee who apparently could get along with Victory was Frank E. Herbert, chief clerk from 1920 to 1922. If his request for supplies and personnel on 7 Apr. 1921 is any indication, the key to success with Victory was frankness and a certain disdain for the engineers. Herbert justified his request for another clerk-stenographer because "this Laboratory force has grown and they are turning out a lot of deep stuff or pretending they are, which is all the same where the stenographers and clerks are working up the details." He concluded his appeal: "You will not hurt my feelings if you turn the propositions down after you've given them some consideration. But do'nt [sic] pull any snap judgment stuff on them."

39. Though Griffith's fate was sealed in the spring of 1925, he stayed on officially as engineer-in-charge until the end of the year. In the intervening months, Marsden Ware and Henry Reid shared duties as head of the laboratory. Reid proved the more acceptable and took over in 1926. Keller, "From Kitty Hawk to Muroc," pp. III-7—III-8. Reid and his colleague, R.V. Rhode, developed the V-G recorder in 1930, after Reid had taken over direction of the Langley laboratory. George W. Gray, *Frontiers of Flight: The Story of NACA Research* (New York: Alfred A. Knopf, 1948), p. 168.
 40. Before Reid took over from Griffith, Victory visited the laboratory and reported that the "girls" in the office "did not know whether the Committee was a corporation, a stock company, or a partnership, and finally guessed it had some connection with the Government." Victory to Lewis, 3 Aug. 1925. Victory and Reid were equal to dispelling that confusion and ensuring that it never returned.
 41. The quoted phrase is from a typescript transcription of testimony of Samuel W. Stratton before a subcommittee of the House Appropriations Committee on the Independent Offices Appropriation bill for 1919. Joseph Ames used the terms "technical development work and

... experimental problems" when describing the activities of McCook Field in a 5 Jan. 1920 letter to Charles T. Menoher. Thurman H. Bane spoke of "production and engineering of Army and Navy airplanes" in a 4 Feb. 1920 letter to Ames. The clearest exposition of the NACA position came in the *Annual Report for 1925*, p. 56: "Without attempting to be specific, the committee is of the opinion that the military and naval services should maintain aeronautical engineering divisions which should be charged primarily with the formulation of specifications of military aircraft, their characteristics and performance; with the critical examination and testing of designs and of aircraft offered by the industry; and with such experimental and development work as can be carried on by them most effectively and most economically."

The navy had established an aircraft factory in Philadelphia during World War I to manufacture seaplanes, but throughout most of its history the facility did more research and testing than manufacture. Turnbull and Lord, *History of United States Naval Aviation*, pp. 116, 117, 285-86.

42. Dr. Stratton, as head of the National Bureau of Standards and a member of the NACA, spoke for both agencies. He told Congress that the NBS limited itself to "the fundamental physical propositions," which he was pleased to call "scientific work of the highest class . . . , a laboratory problem pure and simple." "The problems at the Langley Field laboratory," he observed, "are more or less those that are specific to aviation," even though of the same fundamental character. Extracts of his testimony on the Independent Offices Appropriations bills for 1919, 1922, and 1923. See also the typescript "Allocation of Experimental Work in Aeronautics" [ca. 10 Jan. 1921], which assigns to the NBS and the NACA "the conduct of scientific research or the investigation of the more fundamental problems."

In forwarding his suggestions for an aeronautical research program for the Committee, Jerome C. Hunsaker wrote to Ames on 9 Sept. 1920: "I have assumed that the general policy will be approved that Langley Field shall, so far as possible confine itself to scientific research rather than miscellaneous engineering experiments."

43. Rexmond C. Cochrane, *Measures for Progress: A History of the National Bureau of Standards* ([Washington:] National Bureau of Standards, U.S. Dept. of Commerce, 1966), pp. 179-86, 276-86. At least one NACA employee felt that the NBS got the engine work because of Stratton's position as chairman of the Power Plants Committee.
44. This interpretation is somewhat at odds with that of Robert Schlaifer, *Development of Aircraft Engines* (Boston: Graduate School of Business Administration, Harvard University, 1950), which maintains that the NACA was unfit for the development work required in improving engines. I believe Schlaifer has discounted excessively the extent to which aircraft-engine manufacture in World War I was in the hands of automobile-engine manufacturers, and thus beyond the NACA's reach. I do, however, agree with Schlaifer that by 1926, even in engine research, there was an increasing duplication of effort by government and industry. C.M. Keys, president of Curtiss Aeroplane and Motor Company, wrote to Ames on 16 Jan. 1926 asking for greater coordination between the public and private sectors in aeronautical research. He warned: "I think it will presently prove altogether unprofitable to us or anyone else to maintain a highly developed laboratory in aviation, either in motors or in planes, unless some sort of an understanding is reached as to this matter between the Government agencies carrying on such work, and the companies engaged in it."

On the care taken by the NACA not to intrude on the domain of any other government agency, see, for example, Lewis's letter to LMAL of 12 Aug. 1924, in which he warned "there is a certain amount of resistance on the part of the personnel of all the services in handing over to the committee what in their minds is the proper function of their experimental departments." 57 A 415 (20), 21-2, 1922-1931.

John B. Rae, *Climb to Greatness: The American Aircraft Industry, 1920-1960* (Cambridge: MIT Press, 1968), p. 24, substantiates my contention that the NACA avoided engine work because the industry was already working in the field; he further maintains that aerodynamics promised the greatest return on capital investment for research equipment, but I find no convincing evidence to support the latter contention. Rae cites Jerome C. Hunsaker, "Forty Years of Aeronautical Research," *Smithsonian Institution Annual Report for 1955* (Washington: Smithsonian Institution, 1956), pp. 262-63, but this article was actually written for Hunsaker by Walter T. Bonney, public relations officer for the NACA, and the cited passage is an attempt to explain why the Committee failed to develop jet propulsion before World War II. See pp. 186-194.

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45. On 11 Feb. 1922, Lewis wrote to the staff at Langley:

Dr. Ames and I both realize the importance of interesting the Committee as a whole in the scientific research that the Committee is carrying on, but feel that the matter must be presented to the members in such form that it will demand their immediate interest, and not be read to them in the form of a report. This will be in line with the functions of the Committee, and I feel that it will also be of an educational value, as most of the members of the Committee, with the possible exception of Admiral Taylor, do not fully appreciate the necessity of their hearty support of scientific research. (57 A 415 (5), 1-16G)

Lewis once told Edward P. Warner, the former chief physicist at Langley and later a member of the Main Committee, that he [Warner] was the only one on the Committee qualified to understand what the laboratory was doing.

In 1917 Prof. John F. Hayford proposed a research program for the NACA that was accepted as policy; it was very general, however, and had little influence on the actual research conducted at Langley. See note 1; Hayford's "Memorandum on Free Flight Tests of Airplanes," 11 Sept. 1917 in NA RG 255, entry 3, box 9, Hayford, 1915-1917; and the minutes of the Executive Committee meeting of 7 Aug. 1917 and of the NACA, 4 Oct. 1917.

46. See appendix H for Griffith's memorandum.

47. Ames to Stratton, 18 May 1918.

48. Stratton to Ames, 20 May 1918. Most of the following material on Bothezat is derived from his two biography folders in NA RG 255, entry 3, box 5.

49. Bothezat to Subcommittee on Buildings, Laboratories and Equipments, 15 Feb. 1919. In the same report Bothezat made another suggestion that was to take root within the NACA:

From a general standpoint a programme for research must not so much consist in a detailed enumeration of all the questions and problems that can be submitted to research or investigation but rather give the systematization of these problems or questions. That is what I have tried to do in the programme herewith presented. What concerns the detailization of such a programme in each special case it must be left fully to the liberty of those who will undertake these researches, and this is fully necessary for the success of the researches themselves.

The autonomy which NACA laboratory personnel were in later years to cherish so dearly had its beginning here.

50. The warning about Bothezat came from Prof. E.B. Wilson of MIT, in a letter of 10 Dec. 1918 to Joseph Ames. Wilson also warned that F.W. Lanchester, one of the greatest contemporary authorities on aeronautics, had said of Bothezat's work on stability:

When we examine the work so described we find the subject not more than one-half dealt with and in so ineffective a manner that scarcely one of the conclusions can be regarded seriously.

On Bothezat's dispute with Hunsaker, see Hunsaker to Ames, 22 July 1919; Bothezat to editor, *Aviation and Aeronautical Engineering*, 2 Sept. 1919; and Victory to Bothezat, 16 Sept. 1919, enclosing a suggested revision to his letter of 2 Sept. 1919. Bothezat's sorry record at McCook Field is reported, perhaps with some prejudice, in John F. Hayford to S.W. Stratton, 6 Dec. 1919, in which Hayford demands that Bothezat be "separated from the service" of the NACA. When Bothezat's association with the army at McCook Field ended in similar unpleasantness, Lewis attributed it to "his lack of appreciation of the way things are done in this country and his temperamental nature." Lewis to F.W. Caldwell, 28 May 1923, NA RG 255, entry 3, box 5, George de Bothezat.

51. Minutes of Executive Committee meeting, 11 Nov. 1920.

52. Minutes of NACA meeting, 19 Oct. 1922; minutes of NACA meeting, 24 Apr. 1924, pp. 8-9; Lewis to Ames, 2 July 1924. Ames's summary appeared as NACA Report 213, "A Resume of the Advances in Theoretical Aeronautics Made by Max M. Munk," 1925.

53. This discussion of the background and development of the variable density wind tunnel is derived from George W. Gray, *Frontiers of Flight: The Story of NACA Research* (New York: Alfred A. Knopf, 1948), pp. 34-36; Keller, "From Kitty Hawk to Muroc," pp. IV-1-IV-10; and Max M. Munk and Elton W. Miller, "The Variable Density Wind Tunnel of the National Advisory Committee for Aeronautics," NACA Report 227, 1925. In part I of Report 227 Munk described the "Fundamental Principles" behind the tunnel; in part II Miller provided a "Description of Tunnel."

54. I am indebted to Ira H. Abbott, John V. Becker, and Walter G. Vincenti for instruction in the principles of the variable-density tunnel, though none of them is responsible for the exact wording of this paragraph.
55. A British engineer writing in *The Aeroplane* in 1929 stated that "the only people so far who have been able to get at something like accurate results from wind-tunnel experiments are the workers at the experimental station at Langley Field." In the same year, the editor of *Aircraft Engineering*, also of London, said of the Langley group:
- They were the first to establish, and indeed to visualize, a variable-density tunnel; they have led again with the construction of the twenty-foot propeller research tunnel; and the steps are now being taken to provide a "full scale" tunnel in which complete aeroplanes up to thirty-five-foot span can be tested. The present day American position in all branches of aeronautical knowledge can, without doubt, be attributed mainly to this far-seeing policy and expenditure on up-to-date laboratory equipment.
- Both quotations appear in Gray, *Frontiers of Flight*, p. 16.
- Actually, Munk's original variable-density tunnel was not as reliable as it first appeared. Unknown to researchers at the time, it produced intense airstream turbulence, causing an exaggeration of scale effect equivalent to multiplying the actual Reynolds number by about 3. This caveat was brought to my attention by John V. Becker and Ira H. Abbott, who also note that it was the Langley staff which finally identified and corrected this distortion in the 1930s. See Abbott's "Airfoils: Significance and Early Development," in *The Evolution of Aircraft Wing Design: Proceedings of the Symposium, Dayton, Ohio, March 18, 19, 1980* (New York: American Institute of Aeronautics and Astronautics, Inc., 1980), pp. 21-24.
56. Max M. Munk and Elton W. Miller, "Model Tests with a Systematic Series of 27 Wing Sections at Full Reynolds Number," NACA TR-221, 1925. On Munk's many contributions to aeronautics while he worked for the laboratory, see R. T. Jones, "Recollections from an Earlier Period in American Aeronautics," *Annual Review of Fluid Mechanics* 9 (1977): 1-11, esp. 4-6.
57. For example, in commenting on the draft of Munk's "The Tail Plane," NACA Report 133, 1922, two distinguished members of the Langley staff came to exactly opposite conclusions. F. H. Norton found evidence of "a most surprising ignorance of the extensive work done by the British and even by the N.A.C.A.," and concluded that there was "nothing in this report which has not been said in a better way in previous reports of the Committee." David L. Bacon, however, found it "undoubtedly a valuable addition to our information on the subject. . . [which] may enable us in future experiments to work with much better insight of the problem." Norton to Lewis, 9 Aug. 1921; Bacon to Lewis, 24 Aug. 1921.
58. Records of the staffing at Langley in these early years are extremely sketchy. For the organization referred to here, see Griffith to Victory, 12 May 1923.
59. Griffith to Lewis, 9 Nov. 1923, in 57 A 415 (2), 1-5A, 1919-1925.
60. Of this passage, Ira Abbott remarked:
- There is an element of truth here, but that is all. The good research man is both a scientist and an engineer. Some lean more one way than another. Even the pure types can work together without friction. The thing that causes friction is the personality, not the technical leanings.
- Abbott to Monte D. Wright, 30 April 1980, enclosure, p. 7.
61. Munk to Lewis, 25 May 1926, and Reid to Miss Dillon, 27 May 1925, both in Langley Historical Collection, box 4, miscellaneous correspondence.
62. The NACA records on Munk are uncharacteristically sparse, as if most traces of him had been expunged after he left. The best available evidence of the unpleasantness surrounding his departure in 1926 is the correspondence between him and the Committee just before World War II, when he sought a contract or a new position with the NACA. See Victory to Munk, 19 June 1939; Munk to Victory, 3 July 1939; Munk to Ames, 5 July 1939 (two letters on that date); Munk to Ames, 8 July 1939; Munk to Victory, 3 July 1939, with a handwritten note from Edward H. Chamberlain to Victory dated 5 July 1939; Victory to Chamberlain, 8 July 1939; Lewis to Munk, 28 July 1939; Munk to Lewis, 2 Aug. 1939; Munk to Lewis, 9 Sept. 1939; and Munk to Vannevar Bush, 20 May 1940.
63. *AR 1926*, p. 57; *AR 1925*, p. 58.
64. Lewis to Reid, 15 Feb. 1926, quoting Edward R. Weidlein, director of the Mellon Institute of Industrial Research of the University of Pittsburgh, in a paper presented to the American

Association for the Advancement of Science, as reported in the Feb. 1926 issue of *Mechanical Engineering*.

65. Many NACA veterans disagree with this conclusion. John V. Becker writes:

In the early '20s no one knew for sure what the right problems for research were for an agency like NACA. Munk came and did his thing which proved fruitful for awhile. By 1926 experience was beginning to show that many of the most urgent problems in that period involved engineering questions like "is it worthwhile to retract landing gears," or "can I reduce engine drag without degrading cooling"—questions which NACA could answer with the aid of large new facilities, affordable only by the government.

Dr. Ames fostered and approved such work because it was urgently needed—not because NACA had decided to reject science or theory. As a PhD in physics, Ames understood scientific research at least as well as Munk. Lewis also had a stronger than usual academic background. There was no rejection of individual research, or theory, or fresh ideas.

But how does one verify such an assertion? Did the NACA choose to address engineering problems because they were the most compelling, or because the agency was staffed by engineers who found them most compelling? Ames signed many papers on his weekly trip to Washington, but I find little evidence that he played an active role in formulating the research program.

CHAPTER 5

1. John B. Rae, *Climb to Greatness: The American Aircraft Industry, 1920-1960* (Cambridge: MIT Press, 1968), p. 216 *et passim*. Rae applies the quoted comment to the period 1920-1960.
2. *Ibid.*, p. 35; Lewis to Ide, 24 Sept. 1927 in 57 A 415 (66), 51-6G, 1927-1929.
3. Minutes, NACA meeting, 21 Oct. 1926; *AR 1927*, pp. 1-4. See also pp. 15-25.
4. In recommending Lewis and Victory for salary increases on 12 May 1923, the Committee on Personnel, Buildings, and Equipment, of which Ames was the chairman, made the following endorsement to the secretary of the NACA:

These two men are largely responsible for the success of the Committee. During the past two years there has been a notable increase in the activities of the organization. The efficiency of all sections and the harmonious working of the whole have been brought to a point where the general effectiveness of the Committee's work has become remarkable in view of the small total expenditures made, and is now a source of gratification to the members of the Committee.

Mr. Lewis and Mr. Victory work well together and are thoroughly loyal to the Committee, seeking always to advance its best interests. They have carried into effect the Committee's policy of actual cooperation with, and service to, the other activities of the government concerned with aeronautics, and with the industry, in such a way as to command for the Committee the confidence and respect of all. The Committee has gradually become more and more indispensable [sic] to the Army and Navy. The Bureau of the Budget and the Congress are recognizing the success of the Committee's work. . . .

5. Ames to Lewis, 11 Aug. 1924, handwritten, in NA PG 255, entry 3, box 1, Joseph S. Ames, 1915-1924.
6. The 1926 legislation, S. 4529 and H.R. 13115 (69/1), was predicated on the recommendation of the Morrow board. By 1929 it seemed more important (as Ames put it in a letter to the chairman of the Senate Committee on Military Affairs) to have "additional persons from private life who, while broadly acquainted with the needs of aeronautical science, can bring to bear in the discussions before the Committee the points of view of the manufacturer of aircraft and the operator of airlines." Ames noted that "for several years, there has been a growing sentiment that the aircraft manufacturing and operating industries should have direct representation on the Main Committee, as well as on the subcommittees," but there was no effort then to take that bold step. The three new positions were filled by William P. MacCracken, Jr., assistant secretary of commerce for aeronautics; Harry F. Guggenheim, president of the Daniel Guggenheim Fund for the Promotion of Aeronautics; and Edward P. Warner, then editor of *Aviation*. Neither Warner nor Guggenheim was a direct representative

of either airplane manufacturers or operators, but their appointments brought the committee closer to the industry than it had ever come. Minutes of NACA meeting, 21 Oct. 1926; Ames to David A. Reed, 29 Jan. 1929; *AR 1929*, p. 5; appendixes A and B. See pp. 108-111, 163-169, and 207-211 for more on industry representation in the NACA.

7. For the exact wording of the new regulations, see appendix A. The changes to the rules and regulations were proposed at the semiannual meeting of the NACA, 21 Apr. 1927, submitted to the president 27 April and approved by him 17 May. Taylor was elected vice chairman of the Executive Committee at its meeting on 22 June 1927 and vice chairman of the NACA by letter ballot circulated under the date of 28 June. Victory was appointed secretary on 22 June 1927. Promotion of E.H. Chamberlain from chief clerk to the new position of assistant secretary was approved by the Main Committee on 24 Oct. 1929. Minutes of NACA meeting, 21 Apr. 1927; minutes of Executive Committee meeting, 22 June 1927; *AR 1927*, p. 6; minutes of NACA meeting, 24 Oct. 1929. On the role of Taylor, see Ames testimony in House Appropriations Committee, Independent Offices Appropriation Subcommittee, *Independent Offices Appropriation Bill, 1929*, hearings, 72/1, 1932, pp. 306-07.

Commenting on Victory's functions as envisioned in the change to the rules and regulations suggested in 1927, an official at the Bureau of the Budget wrote: "I see no objection to this change as the Secty. is under the control of the Chairman and Vice Chairman, the approval of each being necessary before funds can be obligated. The high sounding title and duties are mainly for purpose of guiding Pers[onnel] Class[ification]. Board in passing on changes in grade." Adams to Mr. Wiseman, 11 May 1917.

8. The subtle difference in the NACA role can be seen by comparing the 1926 legislation with the 1927 amendment in appendix A. As Ames summarized it in a memorandum read to the Executive Committee on 18 Mar. 1927:

The effect of the act of Congress approved Mar. 3, 1927, amending the act creating the Patents and Design Board, is to limit the jurisdiction of the Board in making awards to those cases in which the NACA shall submit favorable recommendations and to make the Committee a responsible agency in the Government for the final disapproval of applications for awards for aeronautical inventions or designs submitted to the Government.

See also the discussion at the Executive Committee meeting, 25 Feb. 1927, in which Ames expressed concern that the pending legislation could burden the NACA with duties that might interfere with the committee's basic job of research and that the Executive Committee might be drawn into hearings with disgruntled inventors. Though the NACA handled many suggestions over the years, they never became as important or as time-consuming as Ames feared.

9. See appendix B.

10. The following excerpt from the minutes of the Executive Committee meeting 18 Mar. 1927 reveals the nature of the problem. The chairman reported that Dr. Max M. Munk, technical assistant at \$5000 per annum, had submitted his resignation effective March 31, and added that there was a positive need for:

The employment of exceptional personnel at Langley Field. . . . He stated that the Committee needed a few men with knowledge of the existing state of the science of aerodynamics, experienced in the scientific study of its fundamental problems, and who combine engineering training with profound mathematical knowledge, a good knowledge of physics, the rare gift of originality, and demonstrated ability in the conduct of research. He stated further that, in short, what is essentially needed is at least one or two men who can bring to bear sound mathematical and physical knowledge in the analysis of the results obtained by observers and investigators, and who at the same time can initiate problems of a fundamental character. He added that American educational institutions and methods do not produce the type of men needed by the Committee, and that, after conferring with the Director of Aeronautical Research and others, he was of the opinion that there is no American available with proper qualifications. In this the members concurred.

11. *AR 1925*, p. 11; Lewis to LMAL, 28 Jan. 1924 and 12 Feb. 1930. In a memorandum to the laboratory dated 11 Nov. 1926, Lewis wrote:

It is requested that all recommendations made by the technical staff at the Langley Memorial Aeronautical Laboratory with reference to new research

projects be forwarded to this office, with or without comment, for the attention of the Director of Aeronautical Research for presentation to the subcommittee concerned.

All suggestions by members of the technical staff with reference to new research projects are to be made in writing and transmitted through the Engineer-in-Charge to the Director of Aeronautical Research. No member of the technical staff of the Laboratory who may be present at a meeting of one of the technical subcommittees is to present any new project at the meeting without first having presented the project in writing to the Director of Aeronautical Research in the manner indicated. (57 A 415 (4), 1-16D, 1922-1926)

That is an excellent example of George Lewis's best engineering prose and his methods of maintaining control over the Committee's research program.

12. See appendix G. The first RA was approved 18 July 1918, using a form approved by the Executive Committee at its meeting on the same date. RA 2 was not issued until 28 June 1920; it used a somewhat different form, thereafter changed very little.

Some work at LMAL was done under job orders. These work authorizations funded such activities as development of instruments and equipment and modification of facilities, work not exclusively associated with a single aeronautical investigation. Work done under job orders generally was not reported in the Committee's publications.

13. On 11 Feb. 1925, Griffith wrote to Lewis:

I am a little uncertain as to just how far you believe it advisable to carry the matter of the proposed separate control of detail researches which involve extension or addition to the work covered by the research authorizations which have been formally approved by the Executive Committee. It seems to me that extra work should be treated in one of two ways. If we handle such items as lettered extensions of the original research, it will be necessary to issue a sort of appendix to the original research authorization in order to have the additional work properly specified and authorized. A copy of this appendix should then be attached to each copy of the research authorization and made a part thereof. In this case, it is my idea that we would make no effort to separate the cost of work executed under authority of these appendices, so that the costing unit would still continue to be the research authorization number.

The other method would be to treat the supplemental research items as separate researches and have them authorized in the regular manner. In this way, the cost of work on these supplemental items would be automatically separated from the cost of the work done under the original or parent research authorizations, which might in some cases be a distinct advantage.

I am inclined to believe that a combination of the two methods would be the best solution of the matter, all supplemental work of less than a certain rather indefinite importance or estimated cost being treated as an appendix to the original research authorization, while all supplemental work of greater cost or importance should be accorded the dignity of a separate research authorization. In order to provide a basis for discussion, I would suggest that any given item of supplemental research should be considered as an appendix to the original authorization, if it is a logical extension of the original research and if its cost does not exceed say \$1000 and does not exceed the estimated cost of the original research authorization. This latter provision would tend to prevent the supplemental work in any case from assuming a preponderating importance.

Lewis wrote back on 25 Feb. 1925: "The general recommendation as to extensions of research authorizations contained in your letter of reference has been given careful consideration, and will be followed in future cases in which they [sic] apply." (57 A 415 (74), 54-6, 1920-1925.) See also Lewis to acting chief physicist, LMAL, 13 July 1920. Changes to research authorizations imposed by headquarters could be a real irritant to the staff at Langley: see, for example, Elton W. Miller to engineer-in-charge, 9 Nov. 1933.

14. Lewis to LMAL, 28 Jan. 1924.
 15. "Memorandum for Members of the NACA," a summary of Dr. Ames's remarks before the Executive Committee, 31 Aug. 1922, regarding his trip to Europe.
 16. *Aircraft: Hearings before the President's Aircraft Board* (4 vols.; Washington, 1925), 1: 345-46.
 17. See note 10.

18. Lewis to LMAL, 9 June 1931, in 57 A 415 (43), 25-40, 1925-. Hoover's address was printed in *Science* 70 (1 Nov. 1929): 411-13. The paragraph quoted here is from the latter source.
19. *AR 1930*, p. 58. Lewis expanded on this line of thought in a letter to Senator Hiram Bingham, dated 1 Feb. 1928:

In reviewing the progress in aerodynamics, it is apparent that the time has now arrived when the main theoretical foundation has been laid, and we may expect in the future to find extensions of and additions to existing theory rather than new fundamental conceptions. We are therefore entering into a phase of refined and applied theory, which requires a large amount of experimental research if real progress is to be made.

The necessity for experimental research in the progress of any science is emphasized by the development of the electrical industry. . . .

All progress and future developments of the electrical industry are entirely based on the results obtained in the research laboratory, where combined mathematical theory and research on fundamental problems are closely linked, and of the two the experimental research is the most important.

Mathematical theory is of little or no practical use without experimental research. The unknown factors which are used in mathematical equations and are affected by the angle of attack, the condition of the surfaces, the interference of one surface with another, the Reynolds Number, and many other factors, make the application of the mathematical theory impossible without results obtained from experimental research. . . .

To insure satisfactory progress in aerodynamics it is necessary that a well-balanced program should include as much fundamental research as possible. The present demands are largely for specific problems, and careful analysis of these problems shows that in addition to the possibility of some immediate practical application as one of the objects, the investigation also has an important bearing on some fundamental problem. Fundamental research and mathematical theory work hand in hand, and it is largely due to the results of research problems in wind tunnels and in free flight that extensions and additions to existing theory are made.

20. Ames wrestled with this compromise in the 11th Wilbur Wright Lecture, delivered 31 May 1923:

What we would like to do would be to give free scope to [competent mathematical physicists familiar with aerodynamics], and to conduct the laboratory tests under their direction, so that theory and knowledge of facts could make progress together. But this is not possible in an establishment whose primary purpose is to give advice to other governmental services, especially advice concerning questions raised by these services. It is true that we can often inspire these questions, and we can always, in the process of obtaining answers, learn more than is required for the specific purpose. It follows, that while we are conducting practical tests we are also doing fundamental scientific work continuously, exactly as a justice of a high court expresses his deepest thoughts as *obiter dicta*.

21. See appendix F for an example of how the research process worked in practice.
22. On the origins of the propeller-research tunnel, see the transcript of Michael D. Keller's interview with Fred E. Weick, 2 Oct. 1967, pp. 20-24. See also George W. Gray, *Frontiers of Flight: The Story of NACA Research* (New York: Alfred A. Knopf, 1948), pp. 36-37. The fiscal 1927 budget included \$33,000 for the propeller-research tunnel.
23. Gray, *Frontiers of Flight*, pp. 37-38. Another \$375,000 was appropriated the following year to complete the full-scale tunnel.
24. Minutes, Executive Committee meeting of 1 Jan. 1929, at which Lewis reported on his trip to Europe from 9 Sept. through 30 Nov. 1928. See also George Lewis, memorandum on "Need for the construction of a special water channel for the investigation of seaplane boats," 11 Feb. 1929; and Ames to Director, Bureau of the Budget, 11 Feb. 1929. The NACA appropriation for the seaplane tank appeared in the Second Deficiency Act of 1929.
25. Minutes of NACA meeting, 21 Apr. 1927, p. 15.
26. See appendix B and the annual reports for 1926-1930.
27. T.P. Wright, "Edward Pearson Warner, 1894-1958: An Appreciation," *The Journal of the Royal Aeronautical Society*, Oct. 1958, pp. 31-43. Hugh Dryden said of Warner at the time of

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his death that "among his friends he was known as America's aeronautical encyclopedia, for his memory of things aeronautical was phenomenal. . . . His influence on the development of aeronautics in all aspects was profound." Dryden to T.P. Wright, 8 Aug. 1958.

28. Warner to Ames, 2 June 1927.

29. Ames to the Committee on Personnel, Buildings and Equipment, 28 June 1927; Lewis, "Memorandum for the Chairman, Committee on Personnel, Buildings, and Equipment," 2 Sept. 1927; Ames to Warner, 15 Sept. 1927, in NA RG 255, entry 4, box 1, file 100; *AR 1927*, p. 8. Lewis may have had another objection to the scheme. In 1940, George Mead wrote to Vannevar Bush that Lewis "doubts whether representatives of the industry can work together." Mead to Bush, 20 May 1940, in NA RG 255, entry 1, box 3, "Executive Committee."

30. On visits to aircraft manufacturers, see for example Victory's memorandum to the chairman of the NACA reporting on his trip to the west coast, 15 Sept. to 13 Oct. 1927. The quotation is from *AR 1928*, p. 80.

31. The purpose of these conferences was stated clearly in *AR 1925*, p. 57: "The Committee is of the opinion that with the advent of commercial aviation, a new series of problems peculiar to commercial aircraft will be presented. The committee has therefore decided to hold one or more meetings annually with the engineering representatives of aircraft manufacturing and operating industries, with a view to ascertaining definitely the problems deemed of most vital importance and to incorporating the same, as far as practicable, into the general research programs prepared by the committee." On the conferences themselves, see Michael David Keller, "From Kitty Hawk to Muroc: A History of the NACA Langley Laboratory, 1917-1947," NASA History Office HHM-15, 1969, pp. v-24-v-27.

32. See the exchange of correspondence in 55 A 312 (6), 110.1, Klemin, Alexander (2). The quote is from Klemin to Victory, 7 May 1928. The day after receiving this warning, Victory wrote to another attendee:

It is agreeable to the Committee for you to travel via the Cape Charles route if you feel that you cannot spare the time to accompany the party on the steamer leaving Washington at 6:30 p.m., Monday, May 14. There are certain advantages in spending an evening or two on the steamer in company with the executives and engineers of the aircraft industry and Government officials. I have with reluctance canceled your steamer reservation but will be glad to take care of you if you should ultimately decide to travel via Washington.

Victory to Harvey N. Davis in 56 A 635 (10), 15-1, Davis, Harvey N.

33. One senses from reading the files that the Langley staff felt isolated and unappreciated in its remote laboratory, remote at least from Washington and the aircraft industry. Perhaps the staff members put on such a good show at these conferences, especially in the early years, because it was their chance to escape anonymity and seclusion and to hear the applause of their peers from the outside world. See especially 57 A 415 (20), 21-2, 1922-1931. One appreciative guest wrote to Lewis after the 1934 conference:

I greatly admired the perfect way in which you exhibited the work you have been doing. On much of the work itself I am not competent to comment, but the way in which you dramatized some of your results and methods was superb. (Charles H. Colvin to Lewis, 26 June 1934, in 57 A 415 (14), 13-9A.)

34. J.H. Kindleberger, a successful aviation-industry executive, is reported to have said of the late 1920s, "There were three hundred aircraft factories, including those where you had to shove the cow aside to see the airplane." Only 38 invitations went out to the first NACA industry conference, mostly to larger concerns. Kindleberger is quoted in John B. Rae, *Climb to Greatness: The American Aircraft Industry, 1920-1960* (Cambridge: MIT Press, 1968), p. 40; invitations to the first conference are in 57 A 415 (53), 41-8(1).

In 1931, Lewis told Ames that Edward Warner, then editor of *Aviation*, was interested in the slotted Clark Y wing and intended to bring assistants to the annual conference that year to gather as much information as possible on the subject for publication in the magazine. "Unfortunately," concluded Lewis, "I do not see any way of preventing this." Lewis to Ames, 28 Apr. 1931, in 57 A 415 (10), 11-1, 1931.

After the 1929 conference, Ames reported to the annual meeting of the NACA that industry had suggested 24 problems, many of which were already under investigation. Two had been incorporated into the Committee's program and others were being considered for investigation later. Minutes of annual meeting of the NACA, 24 Oct. 1929.

35. See for example, Lewis to N.J. Medevoff, 21 Jan. 1927, and Lewis to T.P. Wright, 18 Dec. 1929, both in 57 A 415 (11), 13-6, general, 1927-1933. For a fuller discussion of this problem, see pp. 126-130.
36. In 1944 Orville Wright voiced his objection to the pattern into which the awarding of the Collier trophy had fallen. Wright maintained, first, that Robert J. Collier had specifically titled the award the "Aero Club of America Trophy," and that the term Collier trophy was a misnomer, even though the Aero Club of America had since been disbanded and succeeded by the National Aeronautic Association (NAA). More important, he took exception to the politics of the award:

The trophy was founded primarily to encourage and reward invention, as the language of the Deed of Gift indicates. I do not think, however, that [Collier] intended it to be confined strictly to that. The early awards of the trophy were to individuals, as Mr. Collier had intended, and continued so until the formation of the N.A.A. But an examination of the list of recipients since that time will reveal that after the N.A.A. came into possession of it [1922] the awards have been mostly to U.S. Government bureaus and to manufacturing companies, instead of to individuals. This, no doubt, is due to the fact that individuals have more modestly [sic] than bureaus and corporations, and that individuals do not have the "brass" to seek the award, while bureaus and companies have no lack in that respect. I think it may be taken as generally true that what a government department lacks in accomplishment it makes up by its activity in propaganda for its own aggrandizement.

Wright went on to recommend that for 1944 the trophy be awarded:

To the men, women and children; the animals, wild and domesticated; the trees and other plants, with particular credit to spinach for its great gift to man-power; the mines and other objects animate or [inanimate]; living or existing in any part of America except Argentina or Chile; who and which have contributed work, woods, hides, furs, fibers, wools, minerals or anything else to the building and use of the aeroplane, which have been the greatest achievement in aviation in the past year.

Wright was 72 when he wrote that letter, just four years from death, but he was not senile and he was not a bitter old man. He was simply the patriarch of aviation, free to call a spade a spade. Here he was really upbraiding the aviation establishment that had grown up by the mid-twentieth century, for he saw in it a corporate monopoly on the individuality and initiative that had been so much a part of his work and his brother's. Though Wright remained a member of the NACA until his death, there is no doubt that he viewed the Committee as part of that establishment.

37. Chief of BuAer to the NACA/Langley Field, 1 June 1926, in 61 A 195 (24), 54-6B, 172. The letter read in part:

The cowling of the P[ratt] & W[hitney] "Wasp" is dictated at present by the vision factor rather than by engine characteristics. It appears that considerably more of the engine could be cowled without impairing the cooling of the engine. Considerable work has been done abroad on the cowling of air-cooled engines but to date there is no information available as to a result of investigation in this country. This factor will materially affect future development of air-cooled high performance airplanes and it is felt that the whole field should be investigated. It would seem that the proper course of procedure would be to analyze the possibilities of cowling and shuttering from the standpoint of mechanical operation, to choose those methods which appear to be reasonably sound, mechanically and aerodynamically; to build models using the "Apache" as the basis, and check the results in the wind tunnel; and finally to install the equipment which appears the best mechanically and aerodynamically in the airplane, and make actual flights, measuring the performance and noting engine operation.

Research authorization 172, covering this work, was issued 30 June 1926. Work was suspended in 1927 when the navy withdrew the Apache aircraft it had loaned the NACA. The Apache was never returned, and the RA was canceled in 1932.

On the interest of both the military and the industry in cowling at the 1926 conference, see the transcript of interview of Fred E. Weick conducted by Michael D. Keller, 2 Oct. 1967.

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38. Holden C. Richardson to Ames, 21 June 1927; research authorization 215, approved 22 June 1927. The purpose of the investigation was given as:

To investigate the cooling characteristics and the drag on a fuselage fitted with the Wright Whirlwind engine as affected by the spinner cowling of the cylinders and engine, and the shape of the fuselage. Modifications will be made in the fuselage so as to simulate closed type fuselage designs, such as the Fairchild, the Buhl-Verville, the Detroit Stinson, and other commercial types.

39. Weick interview, p. 4; Lewis to LMAL, 30 Aug. 1927 in 61 A 195 (24), 54-6B, 172. See also "Report of Proceedings of Second General Conference between Representatives of Aircraft Manufacturers and Operators and National Advisory Committee for Aeronautics," held 24 May 1927, p. 14.
40. Victory to Reginald M. Cleveland, 7 Feb. 1933 in 57 A 415 (73), 53-3, 1933-1934; 61 A 195 (25), 54-6B, June 1927-Dec. 1928; and Reid to NACA, 17 Oct. 1928, *ibid.* The article appeared in *Aviation*, 17 Nov. 1928, pp. 1556-57, 1586-90. Fred E. Weick, "Drag and Cooling with Various Forms of Cowling for a 'Whirlwind' Engine in a Cabin Fuselage," TN-301, Nov. 1928, and "Drag and Cooling with Various Forms of Cowling for a 'Whirlwind' Radial Air-Cooled Engine," Part I, TR-313, 1929 and Part II, TR-314, 1929.
41. Telegram, Jerry Vultee to the NACA, 5 Feb. 1929; John D. Anderson, Jr., *Introduction to Flight: Its Engineering and History* (New York: McGraw-Hill Book Co., 1978), pp. 256-57.
42. Lewis to Herbert M. Lord, 6 Feb. 1929 in 57 A 415 (17), 19-5, FY 30; *AR 1928*, p. 80.
An internal BoB memo from Wiseman to Director Lord, dated 18 Sept. 1928, stated: Referring to paper by Dr. Lewis of Natl. Adv. Com. for Aeronautics which I sent you yesterday [Lewis, "Some Accomplishments of the National Advisory Committee for Aeronautics," 13 Sept. 1928], I am advised that while the Committee did not want to put it in writing, it estimates that the improvement made at Langley Laboratory in the cowling of the air cooled engine will save \$800,000 per year in cost of fuel of about 4000 air cooled engines in operation. As the number in operation increases this savings will increase proportionately. This is a big step toward reducing operating costs and should aid materially in more planes being purchased and operated by private interests.
43. Rae, *Climb to Greatness*, pp. 31, 240; 61 A 195 (25), 54-6B, 215, June 1927-Dec. 1928; "Cowling and Cooling of Radial Air-Cooled Engines," transcript of a speech by Lewis before the Society of Automotive Engineers, Detroit, 10 Apr. 1929, *ibid.*, Apr.-July 1929; C.J. McCarthy to Lewis, 5 June 1928, in 55 A 291 (5), RA 215 (1).
44. Victory to Reginald M. Cleveland, 7 Feb. 1933 in 57 A 415 (73), 53-3, 1933-1934; 61 A 195 (25), 54-6B, 215, "Cowling Patents." See also Charles H. Helms, "Memorandum on Aircraft Engine Cowling," 12 Dec. 1930, rev. 24 Sept. 1931; "Report of Meeting Between Representatives of National Advisory Committee for Aeronautics and of the Army and Navy to Discuss the Cowling Patent Situation," 21 June 1932; V.E. Clark to Joseph S. Ames, 2 July, and Ames to Clark, 7 July 1931; Lewis to LMAL, "Criticism of Committee's attitude with reference to Townend ring cowling," 14 Feb. 1931; Elton W. Miller to [LMAL] engineer-in-charge, "Criticism of Committee's attitude with reference to Townend ring cowling," 3 Mar. 1931; Melvin N. Gough to [LMAL] engineer-in-charge, "Comments on Mr. Sayers' article in *Aviation Engineering* for January, 1931," 4 Mar. 1931; Tom Carroll to Lewis, 20 Feb. 1931; Lewis to LMAL, "Article on Townend ring, prepared by Mr. Thomas Carroll," 24 Feb. 1931; Lewis to Carroll, 24 Feb. 1931; Elton W. Miller to [LMAL] engineer-in-charge, "Article on Townend ring prepared by Mr. Thomas Carroll," 3 Mar. 1931; Lewis to Carroll, 7 Mar., and Carroll to Lewis, 13 Mar. 1931. H.J.E. Reid wrote to headquarters on 6 Mar. 1931: "It is regretted that the Laboratory, in its report on cowlings, did not mention the work of Townend and give him credit."

Those with conflicting claims were not the only ones to misunderstand the NACA cowling. After viewing some of the aircraft about to take part in the Gardner Trophy Races in 1929, Lewis sent the following report to Langley:

The airplane which won the race, a Laird equipped with a Wright Whirlwind engine, had a type of N.A.C.A. cowling. The original cowling on the airplane had not been modified, and an N.A.C.A. type of cowling in very crude form had been slipped over the nose. The fuselage had not been faired in any way, and the space between the rear of the cowling and the fuselage varied from 4 to 7 inches. From an examination of the installation, it is difficult to see how the speed could be

increased more than 3 or 4 miles per hour. I saw one other airplane equipped with the cowling, and the installation was just as poor. There was also a Lockheed belonging to the Texaco people, which was equipped with the cowling. Here again the inner cowling had not been disturbed and the outer cowling was very much the same as that used by Hawks on his transcontinental flight.

From the commercial type airplanes that I have seen it is remarkable that the cowling has been as favorably received as it has, for the haphazard installations have been anything but what the Committee recommended. It is also apparent that if the cowling is to be properly applied some manufacturer must build an airplane around the cowling, or, better still, some engine manufacturer furnish an engine with the cowling. (Lewis to LMAL, 1 June 1929, in 55 A 291 (5), RA 215 (1))

45. In its *Annual Report* for 1928, the NACA said of the cowling: "This single contribution will repay the cost of the propeller research tunnel many times and fully justifies the committee, not only in having built such a tunnel, but also in recommending as it does that additional funds be provided next year for construction of a full-scale wind tunnel" (p. 80).
46. During the 1920s, the NACA was careful to list every year in its annual report the research projects it was performing for the military services.
47. Lewis to chief physicist, LMAL, 4 May 1922, in 57 A 415 (4), 1-16C, 1921-1922.
48. Lewis memorandum for General Lord, "Some Accomplishments of the National Advisory Committee for Aeronautics," 13 Sept. 1928.
49. Hy Fowler to Ames, 22 Dec. 1919.
50. In 1924 Lewis could make the trip to the laboratory in an hour and a quarter in the Vickers amphibian available to the Committee. Lewis to Redmond D. Stephens, 16 Apr. 1924, in 64 A 518 (8), 1925.
51. Quote is from Victory to the Committee on Personnel, Buildings, and Equipment, 28 July 1923, in 57 A 415 (29), 21-21A. This file contains the most complete information available on the camp, including Victory's letter to Walter H. Reiser of 26 Aug. 1931, stating that the expenses of Woodrum's last visit were to be covered by the Camp and Entertainment Fund. (How the NACA came by the *Retriever* is unclear, though it seems to have been a gift of the navy—perhaps surplus salvaged by the Committee.)

An otherwise unidentified typescript marked 21-21a and dated Oct. 1936 contains the following information on the camp:

The camp is financed by the N.A.C.A. Exchange funds, and when equipment has been needed special collections of money and equipment have been taken up from the employees, both at Langley Field and in the Washington office. Surplus Government equipment has been loaned to the camp. Scrap material salvaged from the dump has been used, and at times immediately needed items of supplies have been furnished. The camp is used by employees and their guests. Charges are made for the use of the camp and for all supplies consumed by parties using the camp. Payments are made to the N.A.C.A. Exchange by the parties using the camp. The accounts of the N.A.C.A. Exchange are audited monthly.

The camp is principally used by groups of employees in the same section, and frequently by assemblies of section and division chiefs. It has on occasion been used for large assemblies of the employees on picnics, and also for large gatherings of the Army personnel at Langley Field, on several occasions as many as two hundred people being present, although the number staying overnight usually runs from four to ten. The camp was first conceived in 1922 as a necessary attraction for members of Congress to visit the laboratory. The camp has been visited by many members of Congress, Republicans and Democrats alike, and other high Government officials.

An unlabeled folder in NA RG 255, entry 9, contains bylaws of the "Oak Point Club, Inc.," which seems to have been a forerunner of the camp.

52. See appendix C.
53. Interview of Ira H. Abbott by Walter T. Bonney, 28 Oct. 1971, p. 3. Lewis agreed with Abbott. He wrote to Alexander Klemm:

Personally, I feel that an engineering graduate who obtains a position with this Committee has an excellent opportunity to extend his theoretical knowledge, and in particular prepare himself as a research engineer. The opportunities for

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advancement are good, as evidenced by the fact that all of the activities at Langley Field are in charge of engineers who are recent graduates. All of the men who have left the Committee and who were in charge of major activities at our laboratory are now in charge of research laboratories. (Lewis to Klemm, 24 Mar. 1926, in 55 A 312 (6), 110.1, Klemm, Alexander (2).)

54. House Committee on Appropriations, Subcommittee on Independent Offices, Independent Offices Appropriation Bill, 1929, hearings, 70/1, 1928, p. 305.
55. Richard P. Hallion, *Legacy of Flight: The Guggenheim Contribution to American Aviation* (Seattle: University of Washington Press, 1977); *The Final Report of the D.G. Guggenheim Fund for the Promotion of Aeronautics, 1929*, Sept. 1930; Lewis to Griffith, 11 Oct. 1927, in 57 A 415 (34), 24-20, 1923- . Lewis wrote to William F. Durand on 25 Mar. 1927: "The personnel question is the most serious problem that now confronts the Committee."
56. R.T. Jones, "Recollections from an Earlier Period in American Aeronautics," *Annual Review of Fluid Mechanics* 9 (1977): 1-11.

CHAPTER 6

1. John B. Rae, *Climb to Greatness: The American Aircraft Industry, 1920-1960* (Cambridge: MIT Press, 1968), chap. 3.
2. Victory to Porter Adams, 21 June 1929, in 60 A 635 (11), 1-36, Adams, Porter; and 57 A 415 (64), 50-4, "Office Procedure."
3. In 1928, industry representatives held 19 percent of the committee memberships; in 1938 they held 16 percent. The reduction was directed not so much at industry as at increasing government representation; over the same period, representation from private life other than industry fell from 18 percent to 3 percent. See appendix B.
4. Minutes of the Executive Committee meeting, 23 Apr. 1931; "Reorganization of Subcommittees (as recommended by Dr. Lewis)," 10 Apr. 1935; and appendix B.
5. The Subcommittee on Coverings, Dopes, and Protective Coatings held only one meeting, 15 Oct. 1920, before being abolished in 1931. Charles H. Helms to Lewis, 29 Jan. 1935, in NA RG 255, file 1-1 (2).
6. At the Executive Committee meeting 20 Jan. 1931, Ames offered his opinion that "the most useful subcommittee members were those who were otherwise connected with the Government service." Minutes.
7. "Resume of Airship Investigations Made by the National Advisory Committee for Aeronautics," 2 June 1933.
8. Lewis to John J. Ide, 25 Feb. 1922, in 57 A 415 (66), 51-6g, 1921-1923; Rae, *Climb to Greatness*, pp. 35-38; Peter W. Brooks, *The Modern Airliner: Its Origins and Development* (London: Putnam, 1961), p. 32; and Victory to Elmer B. Staats, 13 June 1948.
9. *AR 1935*, p. 20.
10. Lewis to N.J. Medevoff, 21 Jan. 1927 and to T.P. Wright, 18 Dec. 1929, both in 57 A 415 (11), 13-6, general, 1927-1933.
11. "R.V.K." to Colonel Roop (director, Bureau of the Budget), 14 Aug. 1930; Roop to Lewis, 14 Aug., Lewis to Roop, 18 Sept. 1930; minutes, NACA annual meeting, 22 Oct. 1931; 57 A 415 (11), 13-6, general, 1940; and Lewis to C.G. Taylor, 7 Dec. 1931, *ibid.*, 1927-1933. In explaining the new regulations to the Langley staff, Lewis stressed the importance of maintaining independence:

It is the policy of the Committee, in conducting work on any special type of aircraft . . . not to obligate itself to the manufacturers by accepting gratis parts or other equipment for the tests. The Committee, investigating the characteristics of any particular aircraft, should be free to make an independent investigation of such a character that it will not be construed as giving engineering and consulting services to a manufacturer. In order to retain its independent action, it is desirable for the Committee to purchase outright any equipment necessary for the conduct of the tests. (Lewis to LMAL, 18 Nov. 1931, in 57 A 415 (22), 21-14, 1921-1933)

12. Starr Truscott to H.J.E. Reid, 17 Aug. 1936, with Reid's endorsement of 17 Nov. 1936 and Lewis's note of 19 Feb. 1937, in 57 A 415 (11), 13-6, general, 1936; Carl J. Wenzinger to

- Reid, 3 Sept. 1937, *ibid.*, 1937. For evidence of congressional interest in this subject, see Victory to Congressman Robert Crosser, 17 Feb. 1934, in NA RG 255, file 1-1, box 10.
13. Ames to Victory, 5 Nov. 1931.
 14. With this group in mind Edward Warner complained to Senator Royal S. Copeland on 12 Mar. 1936 of

the extraordinary prevalence of professional witnesses upon aviation matters who haunt the corridors of Washington, and who will leap at a moment's notice into any empty witness chair to provide spectacular headline material. I know that no congressional committee escapes acquaintance with some gentlemen of that order, but aviation certainly seems to have more than its share. Some of them have done nothing of importance for a number of years; some of them never did anything of importance; but they all have a story of outrageous mistreatment, and of fantastic ineptitude and iniquity on the part of the Government's aviation authorities, down pat and ready to be recited at the drop of a hat. I hope that when you receive from the witness chair long recitals of how America is ten years behind the rest of the world in aviation; of how American aviation is the victim of an elaborate conspiracy on the part of reactionaries whose personal fear of the air makes them eager that the art of flying should be stifled; of how the American aircraft industry is manned by eighty percent knaves and twenty percent fools; and of how revolutionary developments of world-shaking importance have been melodramatically stifled, to the accompaniment of murder, mayhem, and subornation of perjury, by a 'trust' of vast size and incomparable malignancy; I hope that when you hear all this you will, before allowing yourselves to become too much alarmed, call for specific facts, and then have the facts checked with great care, and not let the checking remain exclusively in the hands of authorities proposed to you by the author of the initial presentation. There have been almost thirty separate investigations of American aviation since the World War. Unless yours is unique, you will hear some strange stories. They will be absolute monochrome, a painting in unrelieved blacks. They will be spectacular, and they will no doubt excite the press, as spectacular condemnations always do. . . . We as a people seem to be peculiarly susceptible to the manner of the muck-raker. We seem to be peculiarly ready to believe the very worst of the achievements of our fellow citizens, and to watch with friendly appreciation the casting of a shadow of infamy even upon undertakings which ought to be valued as a glory to the flag under which they were accomplished.
 15. *A Brief Historical Review Outlining the Origin and Operations of the Manufacturers Aircraft Association, Inc. Following its Organization at the Instigation of the Government in July, 1917*, dated 24 Sept. 1935, records the continuing controversy over the cross-licensing agreement. In his Oct. 1962 interview with Alfred Hurley, Victory said, "Every time we went up to Capitol Hill for anything we were always on the defensive because of the barrage of questions from people who ought to know better and ought not to listen to all the complaints about setting up a patent trust" (p. 3-14).
 16. Frank A. Tichenor, "Why the N.A.C.A.?" *Aero Digest* (Dec. 1930), pp. 47 ff. This article appeared in Tichenor's regular monthly column entitled "Air—Hot and Otherwise."
 17. On 12 Dec. 1930, Lewis wrote to William H. Miller: "I have every reason to believe that the article was prepared wholly by Dr. Max Munk and was published by Mr. Tichenor. From our records, Mr. Tichenor has never visited the Committee's laboratories at Langley Field, although he has been invited to attend all of our aircraft manufacturers' conference [sic], so that I know he is not personally well acquainted with our activities." This letter is in 57 A 415 (14), 13-9, which contains other evidence of Munk's having written the article.

On the rejection of Munk's article entitled "Obstacles on the Lift of Airports" (which was judged interesting but wrong), see 57 A 415 (73), 53-2, 1929-. The quotations are from Munk's letters to Gibbs and Cox, Inc., 11 Apr. 1930, and to Sen. Hiram Bingham, 7 Apr. 1930. In the former Munk also claimed to be the "originator of most of [Ludwig] Prandtl's theory."
 18. Ames wrote to V.E. Clark on 7 July 1931:

I cannot sanction the assumption by the Committee of a defensive attitude with a magazine publisher. So far as I am concerned the Committee's work must continue to speak for itself in the collective mind of the aircraft industry and others

competent to judge. If any element of the industry seeks to cripple or destroy an agency useful to the industry as a whole, that, as I see it, is an affair for the industry to handle as effectively as may be necessary or itself suffer the consequences of its impotency or neglect. (55 A 312 (5), 11-10, Clark, V.E.)

Miller's comments appeared in a 19 Dec. 1930 memorandum for the engineer-in-charge forwarded to headquarters as an enclosure to H.J.E. Reid's memorandum for Lewis entitled "Comments on the Article in the December, 1930 Issue of *Aero Digest*, Entitled 'Why the N.A.C.A.?' " dated 2 Jan. 1931.

19. *Aviation* 30 (Jan. 1931): 3-4.
20. Frank A. Tichenor, "The N.A.C.A. Counters," *Aero Digest*, Feb. 1931, pp. 50 ff.
21. On boundary-layer control, see appendix F. See also Thomas S. Kuhn, *The Structure of Scientific Revolutions* (2d ed.; Chicago: University of Chicago Press, 1970).
22. Warner wrote to Lewis on 5 Jan. 1931:

One thing you never need to worry about in any year is the worth-whileness of the work that you are guiding. I have never overheard so much comment on anything that appeared in *Aero Digest* as on Frank Tichenor's attack on the Committee, and the comment has been about ninety-eight per cent unfavorable—and I have already begun receiving congratulations, other than your own, on my mild retort. (57 A 415 (14) 13-9)

23. "Page Mr. Byrns!," *Aero Digest*, Feb. 1932, and Frank A. Tichenor, "Take Politics Out of Research," *Aero Digest*, Mar. 1932, pp. 33 ff.
24. Transcript of interview with Alfred H. Hurley, Oct. 1962, pp. 3-14; the Mapes bill was H.R. 9742, 72/1, 25 Feb. 1932; Joseph W. Byrnes to Ames, 27 Feb. 1932, reprinted in minutes of the Executive Committee meeting, 2 Mar. 1932; Victory to Porter Adams, 26 Apr. 1932, in 60 A 635 (11), 1-36, Adams, Porter. Victory's comment wins my award for the longest sustained metaphor in a single sentence by a dramatic actor in a supporting role.
25. Minutes of NACA meeting, 21 Apr. 1932; Senator William H. King (D, Utah) in *Congressional Record*, 72/1, Vol. 75, Pt. 13, 1932, pp. 13961-62.
26. *Congressional Record*, 72/1, Vol. 75, Pt. 13, 1932, pp. 14024-27. Ames, who was in Paris at the time, received summaries of these events from Victory (28 June 1932) and Lewis (2 July 1932).
27. Executive Order 5960, "Consolidation and Coordination of Governmental Activities Affecting United States Commerce," 9 Dec. 1932; Clifford L. Lord, ed., Joseph E. Vaughan and Charles E. Baker, assoc. eds., *Presidential Executive Orders, Numbered 1-8030, 1862-1938* (2 vols.; New York: Books, Inc., 1944) vol. I, p. 494; Hoover quoted in Richard Hofstadter, *The American Political Tradition and the Men Who Made It* (Vintage Books; New York: Random House, 1948), p. 291; Victory to Ames, 10 Dec. 1932. Ames wrote to Albert C. Ritchie on 8 Dec. 1932:

I can assure you that the situation so far as the independent existence of the Committee is concerned is serious. It is very difficult to ascertain what the real reasons are animating those who wish either to do away with the Committee or merge its activities with other Government agencies. No one can question, however, that we have our enemies, and it is essential that those who are in real authority should be led to appreciate the work that the Committee is doing, and that can only be done with the present organization. (57 A 415 (36), 25-9, 1930-1934)

- See also Lewis to C.N. Monteith, 30 Dec. 1932, in 57 A 415 (14), 13-9.
28. Minutes of the special meeting of the Executive Committee, 15 Dec. 1932, to which is attached a copy of the Special Committee report.
 29. *New York Times*, 20 Jan. 1933, and the *United States Daily*, 20 Jan. 1933; minutes of the NACA meeting, 20 Apr. 1933.
 30. C.N. Monteith to Lewis, 27 Dec. 1930; Lewis to Monteith, 7 Jan. 1931 and 3 Feb. 1931; Monteith to Lewis, 4 Feb. 1931; all in 57 A 415 (14), 13-9.
 31. The card file is now in the NASA History Office. I have found no file of criticisms.
 32. See, for example, the complimentary letters in 57 A 415 (14), 13-9A. Most are from industry in the years 1919-1943.
 33. For an example of how the quotations were used, see "Some Comments on the Work of the National Advisory Committee for Aeronautics," and the enclosure to Ames' letter of 24 Feb. 1932 to Congressman F.H. LaGuardia. Compare these with the letters in 57 A 415 (74), 54-

13B, most of which were solicited by the NACA at the time of the 1932 Hoover Executive Order transferring the Committee to the Department of Commerce.

34. In the debate on the 1933 NACA budget, for example, one senator asked if the army and navy were not doing "the same sort of technical research work" as the NACA. The Committee's defender had no ready answer, but by the time the issue arose again on the floor of the Senate, the Committee's friends were armed with a whole string of endorsements, including a statement by the navy that "we have no aeronautical research" and a statement by the army that its aeronautical research was "devoted primarily to engineering experimentation." The critics then fell silent on the issue of duplication. *Congressional Record*, 72/1, Vol. 75, Pt. 13, 1932, pp. 14025.

Congressmen were not the only ones confused by the question of which government agencies did which research. Ames explained the distinctions to the chief of the Bureau of Efficiency in 1932:

Aeronautics is a young, rapidly growing, engineering science and, as in other engineering sciences, progress is dependent upon the continuous prosecution of well organized scientific research on the fundamental problems. The conduct of such research is the major function of this Committee. The Army and Navy air organizations do not conduct fundamental research, but refer their fundamental problems to the Committee. The Bureau of Standards and the Forest Products Laboratory have no function to initiate aeronautical research, but some aeronautical problems for the investigation of which their facilities are well adapted, are assigned to them by the Committee, by the Navy, and by the Department of Commerce, and are financed by transfers of funds. So far as aeronautic research is concerned, the Aeronautics Branch of the Department of Commerce is limited by the Air Commerce Act of 1926 to advising with and assisting other agencies in carrying forward research connected with the development of radio communication facilities, airway and airport lighting, and other air navigation facilities, which work is done largely at the Bureau of Standards. Aside from this special authority, the Aeronautics Branch has no function to initiate aeronautic research. The net result is that there is, in fact, no duplication in this field. (Ames to Herbert D. Brown, 23 Apr. 1932, in 57 A 415 (17), 19-5, 1933)

35. Lewis asked the Langley staff to prepare the analysis of economic value in a memorandum of 22 Nov. 1932 on "Preparation of material for Committee's hearings before the House Appropriations Committee for fiscal year 1934"; the Langley paper was dated Jan. 1933; Victory's aphorism appears in a typescript entitled "DEFINITIONS Collected by John F. Victory through the years," 11 Dec. 1950; Ames's comments appear in a letter to Sen. Hiram Bingham, 11 Feb. 1933, in 57 A 415 (36), 25-9, 1931-1934.

The NACA also gathered information during the early years of the Depression to prove that foreign countries were investing huge sums in aeronautical research while the United States devoted comparatively little. It appears, however, that the figures did not support the conclusion and the NACA dropped this line of inquiry. See 57 A 415 (17), 19-5B, FY 1934, "U.S. & Foreign Aviation Costs."

36. Lewis's remark was quoted by Charles H. Helms in a brief description of NACA-military relations dated 3 Aug. 1948.
37. On the criticism faced by the aircraft industry in the mid-1930s, see Nick A. Komons, *Bonfires to Beacons: Federal Civil Aviation Policy under the Air Commerce Act, 1926-1938* (Washington: Federal Aviation Administration, 1978).
38. Victory to Fred M. Vinson, 18 Mar. 1931, in 57 A 415 (36), 25-9, 1930-1934.
39. Victory to Vannevar Bush, 28 June 1939, in NA RG 255, series 13, box 1, 22-1, site for Ames 1939.
40. See appendix C.
41. *Historical Statistics of the United States, Colonial Times to 1970* (2 vols.; Washington: Bureau of the Census, 1975), 1: 1105.
42. A. Hunter Dupree, *Science in the Federal Government: A History of Policies and Activities to 1940* (Cambridge: The Belknap Press of Harvard University Press, 1957), pp. 346-47.
43. For the Committee's justification of a full-speed wind tunnel, see Ames to Harold L. Ickes, 12 Dec. 1933. On the storm damage from the 1933 hurricane, see 64 A 125 (18), storm damage (\$47 944)—1933.
44. *Congressional Record*, 74/1, Vol. 79, Pt. 1, 1935, pp. 385-86.

45. Victory to William F. Durand, 6 June 1934, in NA RG 255, series 3, box 7, Durand, 1920-1939; Lewis, "Recommendations of Federal Aviation Commission relating to work of National Advisory Committee for Aeronautics," memo for record, 18 Mar. 1935; report of Special Committee on Research Policy, 18 Mar. 1935. This committee consisted of Maj. Gen. Benjamin D. Foulois, chief, Air Corps, chairman; R. Adm. Ernest J. King, chief, Bureau of Aeronautics; Eugene L. Vidal, director, Bureau of Air Commerce; and Lewis. For evidence of the NACA's conviction that it had to make up for lost time by 1935, see Lewis to J.L. Keddy, BoB, 26 Mar. 1935.

CHAPTER 7

1. The chronology of events dominating this chapter may be found in "Some Important Facts Regarding Expansion of NACA Research Facilities and War-Time Status of NACA," unsigned typescript apparently prepared by Victory, 17 Jan. 1946.
2. Minutes, Executive Committee meeting, 3 Mar. 1936; George W. Gray, *Frontiers of Flight: The Story of NACA Research* (New York: Alfred A. Knopf, 1948), pp. 22-24; Victory to Lindbergh, 16 June 1936; George W. Lewis, "Report on Trip to Germany and Russia, Sept.-Oct. 1936," undated typescript, 22 pp. plus 10 pp. of handwritten notes. The latter document is the source of the description and quotations concerning German aeronautical research facilities that follow.
3. Ames expressed his reservations in testimony before the Morrow board. See *Aircraft: Hearings before the President's Aircraft Board* (4 vols.; Washington, 1925), 1: 345-46. Lewis summarized his report on the trip to Germany in a letter to Reginald M. Cleveland of the *New York Times*, 4 Jan. 1937:

As a result of my visit to Europe last September, I know only too well that unless something is done, within the next year and a half or two years the lead in technical development resulting from research will cross the ocean and probably be taken by Germany. Aeronautical research in Germany is considered of such importance that it ranks equally with the problem of national defense. With the long-range and extensive program of rearming in the air, the Germans have a parallel long-range and extensive program on aeronautical research. . . . There will be five major stations; one at Aldershof, one at Gottingen, one at Aachen, one at Brunswick, and one at Stuttgart. The policy is to decentralize the research activities, having one large activity in Berlin, three in west Germany, and one in south Germany.

The one thing that most interested Dr. Seewald on his recent visit to the United States was the small number of men employed at Langley Field. It is safe to say that within the next year the number of men employed in the German aeronautical research laboratories will be three or four times the number employed at Langley Field, and with the excellent equipment that is now being constructed in Germany, the answer is obvious. (57 A 415 (73), 53-3, 1937)

4. The files of the Special Committee on Aeronautical Research Facilities are in 57 A 415 (18), 20-2. On the upswing in R&D funds, see A. Hunter Dupree, *Science in the Federal Government: A History of Policies and Activities to 1940* (Cambridge: The Belknap Press of Harvard University Press, 1957), p. 363. Although the NACA requested funds from the Emergency Relief Appropriations Act of 1938 or the Public Works Administration Appropriation Act of 1938, it got none; 64 A 125 (18).
5. Brookings Institution, Institute for Government Research, report 12, published as Senate Select Committee to Investigate the Executive Agencies of Government, Investigation of the Executive Agencies of the Government, S. Rept. 1275, 75/1, 1937. Several years later, Harold G. Moulton, president of the Brookings Institution, tried to explain to Vannevar Bush why the report had recommended transfer of the NACA:

It seemed to the staff of our Government Research division . . . that, whatever might be the efficiency with which the N.A.C.A. has been conducted as an independent agency, its independent status could hardly be justified in terms of effective permanent organization. The problem was studied solely in terms of general principles of organization. The fact that the Committee has been of a unique character, and that it has thus far functioned effectively, did not seem a

sound reason for recommending that it be maintained indefinitely as an independent establishment. Precisely the same argument could be made for supporting certain other scientific research conducted under the auspices of government departments as separate operating agencies. (Moulton to Bush, 3 June 1940)

Moulton expressed sympathy with Bush's view that this had been "a conclusion which is naturally not pleasing to a committee which has gotten along very happily in its independent status and would like to be left alone."

6. The NACA rebuttal appears in the 15 Dec. 1937 "Report of the Brookings Institution on the National Advisory Committee for Aeronautics," reproduced in appendix H. William P. MacCracken tried unsuccessfully to get the institution to revise its recommendation on the NACA, but he was met with the staff's "Memorandum on Report No. 12 on Senate Select Committee making Recommendations Relative to National Advisory Committee for Aeronautics," 8 Nov. 1937, also reproduced in appendix H. See Victory to Harry F. Guggenheim, 29 Oct. 1937, and Moulton to MacCracken, 8 Nov. 1937.
 7. Victory to Guggenheim, 29 Oct. 1937; Ames to Guggenheim, 29 Nov. 1937; Guggenheim to Harry F. Byrd, 7 Dec. 1937. Even before Guggenheim intervened, Victory wrote to Lindbergh: "The present Congress in all probability will not create a Department of Transportation, and reliable assurance has been received that the N.A.C.A. will not be disturbed." (27 Oct. 1937)
- The Brookings report provides one more sidelight on NACA history. Just as Brookings began its investigation, Lewis wrote to his friend Porter Adams (prophetically, as it turned out) on what he feared the institution might do and why he distrusted it:
- As you probably fully appreciate, almost anything can happen, but I am especially anxious that the report of the Brookings Institution will not be unfavorable to the Committee. It is rather difficult to evaluate the importance of the different organizations purely from a paper standpoint, and I am quite sure that the analysis of the Government organizations will be made entirely from statements and organization charts rather than from an intimate knowledge of the value of each organization. The difficulty lies in the fact that it is almost impossible to put everything into an organization chart. (Lewis to Adams, 6 Aug. 1936 in 60 A 635 (11), 1-36, Adams, Porter)
8. See 57 A 415 (74), appropriations, for evidence that the budget cut was prompted, at least in part, by the Brookings report. The NACA fought the cut by appointing a special committee on the 1939 budget; its 1 Mar. 1938 report to Ames was subsequently used to good effect by Woodrum, as reported in Victory to Ames, 9 Mar. 1938.
 9. On the Civil Aeronautics Act of 1938, see Nick A. Komons, *Bonfires to Beacons: Federal Civil Aviation Policy under the Air Commerce Act, 1926-1938* (Washington: Federal Aviation Administration, 1978), chap. 14. The effect on the NACA is outlined in *AR-1938*, pp. 3, 38-39. See also "Analysis of Civil Aeronautics Act of 1938," a 5-page typescript prepared for the Executive Committee meeting of 21 June 1938, probably by Victory.
 10. On the delicate question of why the NACA should not get into commercial aviation development, see Edward P. Warner to Sen. Royal S. Copeland, 25 May 1938, reprinted in appendix H.
 11. On the rapid expansion of the aircraft-manufacturing industry in the late 1930s, see Elsbeth E. Freudenthal, "The Aviation Business in the 1930's," *The History of the American Aircraft Industry: An Anthology*, ed. G.R. Simonson (Cambridge: MIT Press 1968), pp. 98-115; and John B. Rae, *Climb to Greatness: The American Aircraft Industry, 1920-1960* (Cambridge: MIT Press, 1968), pp. 98-113. Another bureaucratic response to commercial aviation needs in these years was the Special Subcommittee on Aerodynamic Problems of Transport Construction and Operation proposed by Ed Warner, which sat from 1936 to 1938. See also Lewis to director, Bureau of the Budget, 31 Dec. 1936, in which he asks for increased funds to meet the research demands of the engineers' committee of the Aeronautical Chamber of Commerce.
 12. *AR 1928*, pp. 21-23; *AR 1929*, pp. 23-24; *AR 1930*, pp. 18-19; Victory to chairman, NACA, "Subcommittee on Aeronautical Research in Universities under Committee on Aerodynamics," 26 Jan. 1934.
 13. U.S. Senate, *Report of the Federal Aviation Commission*, Sen. Doc. 15, 74/1, 1935; *AR 1935*, p. 38; Victory to Willis Gregg, 6 Dec. 1935, enclosing "Cooperation between the Universities and the N.A.C.A." On increased appropriations for university research in later years, see, for

- example, House Committee on Appropriations, Subcommittee on Independent Offices, Independent Offices Appropriation Bill for 1941, hearings, 76/3, 1941, pp. 337-38.
14. Alexander Klemin to Earl M. Findley, 16 May 1935, identified "Cooperation between the Universities and the N.A.C.A." as a statement prepared by him on behalf of the American Engineering Council and approved by Grover Loening, chairman of the council. The marginalia are in the NACA copy, cited in note 13.
 15. See appendix B.
 16. House Committee on Appropriations, hearings on the Sundry Civil Bill, 1941, 76th Cong., 3d. sess., 4 Dec. 1939, pp. 328-29; minutes of Executive Committee meeting, 19 Aug. 1938; Lewis to Ames, 19 Aug. 1938, in 57 A 415 (20) 21-2, 1932-1940.
 17. Lindbergh to Ames, 4 Nov. 1938; Clinton Macauley, "Millions for Research—Abroad!," *National Aeronautics*, Oct. 1938, pp. 22-23; *AR 1938*, pp. 1-2. Victory wrote to Russell Owen on 16 Feb. 1939:

Our present philosophy is based upon a conviction that at Munich Hitler was not bluffing. You would not call it bluffing when you bet on four aces. Germany's remarkable progress in the technical development of aircraft is founded upon her extensive organization of brain power and modern facilities for aeronautical research. So whatever pride we may take in our present research efforts, we must realize that Germany has laid well a foundation for enduring supremacy in technical development. Our plan for a second major research station at Sunnyvale was arrived at after months of sober reflection on the responsibilities facing us. We must look not only at the present, but at the situation that will exist three years from now, ten years from now. The present German advantage will have cumulative results with the passing of time unless America takes adequate measures to strengthen the research foundations for its air development. (57 A 415 (73), 53-3, 1938-1939)

18. Both Lewis and Victory wanted the laboratory located inland. In an 8 Nov. 1938 memorandum, Lewis listed as one of the desirable objectives for the new lab that it be 500 miles from either coast. (47 A 415 (33), 22-1, 1938-1939). In a 4 Nov. 1938 memorandum for Adm. Cook, Victory stated that the "site should be accessible from Washington, preferably within four to five hours by air." In 1938 the transcontinental speed record was over ten hours, so Victory could not have been thinking much beyond the Mississippi River.
19. Rae, *Climb to Greatness*, p. 108.
20. Robert A. Millikan, *The Autobiography of Robert A. Millikan* (London: Macdonald & Co., Ltd., 1951), p. 253; Millikan to H.H. Arnold, 10 Dec. 1938, enclosing "Discussion of a Proposal to Establish an Aeronautical Laboratory for Applied Research."
21. Arnold to Lewis, 5 Jan. 1939, reproduced in appendix H.
22. Victory to Lewis, 9 Jan. 1939, reproduced in appendix H.
23. Clark Millikan and von Kármán even visited Dr. Lewis while the NACA request for a new laboratory in California was pending before the Bureau of the Budget. Lewis told Henry Reid that in the conference he did "a great deal of listening and very little talking." Later he apologized to Millikan, saying he "felt rather embarrassed at not being able to discuss it in more detail." Lewis to Reid, 2 Feb. 1939; Lewis to Millikan, 25 Feb. 1939.

Lewis had been advised as early as 14 Dec. 1938—just four days after Millikan's first proposal to Arnold—that within the Army Air Corps "consideration was being given to the construction of the wind tunnel on the West Coast at some educational institution." Lewis, memorandum for the chairman, re: visit of Major A.J. Lyon, 14 Dec. 1938. On industry support of the Caltech proposal, see Millikan to Congressman John Costello, 29 Mar. 1939, and Jerome C. Hunsaker to E.E. Wilson, 6 Jan. 1940.

When the NACA and the army finally rejected the Caltech proposal, Congressman Carl Hinshaw (whose district included Caltech) said in Congress that "there seems to be a certain feeling on the part of the N.A.C.A., which I can hardly describe, but the best way to describe it is that they would like to retain a concentration of research facilities entirely within the N.A.C.A. They do not seem to be inclined to favor allowing these facilities to be spread out among the several qualified educational institutions. I do not just know whether it is the old question of professional jealousy or the old question of expanding bureaucracy or some other queer incomprehensible angle." (*Congressional Record*, 77/1, Vol. 87, Pt. 1, 1941, p. 416)

24. A. Hunter Dupree, *Science in the Federal Government: A History of Policies and Activities to 1940* (Cambridge, Mass.: Belknap Press of Harvard University Press, 1957), pp. 296-97.
25. See pp. 152-153.
26. On von Kármán's remarkable career, see R. Cargill Hall, "Shaping the Course of Aeronautics, Rocketry, and Astronautics: Theodore von Kármán, 1881-1963," *The Journal of Astronautical Sciences* 26 (Oct.-Dec. 1978): 369-86.
27. Even industry landed in the NACA camp on this issue. John H. Jouett, chairman of the Aeronautical Chamber of Commerce of America, wrote to Clark Millikan on 22 May 1939 that "it seems to be Sunnyvale or nothing" and asked him to support the NACA plan.
28. Hunsaker to E.E. Wilson, 6 Jan. 1940.
29. *Congressional Record*, 76/1, Vol. 84, Pt. 3, 1939, p. 3110.
30. House Committee on Appropriations, Subcommittee on Independent Offices, *Independent Offices Appropriation Bill for 1940*, hearings, 76/3, 1940, facing title page.
31. Victory to DeFrance, TWX, 22 Mar. 1939, in 57 A 415 (33), 22-1, 1938-1939. Notes prepared by Victory for his own history of the NACA said that Drew Pearson at this time wrongly blamed Woodrum for the failure of the Sunnyvale proposal. This interpretation suggests that members of Woodrum's committee were the ones gathered around the pork barrel, not the chairman himself.
32. "Some Important Facts Regarding Expansion of NACA Research Facilities and War-Time Status of NACA," typescript, 17 Jan. 1945.
33. Minutes, Executive Committee meeting, 23 June 1939; Victory to Ames, 3 Aug. 1939.
34. *AR 1939*, pp. 2-3, in which is printed the "Report of the Special Survey Committee on Aeronautical Research Facilities." See also Victory, "Memorandum for the Chairman, NACA," on "Origin and Status of the Aircraft Engine Research Laboratory," 7 Oct. 1941. On 6 Jan. 1940, Hunsaker wrote to E.E. Wilson: "I, personally, am pressing the N.A.C.A. (now with George Mead's active support) to ask Congress for a Power Plant Research Laboratory." The implication is that this urging was not new. For confirmation of this, see Hunsaker to Lewis [ca. 18 Aug. 39].
35. Rae, *Climb to Greatness*, pp. 25-30, 107; Robert Schlaifer, *Development of Aircraft Engines* (Boston: Div. of Research, Graduate School of Business Administration, Harvard University, 1950), pp. 246-86. Schlaifer also maintains that the American system of engine development gave the industry *de facto* a stronger voice in determining what lines of development to pursue, and industry naturally followed those that promised commercial as well as military applications.
36. Up to 1939, for example, the NACA had published only 670 reports on propulsion, compared with 2437 reports on aerodynamics, and much of the engine research was on fuels and supercharging and control. See appendix G on reports, and the author's tables from which that appendix was compiled.
37. Ames to F.J. Bailey, 25 June 1937; Lewis to Ames, 10 Jan. 1933.
38. Compare Thomas P. Hughes' concept of "reverse salients in an expanding technological front" in "The Science-Technology Interaction: The Case of High-Voltage Power Transmission Systems," *Technology and Culture* 17 (Oct. 1976), 646-59.
39. See Mead's card in the running card file at NASA Headquarters of NACA committee members. NACA veteran Ira Abbott makes a comment on the NACA dilemma that could well apply to other aspects of the Committee's history: "Industry would have been—and [was]—the first to object to encroachment by the NACA on their territory. As soon as industry did not meet the needs of the military, they were also the first to declare it was because of the neglect of their needs by the NACA. It was strictly a no-win situation." Abbott to Monte D. Wright, 30 April 1980, enclosure, p. 13.
40. Hunsaker's ties to industry are revealed in box 7 of his papers at the National Air and Space Museum, Washington, D.C. On Warner's career, see T.P. Wright, "Edward Pearson Warner, 1894-1958: An Appreciation," *The Journal of the Royal Aeronautical Society*, Oct. 1958, pp. 31-43. On Kilner's brief tenure, see *AR 1940*, p. 19; Kilner to Bush, 9 Feb. 1940; Victory to Kilner, 5 Mar. 1940; Kilner to Bush, 12 Mar. 1940; Victory to Kilner, 16 Apr. 1940; and Kilner to Victory, 22 Apr. 1940 (all the correspondence in NA RG 255, entry 3, box 27, Kilner, 1939-1940.) Although the Kilner correspondence evidences no bad feelings, there is an obvious coolness in the NACA's response. On the tenures of all three men, see appendix B.

In 1931 Ames recommended appointing industry representatives to the Main Committee, but by 1938 he was advocating their continued exclusion from the Aerodynamics, Power Plants, and Structures committees. Ames to President Hoover, 3 Nov. 1931; Ames to Victory, 5 Nov. 1931; and Ames to Executive Committee, 7 Dec. 1938. The last letter was probably written by Lewis and signed by the failing Ames.

41. Mead had been an engineering undergraduate at MIT when Hunsaker was establishing a program in aeronautics there. Since then, his career had been confined almost exclusively to industry, most notably as chief engineer of Wright Aeronautical Corp., then as engineering founder and vice president of Pratt and Whitney Aircraft Co., whence he rose to be vice president, director, and member of the executive committee of the present United Aircraft Corp. to which Pratt and Whitney was subsidiary. Mead left in June 1939, reportedly in a dispute over advocacy of liquid-cooled engines. *Who Was Who in America, II, 1943-1950* (Chicago: A.N. Marquis, 1950), p. 366; Schlaifer, *Development of Aircraft Engines*, p. 290.

The membership of the Special Committee on Aeronautical Research Facilities is listed in the minutes of the annual meeting of the NACA, 19 Oct. 1939. The membership of the reorganized Power Plants Committee and the quotation explaining the change appear in the minutes of the Executive Committee meeting, 7 Feb. 1940. On the friction between Mead and the NACA, see Mead to Hunsaker, 19 Jan., and Hunsaker to Mead, 21 Jan. 1937.

As recently as 1937, Lewis had written, "it is the Committee's policy that there shall be no representation of the industry or of engineering societies on the Committee on Power Plants for Aircraft." (Lewis to C.B. Veal, 6 Jan. 1937, in 55 A 312 (5), 14-3, Crane, H.M.)

42. Warner raised the issue at the 7 Feb. 1940 meeting of the Executive Committee. At the 12 Mar. 1940 meeting of the Executive Committee, the chairman of the Committee on Aircraft Structures raised the issue again, eliciting Bush's response. (Minutes.) On the composition of NACA technical committees, see appendix B.
43. In Apr. 1940, for example, Warner sent to Bush a proposed new membership list for the Aerodynamics Committee, expressing the hope that the new membership would be "reasonably representative of the industry." (Warner to Bush, 27 Apr. 1940, in 60 A 635 (11), 101.1, Bush, Vannevar.) This issue of industry representation was later to become a source of misunderstanding and friction between the NACA and the industry. See pp. 207-211.

In a letter of 20 May 1940 Mead pointed out that the NACA staff lacked the technical expertise to establish a new engine-research laboratory. (NA RG 155, entry 1, box 3, Executive Committee.) In the Executive Committee meeting of 7 Feb. 1940, Bush stated that the major misgiving over industry representation on the main technical committees was access to classified information; he did not mention conflict of interest. On the patriotic service of industry representatives in NACA engine research, see Leonard S. Hobbs to Hunsaker, 1 Jan. 1942, and Hunsaker to Hobbs, 9 Jan. 1942; Mead to Frank Caldwell, 28 Dec. 1939 and Caldwell to Mead, 4 Jan. 1940.

44. Harold D. Smith, director, Bureau of the Budget, undated memorandum for the president [ca. 7 May 1940]; Smith to L.C. Martin, 7 May 1940; "Mr. A'Hearn" to Martin and Smith, 11 May 1940; *Congressional Record*, 76/3, Vol. 86, Pt. 7, 1940, p. 8084, 12 June 1940. On 25 Jan. 1940 Victory wrote to Lindbergh: "I was recently told by a veteran correspondent who had chatted with members of the Appropriations Committee that various members of the committee had said that the N.A.C.A. could have whatever it asked for."
45. Victory to Durand, 7 June 1940, in 59 A 2112 (10), 17-3, Durand, 1931-1951.
46. The following account relies heavily on John D. Holmfeld, "The Site Selection for the NACA Engine Research Laboratory: A Meeting of Science and Politics," NASA History Office HHN-69, 1967. Holmfeld concludes, as do I, that politics and objectivity were about equally involved in the selection of a site.
47. Victory to Bush, 7 Oct. 1940.
48. The quote is *ibid.*; the sequence of events is in Holmfeld, "Site Selection" and "Report of Special Committee on Site, Aircraft Engine Research Laboratory," 24 Oct. 1940; the confidential file is in 62 A 35 (8), 123.
49. Holmfeld infers that one reason for settling on Cleveland was the close and comfortable relationship Victory established with the local officials there. He also notes that the Glenview site would probably have been disqualified in any event because it was not publicly owned, even though the navy was then negotiating for its purchase from the Curtiss-Wright Corp.

The criteria used to evaluate proposed sites were (1) general characteristics of flying field, (2) details of site proposed, (3) vulnerability from strategic standpoint, (4) electric

power, (5) water, (6) proximity to industrial center, (7) accessibility to engine manufacturers, (8) climate and weather, and (9) accessibility to centers of scientific and technical activity. Cleveland also ranked first in (2) and (5), but not in all the subcategories that made up those criteria. Furthermore, it had been tied with Glenview in criterion (2) before the shuffling began.

50. Holmfeld, "Site Selection," chap. 8.
51. "Westover Committee Report," 19 Aug. 1938; minutes of Executive Committee meeting, 15 Sept. 1939. See also Victory to chairman, NACA, 2 Mar. 1939; and 57 A 415 (1), 1-1.
52. On the drain of personnel by industry, see Lewis to E.E. Wilson, 17 Jan. 1937, in 57 A 415 (48), 38-4, July-Dec. 1937; and the two-page typescript summary of "Budget Hearings" of the NACA before the Bureau of the Budget, 9 Oct. 1937. As early as the fall of 1936 members of the NACA staff had expressed concern over their status in the event of war. See Starr Truscott to engineer-in-charge, LMAL, 12 Nov. 1936; minutes of annual meeting, 22 Nov. 1936.

53. At its regular meeting on 24 June 1941, the Executive Committee resolved:

That the N.A.C.A. hereby adopts a policy that continuity be maintained in the prosecution of long-range fundamental research in the growing field of aerodynamics and in the application of research results to the improvement of aircraft, and instructs the Director of Aeronautical Research to take the necessary steps to provide increased personnel for this purpose. (Minutes)

This declaration accurately reflected the concern of Hunsaker and others on the Main Committee and on the staff, but it did not (and could not) ensure that fundamental research would continue.

54. At its semiannual meeting 22 Apr. 1920, the NACA had resolved:

That the Executive Committee be instructed to undertake, in so far as may be found practicable, the coordination of aerodynamic research work in the educational institutions of the country where are located aerodynamic laboratories—to the end that greater general efficiency in carrying on such work among scattered research units may be realized, unnecessary duplication of effort avoided, and in order that the work in these various research laboratories may be carried forward, together with similar work in governmental laboratories, as intelligently related parts of a general research program. (Victory to Executive Committee, 8 May 1920)

This was, of course, an ideal, but by the late 1930s considerable sentiment had grown up for the NACA to increase its support to universities.

55. Bush to George H. Brett, 30 June 1939, appointing him a member of the Special Committee on Coordination. The other members were Warner and Sydney M. Kraus. The quote is from Bush to Lewis, 30 Aug. 1939.
56. Hunsaker to Lewis [ca. 18 Aug.]; Lewis to Hunsaker, 26 Aug.; Hunsaker to Lewis, 29 Aug. 1939.
57. Special Committee on Coordination, "Report Submitted to Executive Committee," 15 Sept. 1939; Lewis to Hunsaker, 1 Dec. 1939; "Report of the Coordinator of Research to the National Advisory Committee for Aeronautics," 7 Feb. 1940.
58. Bush to Lewis, 30 Aug. 1939. Bush had offered the chairmanship to Lindbergh in 1939, but Lindbergh had refused. Charles A. Lindbergh, *The Wartime Journals of Charles A. Lindbergh* (New York: Harcourt Brace Jovanovich, 1970), p. 208.

That Hunsaker associated his criticisms of the NACA with Lewis personally is revealed in a 21 Jan. 1937 letter to Mead:

Lewis is somewhat reticent at times! At our recent meeting he did not disclose that Langley is to build a new tunnel along the lines of our M.I.T. proposal (variable density). A year ago when I sent Dr. Peters to Langley to discuss his plans they all tried to dissuade him from pumping it up or out, on the grounds of impracticability. Now the Germans are doing it and I hear N.A.C.A. is to go ahead also.

He was more laudatory in a 2 May 1940 memo to General Arnold, in which he observed of the NACA that "the physical plant is superb . . . , the staff . . . is working both vigorously and with imagination . . . , section heads constitute the country's experts in their specialties . . . , [and] research programs have been wisely selected." On the negative side he reported that "the NACA is not functioning as an *advisory* body in accordance with its original pur-

pose," and that "the over-all picture or trend is not disclosed. That is, we have no machinery for bringing out the cumulative significance of our work." This last criticism anticipated a complaint that Hunsaker was to get from George Mead just a few days later:

As to reports, I feel we would be in a stronger position if we put more stress on quality than quantity. To be perfectly frank, that is one of the principal complaints of the engine industry about the reports. There is nothing wrong with the work as far as I know, but sometimes the conclusions lack a broad understanding of the problem as whole.

Hunsaker apparently became the spokesman for this kind of complaint because he was himself critical of the NACA and because he kept an open mind. At the end of a long and candid critique of the NACA in 1939, Lindbergh remarked poignantly:

There is definitely another side to the picture with which you are well acquainted. I have been keeping in close contact with Dr. Lewis and fully realize the problems, both technical and political, he has had to face, and I feel he has done excellent work. However, I have gone on the theory that we can accomplish more by looking for criticism than for praise—possibly this has been one of our weaknesses in the past. (Lindbergh to Hunsaker, 4 Aug. 1939)

CHAPTER 8

1. NASA news release 65-298, 20 Sept. 1965; Walter T. Bonney notes, from DeFrance's official personnel form; Victory to DeFrance, TWX, 22 Mar. 1939, in 57 A 415 (33), 22-1, 1938-1939. During a flight test in 1924, the aircraft piloted by DeFrance crashed, killing another engineer on board and critically injuring DeFrance. He lost his left eye as a result of the crash and his face was badly mutilated. He carried the scars, both physical and emotional, through the rest of his days. See Victory to Ames, 22 Aug. 1924.
2. John F. Parsons of the Langley staff was actually appointed to take charge of construction at Moffett Field in 1939, but DeFrance had already been working on the project for more than a year and was unofficially the head long before he was formally appointed engineer-in-charge of the new laboratory. DeFrance visited Sunnyvale briefly in 1939, but he performed most of his duties at Langley before moving for good to the new laboratory in August 1940. Edwin P. Hartman, *Adventures in Research: A History of Ames Research Center, 1940-1965*, NASA SP-4302 (Washington, 1970), pp. 25-27, 31-32, 45-46; Donald H. Wood to Victory, 4 Aug. 1942, 62 A 35 (2), 122.3.
3. George Mead outlined the problems at Cleveland for Jerome Hunsaker in a letter of 10 Nov. 1941, suggesting ways to advance the completion date of the laboratory from 1 Sept. 1943 to 1 Dec. 1942. Information on Sharp is drawn from his undated NACA biography [ca. 1957]; Walter T. Bonney to Robert Hotz, 11 Dec. 1960; and Bonney notes from Sharp's official personnel form. Sharp was appointed construction administrator for AERL early in 1942, then manager when the laboratory opened in May. Only in 1947—after attempts to recruit a director from outside the NACA had failed and Sharp had proven himself an excellent head of the lab—was he finally appointed director. On the search for a head for the new laboratory, see L.S. Hobbs to J.C. Hunsaker, 1 Jan. 1942, and Hunsaker to Hobbs, 9 Jan. 1942.
4. George J. Mead to Hunsaker, 10 Nov. 1941; Lewis to Mead, 2 Dec. 1941; Lewis to Harold D. Smith, 26 Jan. 1942; Senate Committee on Appropriations, Third Supplemental National Defense Appropriations Bill for 1942, hearings, 77/1, 1941, pp. 196-201; Hunsaker to L.S. Hobbs, 9 Jan. 1942; Victory to Walter I. Beam, 8 June 1942; Victory to Clifford Gildersleeve, 17 July 1942; H.G. Knight to "Mr. Martin," BoB intra-office memorandum, 17 Aug. 1943.
5. W.J. McCann to George Lewis, 23 Sept. 1943, in 63 A 101 (10), A-4-2, "Jacobs's Visit to England," 1943.
6. 62 A 35 (63), 300.7, Space, Assignments and Repairs, esp. Victory to W.E. Reynolds, 13 Apr. 1940, and Ralph Ulmer, memo for record, 22 Aug. 1940; Victory, memo for the chairman, 14 Sept. 1940; minutes of Executive Committee meeting, 24 July 1941, pp. 4-5.
7. The plan adopted by the Aeronautical Board and approved by the president on 29 June 1939 provided that:

The National Advisory Committee for Aeronautics will operate during a national emergency declared by the President as a consulting and research agency for the Aeronautical Board. The entire facilities of the Committee's research laboratories shall be placed at the service of the Aeronautical Board, and the Committee shall execute the projects requested of it by the Aeronautical Board. (Minutes of Exec. Comm. meeting, 15 Sept. 1939)

In practice, power seems to have gravitated during the war to the Joint Chiefs of Staff for policy; the NACA continued to handle requests that came directly from the services on a first-come first-served basis, with little if any need for the Aeronautical Board to decide which service should have priority. The Aeronautical Board endorsed this policy at its meeting of 12 Mar. 1942, as reported to the NACA Exec. Comm. meeting of 19 March, pp. 18-20, where the formal policy is quoted.

Vannevar Bush established the NACA's wartime policy on giving advice to the services when Secretary of War Robert P. Patterson asked him 5 Dec. 1940 for the committee's opinion on the advisability of continuing an army contract with Pratt & Whitney for development of experimental liquid-cooled engines; the company wished to discontinue the investigation in favor of developing a more attractive air-cooled engine. Bush wrote to the members of the Main Committee 10 Dec. 1940 suggesting "the following premises as a basis for our procedure":

1. The National Advisory Committee for Aeronautics should exercise its advisory capacity whenever called upon for advice within its field of competence by federal departments or agencies concerned with aircraft.

2. In a period of emergency its advice should be rendered as promptly as is consistent with adequate investigation and analysis.

3. The Committee as a whole will wish to control the procedure by which questions are examined and advice rendered.

4. Members of the Committee having special knowledge in the field of a particular inquiry will wish to have an opportunity to express opinions before advice is rendered in the name of the Committee.

5. Concerning requests which the Committee considers to involve broad questions of national policy, on which the Committee may be consulted, the full Committee will wish to meet, examine, and pass upon any report rendering advice in its name.

6. On subsidiary technical subjects, where advice on policy or procedure is requested, the Committee will be content that advice should be rendered in its name if the following steps are taken: (a) A special committee is appointed from the membership by the Chairman upon receiving the request and without convening the Committee in special session. (b) This special committee consults with members having special knowledge of the situation presented, makes such other examination as it deems necessary, and prepares its report. (c) This report is reviewed by the Chairman and transmitted if he approves the steps taken to arrive at conclusions, and considers the advice given within the proper scope of the Committee's functions. (Bush to Mead, 10 Dec. 1940)

The NACA actually followed this procedure in the case of the Pratt & Whitney contract and whenever necessary thereafter. But in fact there was little more to this procedure than common sense and committing to writing what had been the *modus operandi* of the Committee for years. One sees John Victory's hand in this letter as much as Bush's. The difference was that the members of the NACA were taking their role in the war in deadly earnest, and the new men taking over the Committee were establishing fixed and explicit policies to replace the ad hoc methods of the Ames-Lewis-Victory triumvirate.

8. "Coordination" was the Committee's term for liaison, used previously in describing the Coordinator of Aeronautical Research in Universities and soon to be employed in the Western Coordination Office. Presumably the NACA chose this term to impress on Congress that it was actively trying to rationalize the nation's aeronautical research program and to prevent duplication by bringing together information on aeronautical research activities across the U.S. Surely nothing in its behavior during the war suggested that the NACA envisioned itself as being the central aeronautical research agency in the country with authority and responsibility to dictate policy to other aeronautical research teams. Still, the choice of terms was an unfortunate one and invited misinterpretation.

Though Vannevar Bush later forgot the fact, the National Defense Research Committee was modeled on the NACA. The act creating the NDRC was drafted by John Victory. Revealingly, Victory drafted that the NDRC should "co-ordinate, supervise, and conduct scientific research on the problems underlying the development, production, and use of mechanisms and devices of warfare, except scientific research on the problems of flight," while the presidential executive order formally establishing the NDRC declared that it should "correlate and support scientific research on the mechanisms and devices of warfare, except those relating to problems of flight included in the field of activities of National Advisory Committee for Aeronautics." [sic] James Phinney Baxter 3d, *Scientists against Time* (Boston: Little, Brown and Company, 1946), pp. 14, 451. Bush wrote to Victory on 25 Apr. 1966 that he could not recall whether Victory was involved in the creation of NDRC.

9. Mead's views on coordination of advice, as well as those of Jerome Hunsaker, who was soon to take over chairmanship of the NACA, appear in an exchange of letters in mid-1940: Hunsaker to Mead, 8 Aug.; with attached memorandum dated 10 Aug.; Mead to Hunsaker, 28 Aug.; Hunsaker to Mead, 23 Sept.; and Mead to Hunsaker, 2 Oct., from which the quotations are taken. On Mead's position in the National Defense Advisory Commission, see Irving Brinton Holley, Jr., *Buying Aircraft: Materiel Procurement for the Army Air Forces*, United States Army in World War II, Special Studies (Washington: Dept. of the Army, 1964), p. 256; and Wesley Frank Craven and James Lea Cate, eds., *The Army Air Forces in World War II*, vol. 6, *Men and Planes* (Chicago: University of Chicago Press, 1955), p. 308.

Mead's positions on both the NACA and the NDAC (a subsidiary of the Council of National Defense) made him the ideal person to help work out the details of coordination between the NACA and the NDRC, originally an outgrowth of the Council of National Defense. At Bush's prompting, Mead and Richard C. Tolman, vice chairman of the NDRC, negotiated a joint "Memorandum on the Fields of Activity of the National Advisory Committee for Aeronautics and of the National Defense Research Committee," which Mead signed on 6 Feb. 1941, Tolman on 12 Feb. This agreement served both agencies well throughout the war, although one official in NDRC complained to Bush that "the NACA have remained quite aloof" when it came to coordination. (Carroll L. Wilson to Bush, 6 Nov. 1941, in 62 A 35 (72), 370.11, 1941-1945.) The agreement was probably more useful in preventing duplication and conflict than in achieving cooperation and rationalization.

10. See pp. 167-168. S. Paul Johnston seems to have gotten on well with Vannevar Bush, less so with Jerome Hunsaker. Shortly after he became chairman, Hunsaker expressed dissatisfaction with a report prepared by Johnston because it failed to conform to a directive setting out the functions of his office. Within a month Johnston resigned as coordinator of research to become manager of the Washington office of the Curtiss-Wright Corp. On 15 Jan. 1942 Hunsaker received the approval of the Executive Committee to abolish the position of coordinator of research and to reconstitute its functions under the director of aeronautical research. This he did on 9 Feb. 1942. Bush to Johnston, 13 Feb. 1940; Hunsaker to Johnston, 24 Dec. 1941; minutes of Executive Committee meetings, 15 Jan., p. 6, and 19 Mar. 1942, p. 2; Hunsaker to director of aeronautical research, 9 Feb. 1942; Institute of Aeronautical Sciences biography of S. Paul Johnston, 27 May 1955.
11. Minutes of annual meeting of the NACA, 24 Oct. 1940; Hunsaker to Bush, 17 June 1941, in 62 A 35 (29), 53; NACA typescript of 1942 appropriations testimony titled "National Advisory Committee for Aeronautics," 9 pp., undated, marked "Figures OK REU [Ralph E. Ulmer] 1-23-41," p. 8.
12. Victory to Porter Adams, 27 May 1944, U.S. Air Force Academy, Victory papers, box 1, general personal, 1944.
13. For a detailed description of the NACA's work procedures, see appendix F.
14. An undated NACA report on "Utilization of Wind Tunnels from January, 1939 to June, 1945" states that the following tunnels were used for specific tests of army and navy aircraft for the percentages of times shown, based on a 24-hour operating day:

	(Percentage)
LMAL	57
8-Foot High-Speed Tunnel	23.5
16-Foot High-Speed Tunnel	23
19-Foot Pressure Tunnel	55.1
Propeller-Research Tunnel	33
Two-Dimensional Tunnel	79
Atmospheric Tunnel	92
Full-Scale Tunnel	57
AAL	66
7- × 10-Foot Tunnel (No. 1)	56.5
7- × 10-Foot Tunnel (No. 2)	87.8
16-Foot High-Speed Tunnel	66.5
40- × 80-Foot Tunnel	81.25
AERL	(not given)
Altitude Tunnel	92.6
Icing-Research Tunnel	43

It was impossible to compute tunnel time for some of the other specialized tunnels. In the spin tunnel and the free-flight tunnel, for example, any number of models could be tested in a single day because no time was required to rig the model in the tunnel. The stability tunnel had very little applicability to applied research and testing and was used almost exclusively for fundamental research.

The figures suggest that during the war the NACA did a smaller amount of fundamental research than it liked (and was accustomed) to do, but they do not necessarily support George Lewis's 1943 testimony before the House Committee on Appropriations that "since the declaration of war, . . . the work of the Committee is 100 percent war effort on projects presented to the Committee by the War and Navy Departments." House Committee on Appropriations, Independent Offices Appropriation Bill for 1944, hearings, 78/1, 1943, p. 149.

15. Victory to Don L. Hoxie, 7 Oct. 1943, in 59 A 2112 (11), 105, general policies and procedures. For a detailed description of the NACA report system, see appendix G. From 1940 on, the annual report dealt "only in general terms with the results accomplished" (*AR 1940*, p. 1). Reports for 1943 through 1945 were actually not published until after the war.

Even before Pearl Harbor, the Army Air Corps, the Navy Bureau of Aeronautics, the Aeronautical Board, and the NACA agreed that "results of [NACA] investigations made on designs of a given aircraft manufacturer be made available for the duration of the present emergency to other manufacturers if those results were applicable, in the opinion of the Air Corps, the Bureau of Aeronautics, or the Committee, to any other manufacturer's design." (Minutes of NACA annual meeting, 23 Oct. 1942) Generally the NACA was more severe than the services in restricting the flow of information; see, for example, Lewis to Miss Muller, 10 May 1941, in 57 A 415 (46), 32-5, 1937-.

16. Minutes of NACA semiannual meeting, 23 Apr. 1942, p. 6; Edward Warner to Maj. Howard Z. Bogert, U.S.A., 3 Dec. 1940; Bogert to Warner, 6 Dec. 1940; S. Paul Johnston to Vannevar Bush, 6 Dec. 1940; Warner to Bush, 9 Dec. 1940; Bush to Maj. Gen. Henry H. Arnold, U.S.A., 31 Dec. 1940; Maj. Mervin E. Gross, U.S.A., to Bush, 8 Jan. 1941.

17. See appendix B.

18. Warner gave up chairmanship of the prestigious Aerodynamics Committee to T.P. Wright in order to take over Operating Problems. The entire story appears in minutes of Exec. Comm. meeting, 16 June 1942, pp. 28-30. Of Mead's withdrawal, Hunsaker wrote to the members of the Main Committee on 21 Oct. 1943:

The withdrawal of Dr. Mead is a serious loss as he is the only one of us who is really expert on modern engine development. His initiative and advice largely determined the Cleveland Engine Research Laboratory. Dr. Mead assures me that he will continue to be available for consultation.

NOTES

19. Lewis to Ames, 3 May 1939; minutes of Exec. Comm. meeting, 11 Sept. 1941, pp. 2, 11; *AR 1943*, p. 1. During the war the NACA staff did not attend large industry meetings, which Lewis did not consider worth the time. In 1943 he wrote:
 I take a rather pessimistic view toward the success of engineering meetings in the aircraft industry during the war period. Maybe I am wrong, and only reflect my own personal situation and knowledge of the work load that our own staff has to carry, which precludes spending two or three days at technical meetings. (Lewis to John A.C. Warner, 19 Nov. 1943, in 62 A 235 (36), 000.01 Coordination of Research, 1942-1945)
20. Edwin P. Hartman, *Adventures in Research*, p. ix; minutes of Exec. Comm. meeting, 16 June 1942, p. 23; Russell G. Robinson, "Memorandum for Mr. Victory," 2 May 1942; Robinson, "Memorandum for Mr. Hartman," 5 Dec. 1942. For an example of the excellent information Hartman was able to gather, see his memo for coordinator of research, 16 Dec. 1943. Copies of Hartman's reports are in 60 A 635 (14-19); at the San Francisco Federal Archives and Records Center in 62 A 621 (1-4); and at the Los Angeles Federal Archives and Records Center in 68 A 899 and 68 A 935.
21. In 1943, Lewis was authorized to approve contracts with universities and research organizations without prior approval from the Executive Committee. Minutes of Exec. Comm. meeting, 20 May 1943, p. 11. Hunsaker reported to Congress in 1943 that a recent survey of the Committee's activities revealed that the staff was working on only 38 percent of the research projects already authorized. House Committee on Appropriations, First Supplemental National Defense Appropriation Bill for 1944, hearings, 78/1, 1943, pp. 1534-35.
22. On the problem of losing personnel to industry, see minutes of Exec. Comm. meeting, 15 Jan. 1942, p. 18; and "NACA Research and the Nation's War Planes," 13 pp., typescript prepared for congressional testimony, 9 Sept. 1942, p. 10. Public Law 450, approved 10 Feb. 1942 and implemented by Executive Order 9117 of 31 Mar., was repealed by P.L. 821, approved 22 Dec. 1942. The latter expired on 30 Apr. 1943 and was replaced by P.L. 49 of 7 May 1943. Minutes of Executive Committee meetings 26 Nov. 1941, p. 3; 25 Feb. 1943, pp. 13-14; and 23 Apr. 1942, pp. 2-3; and appendix A.
23. In congressional testimony late in 1943 Victory expressed his frustration with the replacement schedule:
 The Director of Selective Service in each State where one of our laboratories is located has, under the Selective Service organization, rather exclusive jurisdiction to approve or disapprove a replacement schedule. We submit a replacement schedule; he sends it back—invariably marked up with numerous disapprovals—then we go into a conference and iron out the difficulties man to man. In the meantime, he has had his agents go through our respective laboratories and knows pretty well what the duties of each man are. Then, when an agreement is reached, we resubmit a schedule and it is approved. That holds for 6 months. In the meantime, those indicated for induction are inducted, and they are inducted, I am sorry to say, irrespective of whether replacements have been made or can be secured. That, I think, is one real defect which is crippling work. (House Committee on Appropriations, Independent Offices Appropriations Bill for 1945, hearings, 78/2, 1944, p. 118)
 See also minutes of Exec. Comm. meetings, 15 Jan. 1942, p. 16; 19 Mar. 1942, p. 18; 10 Sept. 1942, p. 14; 17 Dec. 1942, p. 15; 20 May 1943, pp. 9-10; 16 Sept. 1943, p. 4; and minutes of semiannual meeting, 22 Apr. 1943, p. 3.
24. The plan was first proposed by Hunsaker at the semiannual meeting of the NACA on 22 Apr. 1943. (Minutes, p. 7.) The history of the Army-Navy-NACA plan was outlined in James J. Kelly, Jr. to Victory, "Selective Service during World War II," 30 June 1949. See also minutes of Exec. Comm. meetings, 27 Jan. 1944, p. 2; 16 Mar. 1944, p. 5; and 18 Dec. 1944, p. 12; and minutes of NACA meetings, 20 Apr. 1944, pp. 10-11; and 19 Oct. 1944, p. 14.
25. Hunsaker memo, "Priority rating for two private wind tunnels," 23 Apr. 1943; and minutes of Exec. Comm. meeting, 16 June 1942, pp. 4-5.
26. Minutes, Exec. Comm. meeting, 13 Sept. 1940, p. 4; Lewis, "Organization of aeronautical research in the U.S.S.R.," memo for files, 16 Jan. 1943.
27. The difficulties of cooperating with even such close allies as the British became clear in mid-1942. Ed Warner wrote from London recommending a "generally united action in the planning of research and development." As he saw it,

we had reached the point of a free and reasonably efficient exchange of information on what was being done; but . . . the British and American agencies concerned were still acting as separate parties, negotiating with one another, generally making their own independent plans and then advising one another of the results obtained, and of the researches actually in progress, rather than acting as the several parts of a single organization in joint pursuit of a joint objective.

Hunsaker found this "interesting but difficult to see through clearly." He wrote to Lewis: "I can't see how we can function as part of a single research organization as we do not yet function smoothly as a part of our own Army and Navy." Though Hunsaker was surely anxious to effect what cooperation he could with the British, the focus of all joint work was the military. "If we have an important new proposal—such as a rocket ship—we would go to [General] Arnold," he told Lewis, and "the British . . . also go direct to Arnold." Warner to Hunsaker, 14 Aug. 1942; Hunsaker to Lewis, 26 Aug. 1942.

28. See pp. 88–89. On engine development in general, see C. Fayette Taylor, "Aircraft Propulsion: A Review of the Evolution of Aircraft Powerplants," *Annual Report of the Board of Regents of the Smithsonian Institution, 1962* (Washington: Smithsonian Institution, 1963), pp. 245–99.
29. Appendixes B and G; Ames to F.J. Bailey, 25 June 1937; report of Special Survey Committee on Aeronautical Research Facilities, 19 Oct. 1939, quoted in Victory to chairman, NACA, "Origin and Status of the Aircraft Engine Research Laboratory," 7 Oct. 1941; H.G. Knight to "Mr. Martin," "Report of Visit to N.A.C.A. Engine Research Laboratory, Cleveland, Ohio, August 5–6, 1943," 17 Aug. 1943.
30. "National Advisory Committee for Aeronautics," typescript of testimony prepared for 1942 appropriations hearings, marked "Figures OK. REU 1-23-41," 9 pp., n.d., p. 2.
31. Robert Schlaifer, *Development of Aircraft Engines* (Boston: Div. of Research, Graduate School of Business Administration, Harvard University, 1950), pp. 321–24; George W. Gray, *Frontiers of Flight: The Story of NACA Research* (New York: Alfred A. Knopf, 1948), pp. 275–76.
32. Lewis to de Bothezat, 30 Apr. 1920. On 13 May, de Bothezat asked Lewis to buy him a personal copy of Goddard's paper that he might keep. (NA, RG 255, entry 3, box 6, George de Bothezat.) On de Bothezat's troubled relations with the NACA, see pp. 89–92.
33. Edgar Buckingham, "Jet Propulsion for Airplanes," TR-159, in *AR 1923*, pp. 75–90.
34. Schlaifer, *Development of Aircraft Engines*, pp. 329–31.
35. 57 A 415 (4), 1–16D, 1929–1935. Research Authorization 328, "Investigation of Methods of Increasing the Thrust Reaction of High-Speed Air Jets," was approved by the Exec. Comm. on 24 June 1930. The results appear in Eastman N. Jacobs and James M. Shoemaker, "Tests on Thrust Augmentors for Jet Propulsion," TN-431, Sept. 1932; and G.B. Schubauer, "Jet Propulsion With Special Reference to Thrust Augmentors," TN-442, Jan. 1933. See also Schlaifer, *Development of Aircraft Engines*, pp. 445.
36. Bush to Lewis, 14 Oct. 1938, in NA RG 255, entry 3, box 4, Bush, 1938–1940; U.S. Navy Dept., Bu. of Ships, Technical Bulletin 2, "An Investigation of the Possibilities of the Gas Turbine for Marine Propulsion," report submitted to the secy. of the navy by a committee on gas turbines appointed by the National Academy of Sciences, 10 June 1940 (Washington: Dept. of the Navy, 1941), p. 37. Commenting on this report in 1946, Jerome Hunsaker concluded that the lesson to be drawn from this product of "eminent doctors who looked pretty much backward" was ". . . do not depend on a survey of past efforts to forecast engineering possibilities under different conditions." Hunsaker suspected "the report was written by Professor [Lionel S.] Marks [of Harvard], a good engineer but old and not in touch with aviation developments. The others [including Millikan and von Karman] would sign what Marks had written after seeing how carefully he had surveyed the prior art." Hunsaker to Capt. G.L. Schuyler, U.S.N., 17 May 1946.
37. Jacobs's work was first authorized under a LMAL job order written in Feb. 1939; an official research authorization was not approved until 10 Sept. 1942. 58 A 454 (4), special file, RA 1020, Sept. 1942–July 1949.

On American tardiness in developing jet propulsion, NACA veteran Ira Abbott writes: This country was not, and is not, good at producing new things. There are a few exceptions, done under special circumstances, such as the atom bomb, but by and large, we excel at perfecting what other people start. . . . Consider space activities. Consider the ballistic missile. Consider atomic power in general and the breeder reactor in particular. The NACA was American through and through. Abbott to Monte D. Wright, 30 April 1980, enclosure, p. 15.

38. The discussion in this chapter of jet-engine development in the U.S. is based primarily on Schlaifer, *Development of Aircraft Engines*, chap. 16. Gray, *Frontiers of Flight*, is accurate as far as it goes but omits several facts that cast the NACA in a poor light. From 1929 to 1936, Durand supervised the planning, preparation, and publication of a six-volume study of *Aerodynamic Theory* sponsored by the Guggenheim Foundation. He wrote three of the 20 divisions in the set and worked closely with the other authors, therefore was fully abreast of the state of the art shortly before World War II. Hugh L. Dryden, "The Contributions of William Frederick Durand to Aeronautics," paper delivered at the Durand Centennial Conference, Stanford University, 5 Aug. 1959.
39. The membership of the Durand committee and a brief summary of its history are in R.E. Littell to Lewis, "Information desired by Mr. Gray on NACA jet propulsion activities," 9 Aug. 1946, from which the quotations are taken. Arnold's views are reported in Schlaifer, *Development of Aircraft Engines*, pp. 458-59. Hunsaker is reported to have said later that the "regular aircraft companies were approached but were not one bit enthusiastic" about joining the Durand committee. First Lt. Ezra Kotcher, Experimental Engineering Div., Materiel Command, U.S. Army, memo report of jet propulsion meeting, 27 Nov. 1942, quoted in Craven and Cate, eds., *Men and Planes*, p. 247. See also minutes of NACA semiannual meeting, 24 Apr. 1941, p. 5; minutes of Exec. Comm. meeting, 11 Sept. 1941, p. 9; and minutes of annual meeting, 23 Oct. 1941, pp. 4-7.
40. Schlaifer, *Development of Aircraft Engines*, pp. 450-51, 459-61; and Macon C. Ellis, Jr., and Clinton E. Brown, "NACA Investigation of a Jet-Propulsion System Applicable to Flight," TR-802 (1944). On the rejection of the Jacobs design, see Maj. Gen. O.P. Echols, U.S.A., to Durand, 16 Mar. 1943; Durand to Lewis, 22 Mar. 1943; and Lewis to LMAL, 22 Mar. 1943. The reaction of Jacobs, from which the quotation is extracted, appears in H.J.E. Reid to NACA, 30 Mar. 1943.
- During a liaison visit in England in the summer of 1943, Jacobs wrote to Lewis that the staff at the Royal Aircraft Establishment "profess to agree with me that the Army and Navy are short sighted in not backing our project to have constructed the N.A.C.A. jet propulsion airplane." Lewis replied: "I have always felt that if a jet-propulsion device was to be considered at this time for a single-engine airplane, and if range was an important factor, your particular scheme offered the best opportunity of answering the requirements." Jacobs to Lewis, 25 June 1943, in 61 A 195 (2), "Mr. Eastman Jacobs' visit to England"; Lewis to Jacobs, 12 July 1943, in NA RG 255, entry 3, box 12, 101.1, Hunsaker, OSRD.
41. Russell G. Robinson heard "rumors" of the "Buck Rogers" project that later became the P-59 during a visit to Bell Aircraft on 4 May 1942. Robinson to Lewis, 6 May 1942, in 61 A 195 (17), visits by NACA, April-June 1942. Hunsaker's remarks to Warner are in a letter of 16 June 1943 in 63 A 29 (10), 623, jet propulsion power plants. The story of secrecy in U.S. jet-propulsion development is in stark contrast to the policy pursued in England, where the Gas Turbine Collaboration Committee saw to it that resources were pooled and duplication avoided. See H. Roxbee Cox, "British Aircraft Gas Turbines," The Ninth Wright Brothers Lecture, *Journal of the Aeronautical Sciences*, 13 (Feb. 1946): 53-83. See also Lewis to Hunsaker, 28 Dec. 1942.
42. Arnold to Hunsaker, 14 Oct. 1942; rough draft of "Suggested Content of Letter to General Echols (To be signed by Dr. Hunsaker)," n.d.; Lewis to E.S. Taylor, 19 Jan 1943; Lewis and Hunsaker, "Memorandum of conference with General Echols regarding suggestions contained in General Arnold's letter of October 14, 1942, to Dr. Hunsaker, relating to engine design improvements especially for fighters," 23 Jan. 1943; Lewis to E.S. Taylor, 25 Jan. 1943.
43. Unfortunately for the NACA, most of its supercharger work was on the Roots type that George Lewis brought with him when he came to the NACA in 1919. This was a gear-driven positive-displacement supercharger, using neither the axial- nor the radial-flow compressors found efficient for jet propulsion, nor the exhaust-gas turbines developed with technology applicable for jets. See Marsden Ware, "Description and Laboratory Tests of a Roots Type Aircraft Engine Supercharger," TR-230, in *AR 1925*, pp. 451-61. Eastman Jacobs and E.W. Wasielewski had launched in 1938 a study of axial-flow compressors based on airfoil theory (Schlaifer, *Development of Aircraft Engines*, p. 460n.), allowing Jacobs to report confidently from England in 1943 of the British: "Like us, they realized early that the compressor design con-

stituted the main problem." "Visit to Royal Aircraft establishment at Farnborough," Nov. 1943, p. 13, in 63 A 101 (10), A-4-2, Jacobs' visit to England, 1943.

On 26 May 1944, General Arnold asked the chairman of the War Production Board for "highest precedence for electrical equipment for jet propulsion program," including a new drive motor for the 8-foot high-speed tunnel at LMAL and equipment for the "special laboratory, designed particularly for the investigation of jet-propulsion engines" which was then under construction at AERL.

44. Upon his return from England, Jacobs was asked by Lewis to "prepare for the consideration of the Committee a research program covering jet-propulsion projects which, in his opinion, should be undertaken by the Committee." Lewis to LMAL, 16 Nov. 1943, in 63 A 29 (10), 629, jet propulsion power plants. Lewis went on to say:

The activity of the Army Air Forces and the Bureau of Aeronautics of the Navy in assigning to various aircraft manufacturers special projects incorporating the use of jet propulsion may result in reference of these special projects to the Committee for investigation at any or all of the Committee's laboratories. No attempt has been made definitely to assign special phases of research in different categories to the different laboratories. At the present time, the only objective of the Committee in accepting the projects from the Army and Navy is to carry out the projects as quickly as possible; but, of course, there has been an assignment of problems where equipment is most suitable for the investigations required. In particular, tests of JP units as such will be assigned to Cleveland, where special facilities have been provided, and arrangements are now being made for the investigation of such units in the new engine-research wind tunnel.

Jacobs' argument about coordinating engine and aircraft design appears in "Jet Propulsion in England: Report of a Conference Attended by Officers of the Army and Navy and Representatives of American Industrial Organizations Visiting England during the Summer and Fall of 1943 For The Purpose of Study on the Above Subject," held in NACA offices, Washington, 18 Dec. 1943. His plea was the same as that made by Lockheed Aircraft Corp., credited by Schlaifer with "the first serious American work on a turbojet," the L-1000. *Development of Aircraft Engines*, pp. 448-50.

45. George W. Gray's *Frontiers of Flight* began as a contract with the NACA to record and report the Committee's contributions to the war. The book went far beyond that, but its pages contain a summary of NACA accomplishments in the war years. The NACA prediction on the B-32 is reported in Craven and Cate, eds., *Men and Planes*, p. 210. Lockheed's heated disagreement with the NACA over the P-38 was the subject of a memorandum, apparently by Hunsaker, "Conference on P38 tests at Lockheed (August 14)," memo for files, 24 Aug. 1942, which concluded that the NACA should "treat the Lockheed group with much more formality than others and *give them no advice whatever* [italics in original]." See also Hartman, *Adventures in Research*, pp. 97-99.
46. Both British and American skepticism about the Committee's claims for the low-drag airfoil were reported to George Lewis in a letter from Ed Warner, 25 Aug. 1942. NACA low-drag wing designs of this period achieved laminar flow over 60 percent of the chord in tests, but the Mustang and other aircraft using these wings never achieved such results in flight because of manufacturing irregularities and operating effects on the wing surfaces. Still, the low-drag wings were a dramatic improvement over the conventional types.
47. "NACA: The Force behind Our Air Supremacy," an editorial in the Jan. 1944 issue of *Aviation*, illustrates the general support the Committee received for a return to its prewar role. But as soon as the Allies began to get hard documentation on German Aeronautical research advances during the war, the NACA record began to pale by comparison. See, for example, Adolf Baeumker, "A History of German Aeronautical Research," trans. by F.W. Pick, Royal Aircraft Establishment, translation no. 87, Jan. 1946, typescript, 89 pp. See also pp. 204-205.
48. Mead to Hunsaker [ca. 1 July 1944] (copy):
49. Hunsaker to Mead, 14 July 1944.
50. Don K. Price, *Government and Science: Their Dynamic Relation in America* (Washington Square, N.Y.: New York University Press, 1954), chap. 3.

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51. A. Hunter Dupree has observed:

Many of the characteristics of the wartime research effort were in fact permanent changes in the government's relation to science, more so than even the leaders at the time expected. Expenditures of the order of \$1 billion or more became established. The predominance of weapons research and wide resort to contract were also prominent features which not only changed the shape of government science but also deeply affected the universities as well. As all the estates of science were drawn into a single great effort of applied science, the interests of basic science suffered not only in the government, but in their accustomed home in the private institutions. In the inheritance of these patterns, postwar science was more akin to the war period than to any previous era of peace. *Science in the Federal Government: A History of Policies and Activities to 1940* (Cambridge: Belknap Press of Harvard University Press, 1957), p. 373.

Hunsaker was more pessimistic, and less prophetic. In 1944 he wrote: "Military people are ready for civilian scientific cooperation now, but were extremely reluctant in 1938 and will be again!" Hunsaker to Capt. W.P. Roop, USN, 27 June 1944, in 62 A 35 (53), 300.1, 1944-1946.

52. *Science in the Federal Government*, p. 371.

53. The NACA had always maintained that development was the function of the manufacturers and the military services, but on the eve of Pearl Harbor it changed its stand to meet the exigencies of the coming war. In its annual report to Congress, the Committee claimed:

It falls to the aeronautical laboratories not only to provide the new ideas necessary to insure superior performance [of aircraft], but at the same time to prove in advance the soundness of the design as a whole. The Committee's work, therefore, falls into two principal categories: namely, *research* to furnish new ideas; and *development*, or the application of these ideas to current military designs. (*AR 1941*, p.1. Italics added.)

In 1943, Hunsaker wrote to Bush regarding a successor to the Office of Scientific Research and Development: "I hope the successor can be set up by legislation similar to that establishing the NACA—a Presidential Board or Committee with independent civilian chairman and senior service representatives." Hunsaker to Bush, 3 Sept. 1943, in 62 A 35 (42), 050, OSRD. The following year the NACA Committee on Postwar Research was given a memo dated 22 June 1944, apparently prepared by Victory, on "Outline of an organization paralleling NACA" to be named the National Defense Research Committee.

54. Victory told Gen. John Curry that Lewis had a heart attack on 1 Nov. and another a few days later. He told William Littlewood that Lewis's first attack was on 2 Nov., the second on 7 Nov. Victory to Maj. Gen. John F. Curry, U.S.A., 13 Nov. 1945, and to Littlewood, 18 Dec. 1945; both in 62 A 35 (15), 170.2 (semiofficial) (1).

CHAPTER 9

1. See, for example, Jerome C. Hunsaker, "Statement of Aeronautical Research Policy," before the House Select Committee on Post-War Military Policy, 26 Jan. 1945, in which the chairman stated that "aviation is entering an era of revolutionary change resulting from the development of new methods of propulsion." [p. 5] In *AR 1946*, the Committee said:

The close of the war marked the end of one whole phase of development of the airplane as conceived by the Wright brothers. The airplane in its present form is no longer a sound basis for future planning for the national defense. The power available in jet-propulsion systems brings flight through and above the speed of sound within reach. We now see no definite limit to the power that may become available for aircraft propulsion. Nor do we see a definite limit to the speed that may be attainable.

It is the immediate objective of the NACA to solve, as quickly as facilities and personnel permit, the most pressing problems attendant on high-speed flight, and to provide for the future development of knowledge in this seemingly endless new field of research. [p. 2]

2. In 1944 the \$17 billion of business done by the aircraft industry accounted for 10 percent of the GNP (*Research and Development Contributions to Aviation Progress* (2 vols.; Washington: Department of the Air Force, 1972), vol. 1, p. III-12). In 1945 the annual research and devel-

opment budget for the Army Air Forces alone was more than three times larger than the total NACA budget ("Some Statistics on Federal Aeronautical Funds, 1931-1953," typescript prepared by R.E. Littell, 26 Feb. 1953, in connection with NACA budget presentation).

3. A. Hunter Dupree, *Science in the Federal Government: A History of Policies and Activities to 1940* (Cambridge: The Belknap Press of Harvard University Press, 1957), p. 373.
4. Milton Lomask has counted 21 separate bills to create a national science foundation. Much of the following discussion is based on his *A Small Miracle: An Informal History of the National Science Foundation* (Washington: NSF [1976]), esp. chap. 3. The Vannevar Bush report is *Science, the Endless Frontier: A Report to the President on Postwar Scientific Research* (Washington: Office of Scientific Research and Development, 1945).
5. 62 A 35 (40), 010 legislation (NSF). The quoted comment is on a copy of H.R. 6448, 79th Cong., 2d sess. In describing this bill to his colleagues on the NACA, Vannevar Bush said that it put "the director under the board, much the same as Dr. Lewis is to us." Victory, "Discussion, Executive Committee, NACA, September 13, 1945," 2 pp., typescript, 23 Oct. 1945.
6. Harold D. Smith had been as responsible as anyone for the failure of a plan to create a Research Board for National Security (RBNS). He played the same spoiler role in the early maneuvering for a national science foundation. Profoundly skeptical of claims that scientists needed more independence and autonomy than others who received government funds, he wanted government research brought under the same economic and organizational controls as other federal activities. In rejecting a NACA request for supplemental appropriations in 1945, Smith wrote a subordinate:

We have authorized the building of wind tunnels all over the lot and in each case there has been advanced most logical reasons why the wind tunnels previously constructed did not meet the new requirements. I give the scientists credit for being more ingenious, especially if they are required to be. (Smith to M. Martin, BoB intraoffice memorandum, 1 Mar. 1945)

Commenting 30 Sept. 1943 on an earlier NACA supplemental, Smith had told the same addressee that "many murders are committed in the name of research." Though more extreme in this regard than his successors, Smith nevertheless voiced a sentiment that was to become increasingly dominant in the Bureau of the Budget: the government must be run on sound principles of management, organization, and economy, and scientific research was no exception. See also Kevles, "Scientists, the Military, and the Control of Postwar Defense Research: The Case of the Research Board for National Security, 1944-1946," *Technology and Culture*, 16 (Jan. 1975): 20-47.

7. Although Truman killed the first NSF bill with a pocket veto, he issued a "Memorandum of Disapproval" to make clear his reasons. In it he stated that "the bill would violate basic principles which make for responsible government." He explained in terms that should not have been lost on the NACA:

Full governmental authority and responsibility would be placed in 24 part time officers whom the President could not effectively hold responsible for proper administration. Neither could the Director be held responsible by the President, for he would be the appointee of the Foundation and would be insulated from the President by two layers of part time boards.

For a fuller discussion of the other controversies surrounding the creation of NSF, see Daniel J. Kevles, "The National Science Foundation and the Debate over Postwar Research Policy, 1942-1945: A Political Interpretation of *Science—The Endless Frontier*," *ISIS*, 68 (March 1977): 5-26.

8. Kevles, "Scientists, the Military and the Control of Postwar Defense Research." Hunsaker was on the committee that devised the RBNS plan. See 62 A 35 (73), "Committee on Post-War Research."
9. Thomas A. Sturm, *The USAF Scientific Advisory Board: Its First Twenty Years, 1944-1964* (Washington: USAF Historical Division Liaison Office, 1967), chaps. 1-3.
10. "We have had our troubles," Lewis wrote in Sept. 1945, referring to congressional enthusiasm for demobilization, "and we are not out of the woods yet. . . ."

"This reconversion is a most difficult period. Most everyone in the Government that I have talked with has had the same comment—the war was never like this." (Lewis to LtCol J.H. Belknap, 18 Sept. 1945, in 62 A 35 (15), 170.1 [semiofficial])

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11. The creation of the Department of Defense is described in Borklund, *The Department of Defense*, chaps. 1 and 2.
12. The quotations are from Senate Special Committee Investigating the National Defense Program, *Investigation of the National Defense Program: Additional Report of the Special Committee Investigating the National Defense Program*, S. Rept. 110, Pt. 7, 79th Cong., 2d sess., 3 Sept. 1946, pp. 147-48. Examples of industry criticism are in Senate Special Committee Investigating the National Defense Program, *Investigation of the National Defense Program, Hearings pursuant to S. Res. 55*, 79th Cong., 1st sess., part 31, July and Aug. 1945, pp. 15375-15459. Testifying the following year, Hunsaker told the committee that he was baffled by "relations with the industry—which, strangely enough, have come to you as being not good and have come to me as being wonderful." *Ibid.*, part 33, 27 Feb. 1946, p. 16862. Some manufacturers with comparatively mild criticisms of the NACA sent it copies of their statements to the Mead committee. See, for example, D. Roy Shoults to Hunsaker, 17 Jan. 1946, and Albert E. Lombard, Jr. to Hunsaker, 16 Jan. 1946.
13. Arnold's establishment of a Scientific Advisory Board was an implied criticism of the NACA, as was the air force's recourse to the RBNS. Of the latter Hunsaker wrote in 1945, "the Army is asking the RBNS the same questions it asks NACA and will be sore if RBNS does not take them up actively. They say NACA has not 'solved' the problems and, therefore, more groups should be put on the job." (Hunsaker to Oswald Veblen, 21 May 1945.) When Arnold, in an article published in *Air Affairs*, criticized the NACA for limiting itself too narrowly to aircraft research instead of pursuing more broadly the "problems of flight," Lewis observed that this was "not a well-considered statement." Robert McLarren to Lewis, "Extract from article by General Arnold," 7 Jan. 1947, with copy of Lewis's response.
14. Lewis to Edwin P. Hartman, 1 Aug. 1945, in 62 A 35 (65), 302.122; LMAL, "Appraisal of German Research during the War Relative to that of the NACA," 39 pp., typescript [ca. Oct. 1946]; copy with Hunsaker's comment is in 62 A 35 (24), 073 (1945-1949); Hunsaker to director, Bureau of the Budget, 2 Nov. 1945.
15. Evolution of this policy can be traced in 62 A 35 (73), "Post-War Research Policy." See especially, Hunsaker, "Memorandum on Postwar Research Policy," 27 July 1944; "Notes on Discussion at Meeting of NACA, July 27, 1944," 8 Aug. 1944; minutes of Executive Committee meeting, 7 Sept. 1944; and Hunsaker, "Statement of Aeronautical Research Policy," presented to the Mead committee on 26 Jan. 1946.
16. See appendix H.
17. *AR 1946*, p. 38. By legislative fluke, the section of the Army Air Corps Act of 1926 (USC, Title 10, sec. 310.r) that appointed the NACA Aeronautical Patents and Design Board for the military was never repealed. Technically, this responsibility was transferred to NASA in 1958 and still exists. See C.W. Borklund, *The Department of Defense*, Praeger Library of U.S. Government Departments and Agencies (New York: Frederick A. Praeger, 1968), p. 20. See also appendix A.
18. *Investigation of the National Defense Program*, hearings, part 33, p. 16816; *Research and Development Contributions to Aviation Process*, vol. 2, p. III-12.
19. See note 12 above. Mead suggested in part 33, pp. 16858-59, that the air force might in future do for itself the fundamental research that the NACA had performed for it in the past. The Mead committee was unimpressed with the NACA ploy of rolling out long lists of endorsements. When Hunsaker tried to introduce into the Mead committee hearings "a list of very grateful letters from chief engineers of airplane companies," Senator Hugh Mitchell (D, Wash.) demurred with the observation:

We would be glad to have those for the information of the committee but I don't think they should go into the printed record of this hearing. Of course, there are any number of people who will praise the work of the NACA and certainly we don't want to do anything to lessen that praise of the job you have done. Everybody agrees on that. I think the committee is interested in knowing the reasons why a greater job, a better job—well, not a better job but a bigger job—was not done in leading up to the war. (*Ibid.*, pp. 16831-32.)

Industry criticisms of the NACA may be found in the Mead committee hearings, in direct correspondence with the NACA, and in a 2-page report, "Criticism of the NACA," 23 Oct. 1945, prepared at the request of the Bureau of the Budget by Grover Loening. E.E. Wilson wrote to Hunsaker on 14 Oct. 1941 that the NACA "as now administered, is a politico-scientific organization, with the accent on the first syllable!" The suggestion that the NACA fold

- was made to Hunsaker at a May 1944 meeting in Cleveland with industry representatives and reported by him in "Notes on Discussion at Meeting of NACA, July 27, 1944," 8 Aug. 1944.
20. J.H. Kindelberger to Hunsaker, 10 Dec.; Hunsaker to Kindelberger, 21 Dec. 1945. For surveys of ICC activity, see "A Report to the Industry of the Work of the NACA Industry Consulting Committee," 30 Dec. 1949; and William Littlewood to L.S. Hobbs, 26 June 1956.
 21. Hunsaker to Kindelberger, 21 Dec. 1945: "There is serious objection to a man of important commercial interests [on the Main Committee] . . . Littlewood was our first break with a simon-pure policy, and I believe his appointment has been well received." See appendix B and *AR 1946*, p. 41.
 22. Bush to Hunsaker, 9 Dec. 1946.
 23. Hunsaker to Bush, 24 Dec. 1946.
 24. Hunsaker to Lewis, 26 Dec. 1946, with Lewis's notes. Hunsaker showed keener appreciation of this problem earlier in the year when he wrote to Kindelberger (13 Feb. 1946):

Another matter has to be watched out for. That is Congressional hostility to a suspicion of undue influence by "big Business." The Congressional Committees are strong for national defense and technical progress that makes for employment. Our estimates for next year were pared down by the Budget Bureau, but after strong representations of Dr. Lewis and myself, the House restored some of the cut. There was, however, a period in the hearings when it had to be shown that these funds were to be used on research "in the public interest" and not for projects desired by particular "contractors."

25. Hunsaker to Lewis, 1 Mar. 1947. This controversy can be traced through the records in 59 A 2112 (12).
26. The official NACA position appears in the policy paper "Functions and Responsibilities of Standing Committees and Subcommittees of the National Advisory Committee for Aeronautics," 11 Feb. 1948:

Members of technical subcommittees appointed by the NACA from outside the Government are appointed in their professional capacities as individuals and not as representatives of the employers. Minutes of subcommittee meetings and other reports and data sent to them as members are confidential documents, and are not to be made available to their employers and not to be published. The subcommittee members from the military services and from other Government agencies are representatives of the offices with which they are affiliated, but the members from private life are not representatives of any organizations.

This NACA position was worked out in correspondence in 1945: T.P. Wright to William Littlewood, 30 Apr. 1945; Hunsaker to Lewis, "Industry 'representation,'" 5 May 1945; and Littlewood to Lewis, 28 May 1945, with Hunsaker's notations. Hunsaker elaborated on the confidentiality of committee activities in a letter to H.M. Horner, 19 Nov. 1948. In another letter he wrote:

The subcommittees are appointed primarily to assist the NACA through making recommendations concerning the NACA research program and through the exchange of information which may be helpful in the formulation of such programs. Such exchange of information is intended entirely for the benefit of the government. (Hunsaker to W.M. Holaday, 14 Apr. 1947, in 59 A 2112 (12), 110 subcommittees (gen) (5) 1947)

27. Undated "Notes of Discussions at Meeting of National Advisory Committee for Aeronautics, April 26, 1945," on "Aircraft industry point of view regarding representation on NACA." One industry executive wrote bluntly to the NACA during World War II that, although his men were very busy, his understanding was that committee membership "doesn't call for a lot of meetings, and the prestige and associations are well worth the time and effort expended." Carl Breer to Hunsaker, 11 Mar. 1943, in 59 A 2112 (12), 110 subcommittees (gen) (2) 1943. Another industry executive came closer to the NACA position when he suggested that "successful operation depends primarily on the individual's understanding of his general responsibilities and his use of common sense in discharging them." Paul S. Baker to Milton B. Ames, 28 May 1948.
28. Hunsaker wrote to L.B. Richardson on 9 Feb. 1945: "We do . . . try to bring in men who are directly concerned with work in the various centers of engineering activity. In this way, the distribution of civilian membership sometimes looks fairly 'representative.'" In 59 A 2112 (31), 112.31, organization. The quotations are from undated "Notes of Discussions at

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Meeting of National Advisory Committee for Aeronautics, April 26, 1945," on "Aircraft industry point of view regarding representation on NACA."

29. Bruce E. Ayer to Lewis, 24 Apr. 1945.
30. Lewis to Ayer and Lewis to Sharp, both 15 May 1945; Edward R. Sharp to director of research, "Wind Tunnels," 7 Nov. 1945 (*italics added*). News of German research was also having its effect at headquarters; see R.G. Robinson to Lewis, "Effect of German aeronautical research information on NACA program," 5 July 1945.
31. Sharp to director of research, "Wind Tunnels," 14 Dec. 1945. By this time the Ames laboratory was also recommending new supersonic facilities, but, in contrast with the AERL proposal, Ames was promoting itself as the center to build and control them. See Smith J. DeFrance to NACA, "High-speed research facilities," 7 Dec. 1945.
32. Sharp to director of research, "Proposal for a Supersonic Research Center," 5 Feb. 1946.
33. Arnold Engineering Development Center, "Chronology," n.d., 11 pp., typescript; Sturm, *The USAF Scientific Advisory Board*, p. 6; and Frank L. Wattendorf to Gen. F. O. Carroll, "Proposal for a New Air Forces Development Center," 19 June 1945, in which this member of the Alsos team wrote that "the scope of German plans make[s] it essential that our own plans be certainly not less ambitious in the light of our future security."
34. George F. Gray, *Frontiers of Flight: The Story of NACA Research* (New York: Knopf, 1948), began as an NACA contract to report on the committee's wartime achievements.
35. Minutes of NACA annual meeting, 25 Oct. 1945, p. 5; minutes of special meeting of Executive Committee, 17 Dec. 1945, pp. 2-4; Sharp to director of research, "Proposal for a Supersonic Research Center," 5 Feb. 1946; Sharp to director of research, "Telephone Conversation with Major Jay AuWerter December 20, 1945 Regarding Location for Wind Tunnels," 20 Dec. 1945, with note by Charles H. Helms; D.B. Langmuir, "Extract of Remarks by Dr. Hunsaker Made at the 15th Meeting of the [Joint Committee on New Weapons and Equipment] Guided Missiles Committee on 1 March 1946," attached to R.G. Robinson to Hunsaker, 20 Mar. 1946.
36. Minutes of Executive Committee meeting, 21 Mar. 1946, p. 4.
37. R.G. R[obinson], "Army Air Force plan for 'Air Engineering Development Center,'" memo for file, 25 Mar. 1946, handwritten, marked "Secret Very Limited Internal Distribution."
38. LeMay actually revealed the plan to the press on 20 Apr. 1946, but apparently did not publish the plan at that time. See *New York Herald-Tribune*, 21 Apr. 1946. The NACA received a copy of "Proposed Air Engineering Development Center Summary for Air Staff," undated, 12 pp., on 16 Apr. 1946, but there seems to have been no indication of the campaign that was about to begin to sell the plan. Roscoe C. Wilson to George Lewis, 16 Apr. 1946; Lewis to E.R. Sharp, 16 Apr. 1946.
39. "Notes on Conference with Dr. Lewis, Messrs. Crowley, Victory, Chamberlin, Ulmer, Helms, and Robinson," 27 Mar. 1947; Lewis to Reid, DeFrance, Sharp, "Proposed National Supersonic Research Center," 2 Apr. 1946, with enclosures; NACA, "A Proposal for the Construction of a National Supersonic Research Center," Apr. 1946; T.L.K. Smull to Hartman, 4 Apr. 1946; Hartman to chief of research coordination, "Industry Reaction to NACA Proposal for a National Supersonic Research Center," 29 Apr. 1946.
 For examples of the studiously noncommittal replies from industry, see G.S. Schairer (Boeing) to Lewis, 19 Apr.; J.C. Miller (General Electric) to Lewis, 18 Apr.; J. Carlton Ward (Fairchild) to Lewis, 17 Apr.; and R.E. Hopper (Hughes) to Lewis, 16 Apr. 1946.
40. The Raymond panel did not resolve all the questions surrounding the need for new tunnels, so it was succeeded by a special committee on supersonic facilities, chaired by Hunsaker. That committee met 21, 22, and 24 Oct. to iron out differences. The minutes reveal that one of the major problems was Hunsaker's hostility toward the Army Air Forces, which he claimed "have arrived at the point of wanting to duplicate NACA equipment." The air force representatives denied this, but they seem to have done nothing to allay Hunsaker's concern. The harsh tone of this exchange was edited out of the final version of the minutes, but the source of contention remained. See also "Report of Special Committee on Supersonic Facilities," 24 Oct. 1946.
41. These differing perceptions can be seen in the summary of proceedings of the "NACA Industry Conference on Unitary Plan," held in Los Angeles 14 Nov. 1949, where NACA-industry suspicion of air force intentions is especially evident. The NACA's own ambitions appear most clearly in a staff memorandum for Lewis, "Analysis of Supersonic Facilities," 18 Oct. 1949.

42. The key events can be traced in "Short History of Unitary-Wind-Tunnel Plan," 4-p. typescript, 7 Nov. 1949; "Addendum to Short History of Unitary-Wind-Tunnel Plan," 6-p. typescript, 31 July 1950; and Arnold Engineering Development Center chronology, 11-p. typescript, n.d.
43. These generalizations are distilled from a 6-inch stack of documentation extracted from the NACA files, now to be found with the other documentation for this chapter. There is not room in this study to pursue all the intricacies of this story or to cite all the relevant documents, but these materials could well serve as the basis for a monograph.
44. House Committee on Armed Services, *Report to Accompany S. 1267*, 81st Cong., 1st sess., H. Rept. 1376, p. 4.
45. See appendix A.
46. House Armed Services Committee, *Report to Accompany S. 1267*, p. 10.
47. *Ibid.*, p. 13.
48. Only one member of the aeronautical fraternity in the U.S. seems to have recommended an approach to supersonic facilities less extensive than those advocated by the NACA and the Army Air Forces. Commenting on the unitary plan about to be recommended by the Raymond panel in 1946, Hugh L. Dryden of the National Bureau of Standards said:
 I believe that this plan answers any foreseeable demands of the next twenty years, but there are some doubts in my mind as to whether the 8 ft and 15 ft supersonic and the large hypersonic facilities should be built on the time schedules proposed. If our diplomatic and military leaders feel that a new war is so imminent that active technical preparations should be expedited, the whole program should be prosecuted vigorously. If this is not the case, ordinary engineering prudence would dictate that some operating experience be accumulated in the five large supersonic tunnels now under construction before building facilities of a different order of magnitude. The facts that no other nation has facilities or so far as known is even contemplating facilities remotely approaching those already under construction in this country and that the Germans designed the V-2 and other supersonic missiles on the basis of tests in a 1.3 ft intermittent supersonic wind tunnel appear to me to justify some degree of conservatism. (Dryden to Raymond, 29 May 1946)
- The following year Dryden became the NACA's director of aeronautical research.
49. Industry influence was evident throughout the Mead committee hearings; see note 12. The House Armed Services Committee stated in its *Report to Accompany S. 1267*:
 While the committee is fully aware of the ramifications of the NACA system of committees and subcommittees and the fact that provision is made for industry representation among these various groups, it would appear notwithstanding that there is considerable room for the development of adequate procedures which will insure at all times that basic scientific information is circulated freely and made available to all research groups and technical workers having an interest in the subject matter, except in those cases where there is a very clear and unquestionable need for placing the information in a classified category on grounds of military security alone and for no other reason. (p. 8.)
50. *Ibid.*, p. 5. Appendix E contains a description of the NACA's supersonic tunnels. John V. Becker writes:
 NACA was fortunate it never had to take on the enormous chores of building the NSRC. Most of its grandiose facilities were too huge and unwieldy for research—useful only for hardware testing. NSRC was NACA's gross over-reaction to reports from Germany and to competition from the Air Force. (Becker to Monte Wright, 30 May 1980, encl.)
51. *Ibid.*, pp. 10-11.
52. Edwin P. Hartman, *Adventures in Research: A History of Ames Research Center, 1940-1965* (Washington: NASA, 1970), pp. 150-52. Dryden's comments appear in the minutes of Executive Committee meeting, 24 Sept. 1948.
53. Lewis to Reginald M. Cleveland, 18 Sept. 1945, in 62 A 35 (15), 170.1 (semiofficial).
54. Victory to Woodrum, 23 Aug. 1945, in 62 A 35 (16), 170.2(a).
55. W.H. Shapley to "Mr. Ramsey," Bureau of the Budget memo, "NACA Hearing on Supplemental Estimate for Construction under Unitary Wind Tunnel Plan," 24 Mar. 1950. See also Shapley to "Mr. McCandless," "House Action on Supplemental Estimate for the National

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- Advisory Committee for Aeronautics," 24 May 1950; and Shapley to Ramsey, "Apportionment of NACA Funds for Construction of Unitary Plan Wind Tunnels," 7 Aug. 1950.
56. J.F. Victory, "A Full-Time Paid Chairman for NACA," memo for files, 15 Apr. 1949; *Congressional Record*, 81/1, 1949, vol. 95, pt. 4, pp. 4645-46. See also chap. 11, pp.
 57. Quoted in minutes of Executive Committee meeting, 17 Mar. 1949, p. 5.
 58. Transcript of interview with Willis Shapley, 30 Dec. 1948; Shapley to "Mr. Alger," Bureau of the Budget memo, "Your Draft Memo on Proposed Transfer of NACA to Department of Commerce," 25 Nov. 1949.

CHAPTER 10

1. Richard K. Smith, comp. and ed., *The Hugh L. Dryden Papers, 1898-1965: A Preliminary Catalogue of the Basic Collection* (Baltimore: Milton S. Eisenhower Library, Johns Hopkins University, 1974), pp. 19-20, 38.
2. Biographical information is drawn from Smith, *Dryden Papers*, pp. 19-33, and Jerome C. Hunsaker and Robert C. Seamans, Jr., *Hugh Latimer Dryden, 1898-1965: A Biographical Memoir* (New York: Columbia University Press, 1969), reprinted from National Academy of Sciences, *Biographical Memoirs*, vol. 40.
3. This quotation appears in Smith, *Dryden Papers*, p. 20, without provenance.
4. In the 1920s and 1930s Dryden was author or coauthor of 14 NACA technical reports, the most formal and most prestigious of the NACA report series. See NACA, *Index of NACA Technical Publications, 1915-1949* (Washington: NACA, 1949), pp. 5, 8, 10, 17, 20, 66, 218, 553, and 566.
5. Johns Hopkins University, Milton Eisenhower Library, Hugh L. Dryden papers, subject files, box 3, "1947, June-July-August. Correspondence re Hugh L. Dryden's Appointment as Director of NACA," esp. Hunsaker to Dryden, 30 June 1947.
6. Dryden, "Report of Director of Aeronautical Research Submitted to the National Advisory Committee for Aeronautics at its Annual Meeting, October 23, 1947," attached to minutes of the meeting.
7. See appendix A. In 1945 Hunsaker went a step further and gave Victory a blanket authorization to act as head of the agency. He wrote: "As Executive Secretary of the National Advisory Committee for Aeronautics, you are authorized and directed, under provision of Article II Section IV of the Rules and Regulations for the Conduct of the Work of the National Advisory Committee for Aeronautics, with amendments approved by the President to October 23, 1944, to exercise the functions required by law to be performed by a head of department or agency." There was some question as to whether or not this was legal, let alone advisable; see W.M. Shea, draft memo for [E.H.] Chamberlin, "Heads of Departments—Delegation of Authority," undated. Shea apparently worked in the Office of the Comptroller General, where Victory had sent a copy of Hunsaker's letter on 14 Nov. 1945.
8. Hunsaker night letter to James E. Webb, director of BoB, 13 Dec. 1948, in 62 A 35 (41), 010 legislation general 1942-1948; Victory to distribution, 19 May 1949, in 65 A 953 (2), interoffice memos, 1950; appendix A; Hunsaker to Elmer B. Staats, 21 Feb. 1949. The quote is from C.B. Stauffacher (Arnold Miles, Irving Lewis) to Staats, "Amendments to NACA Regulations," 5 Apr. 1949, which actually says "new program responsibilities," clearly a slip of the pen in light of the context.
9. Stauffacher to Staats, "Amendments to NACA Regulations," and I.J. Lewis to Arnold Miles, "Proposed Amendments to NACA Regulations," 21 Feb. 1949. This latter memo argued that the NACA proposal "would not provide for an integrated organization," a continuing criticism in some quarters at BoB.
10. National Security Branch (W.H. Shapley) to Staats, "Proposed amendments to NACA regulations submitted February 7, 1949," 11 May 1949. On his copy of this memo, Miles, of the Div. of Administrative Management, wrote "Methinks [he] doth protest too much." Reporting the debate to his superiors, Shapley said that "the Administrative Management Division has agreed to disagree." (Shapley to Veatch and Ramsey, 11 May 1949)
11. The postwar change in Victory can be traced most clearly through his personal papers in the Special Collections Branch of the U.S. Air Force Academy, Colorado Springs, which contain copies of his history drafts and the notes he used in numerous speaking engagements in the 1940s and 1950s.

12. The heads of the NACA laboratories were assigned the uniform title "director" in July 1947, two months before Dryden succeeded Lewis but one week after he learned of his selection. Perhaps one reason that the title had not been used before Dryden's time was the opposition of Vannevar Bush. He said in 1939, "I don't like 'director.' It implies *line & this is staff.*" Bush to Lewis, 4 Sept. 1939, in NA RG 255, entry 3, box 4, Bush, 1938-1940.
- A curious footnote to the entire story is that, as soon as Dryden was appointed director by Hunsaker's letter to the Executive Committee of 19 May 1949, he authorized Victory to act as head of the agency. This was the same power Hunsaker had previously conferred on Victory; the difference was that it now came from the director. See Victory to Hunsaker, 1 Feb. 1949, and General Administrative Directive 1-49, 19 May 1949, in 62 A 35 (52), 300.1 1948-1949.
13. On Dryden, see note 2; on Hunsaker, see the biographical information in the Hunsaker papers, National Air and Space Museum, Smithsonian Institution, Washington, D.C.
14. See, for example, M.B. Ames, Jr., to Lewis, "Proposed reorganization of NACA Committees on Aircraft Structures and Materials," 5 Jan. 1943; H.C. Chandler, Jr., H.M. Conway, and W.J. McCann memo, "Recommended reorganization of Committee on Aircraft Structures and Committee on Materials," 26 May 1943; Thomas T. Neill to Lewis, "Membership for coming year on: Committee on Power Plants for Aircraft, Subcommittee on Heat Exchangers, Subcommittee on Supercharger Compressors," 22 Dec. 1943; Neill to Lewis, "Membership for coming year, 1944, on the Committee on Power Plants for Aircraft," 29 Dec. 1943; McCann memo, "Reappointment of NACA Special Subcommittee on Heat-Resisting Alloys," 27 Sept. 1944; Addison M. Rothrock to executive engineer, AERL, 16 March 1943, in 62 A 35 (9), 123.3, research; Rothrock to Lewis, 1 Aug. 1944, in 59 A 2112 (26), 112.11, 1940-1951; Rothrock to Lewis, 9 Aug. 1946, in 59 A 2112 (12), 110 subcommittees (gen) 1945-1946; R.E. Littell to director of aeronautical research, 17 Apr. 1946, in 62 A 35 (2), 122.3; and John G. Lee to Hunsaker, 26 Sept. 1946, in 60 A 635 (12), 110.1, Lee, John G.
15. Harrison C. Chandler, Jr., to Lewis and Crowley, "Relations with NACA Technical Committees and Subcommittees," 2 Dec. 1946.
16. See appendix H.
17. F.W.S. Locke to NACA, 30 Oct. 1951.
18. At least one member was as concerned about the Main Committee's effectiveness as others were about the technical committees and subcommittees. E.U. Condon of the National Bureau of Standards wrote Hunsaker in 1946: "Although I have been a member of NACA for about a year it is not yet clear to me just what degree of responsibility for the operations we are supposed to have." He asked for more information, implying that he wanted to make his own judgments instead of depending on presentations made by the staff for the Main Committee's approval. Hunsaker provided him with the information he requested, but seems not to have changed the policies surrounding the Main Committee as Dryden was doing with the technical committees. Condon to Hunsaker, 28 Oct. 1946; Hunsaker to Condon, n.d., filed at NACA on 2 Dec. 1946.
19. Lewis to James H. Doolittle, 10 June 1947, in NA RG 255, entry 3, box 6, Doolittle, 1946. [Blank in the original].
20. Hugh L. Dryden, "The Responsibilities of Research Directors," a talk delivered to the Institute on Administration of Scientific Research and Development, American University, Washington, 7 June 1949, p. 13. The next and last sentence of the quoted paragraph is: "In this extreme case and in others, the sales effort may be merely a clear and excellent presentation of a scientific paper," revealing clearly where Dryden's preferences lay.
21. Appendix H provides an excellent insight into headquarters thinking about inspections at this period, and indeed throughout most of the Committee's history. Abbott's comment that "Erroneous impressions may . . . result from talks that are strictly accurate" is probably no more sinister than Saki's observation that "a little inaccuracy sometimes saves a ton of explanation."
22. For example, in its *Annual Report* for 1946, the Committee observed that abandonment of fundamental research during World War II "amounted to sacrifice of the future to the present." Recalling its exclusive preoccupation during the war with problems of immediate application, it continued:

Now the reserve of knowledge available when we entered the war, and without which victory would have been greatly delayed, has been exhausted.

NOTES

This forces us to face the urgent necessity for renewed emphasis on fundamental research. Without certain essential design data the development of very high-speed aircraft and guided missiles cannot proceed on a sound basis, nor can tactical or even strategic plans for air warfare be developed with any assurance of practicability. (p. 2)

23. Edwin Hartman, "Comments on Aeronautical Research Policy," 28 Aug. 1944, in 62 A 35 (73), postwar research policy, Sept.-Dec. 1944. The story of icing research appears in George W. Gray, *Frontiers of Flight: The Story of NACA Research* (New York: Alfred A. Knopf, 1948), chap. 14.
24. Ira H. Abbott to Monte D. Wright, 30 April 1980, encl., p. 17; John V. Becker to Monte D. Wright, 30 May 1980, encl., p. 350.
25. Theodorsen revealed the narrow line he walked in justifying a proposed research authorization on "General Theoretical Investigations of Flutter, Compressible and Potential Flow, Boundary Layer and Transitions," pending 18 Sept. 1941:
 In many problems studied at the [Langley] Laboratory it is necessary to extend the scope of the original authorization in a theoretical direction in order to obtain the fullest understanding of the underlying principles. A certain amount of this work is necessarily going on at all times. This R.A. is to cover theoretical work not otherwise chargeable and also experimental work of the fundamental nature not directly chargeable to existing specific R.A.'s. (57 A 415 (1), 1-1)
26. Willis H. Shapley to [Roger] Bounds, BoB, "Visit of Mr. Miller of the NACA Langley Field Laboratory," 11 July 1945.
27. Victory wrote to Hunsaker on 11 Nov. 1948 that the head of defense estimates at BoB had told him that the NACA makes the best budget presentations of any government agency (59 A 2112 (11), 31-1, Hunsaker, 1948-1952). The "favorite project" of another man in the same branch, however, was "reducing the size, bulk, and weight of the NACA budget presentation" (Shapley to Veatch, "NACA 1950 Budget Presentation," 13 Aug. 1948). In a pile of documents as large as that which the NACA annually presented to BoB, it was difficult to separate comprehensive justifications from a calculated avalanche of detail. Throughout the 1940s, the NACA budget rose every year save 1946. See appendix C.
28. Thomas L.K. Smull attended a declassification conference in 1945, where it was implied that "the NACA might possibly be unnecessarily withholding information." He concluded:
 From the trend of the discussions at the meeting, it was readily evident that the NACA should take immediate steps to declassify and give a rather wide distribution to such information as may now be declassified. It was quite obvious that pressure would be brought to bear to see that steps were taken in this direction.
 Smull to Lewis, "Conference on the declassification and dissemination of technical information at the Department of Commerce on September 5, 1945," 5 Sept. 1945.
29. See appendix G.
30. See, for example, LMAL to NACA, 27 Apr. 1948, in 58 A 454 (1), special file, RA 351, Jan.-Sept. 1948.
31. Minutes of Executive Committee meetings, 15 Aug. 1946 and 24 Nov. 1947; minutes of NACA meeting, 24 Oct. 1946. The entire story can be traced in 62 A 35 (53), 300.1, 1940-1950.
32. See appendix A, and minutes of Executive Committee meeting, 21 Sept. 1950.
33. Minutes of Executive Committee meeting, 6 June 1946, pp. 13-14.
34. See appendix B, and pp. 163-164.
35. Lewis to distribution, "Establishment of a Division of Research Information in Washington Headquarters—Mr. E. Eugene Miller, Chief," 18 Sept. 1946.
36. The Office of Aeronautical Intelligence was expected to deal only with published material. Work in progress, especially at universities, remained the responsibility of the Coordination Office. The complexity of the task and the difficulty of staying abreast of aeronautical research is suggested in: W.R. Sears to Hunsaker, 30 Mar.; Hunsaker to Dryden, 5 Apr.; Dryden to Hunsaker, 13 Apr.; and Dryden to Sears, 13 Apr. 1948. Sears, a member of the NACA Committee on Aerodynamics, had attempted to poll all leading academic aeronautical research institutions to prepare a summary of research in progress; Hunsaker and Dryden considered this impractical.
37. See appendix G, and Abbott to Wright, 30 April 1980, encl., p. 18.
38. On Warner's criticism, see his letters to George Lewis in 57 A 415 (2), 1-5A, 1926-1932.

By 1941 the editorial group at headquarters had already adopted the position it would take all through World War II:

Under the stress of the present emergency, it has not been practical for authors of our technical papers to give as much attention to analysis of results as is desirable, and this may account for the fact that the conclusions are not always as definite as they should be. An effort will be made, however, to keep the standard as high as practicable. (Quoted in Lewis to Hunsaker, 13 June 1941, in NA RG 255, series 3, box 10, NACA general correspondence [Hunsaker] 1941.)

When Warner suggested in 1941 that NACA reports contain an executive summary, at least one staff man demonstrated sympathy with what Warner had been trying to get across over the years. He wrote Lewis:

It is appreciated that the ideal form of an NACA publication is a scientific research report in which a thorough and complete analysis of the problem at hand is presented. It is also appreciated that in aerodynamic tests, large amounts of data are obtained which would be impractical to present in published reports, and consequently these data should be analyzed by the laboratory staff and the results of the analyses only could be presented in the interest of keeping reports from being too voluminous.

The suggestion of Dr. Warner that NACA reports be prepared so that a busy executive can glance at them and obtain a quick idea of the scope of the investigation and the results, the writer believes this is essential at this time [sic]. The arrangement of NACA reports to provide this quick summary need not interfere with the usual thorough NACA presentation. The Committee on Power Plants for Aircraft has voiced a strong opinion that more original test data should be included in NACA reports. (R.E. Littell to Lewis, "Content and form of NACA reports," 31 Dec. 1941, in 63 A 29 (3), 618.2 wings.)

The last sentence of Littell's memo demonstrates that the NACA was often damned if it did and damned if it did not. While Warner was asking for more analysis, many engineers in industry were asking that the NACA not fair its curves—that it present the point results of its tests on graphs rather than averaging them out to curves approximating specific findings.

39. Minutes of Executive Committee meeting, 19 May 1949, pp. 11–12.
40. The entire story can be traced in 65 A 953 (36), A-34, 1957.
41. Lewis to C.F. Taylor, 3 Nov. 1934, in 57 A 415 (2), 1-5A, 1933-; David Baker to John Foster, Jr., 4 Dec. 1946, in 62 A 35 (68), 317, 1946–1947. Hunsaker's comment appears in Senate Special Committee Investigating the National Defense Program, Investigation of the National Defense Program, hearings on S. Res. 55, 79/2, 1946, part 33, p. 16845. Interestingly, the senators seem to have been well primed by earlier industry testimony. One replied "Why not?" Another suggested that it "would be helpful to research men in the Army Air Forces and in industry who might get a similar idea 5 years from today and go through the same rigamarole and come up with another 'dead cat.'" Hunsaker replied that "engineers and professional men are not in the habit of writing papers about false ideas unless they are very important ideas held by a lot of people, and then sometimes the controversy is worth publication." When asked, he stated his conviction that the NACA was publishing the papers that merited publication.
42. NACA to Ames, 7 Nov. 1950, in 56 A 35 (4), TN-2288.
43. Abbott to Wright, 30 April 1980, encl., p. 19. Lewis wrote in 1934 that "it is not the policy of the Committee to release in any form detailed information on the design and construction of special instruments developed by the committee." (Lewis to LMAL, 2 June 1934, in 57 A 415 (22), 21-14, 1934.)
44. NACA thinking on university contracts can be traced in Thomas Leland K. Smull to Lewis, "University research—future policy," 7 Sept. 1945; Smull to Lewis, "Expansion of the NACA Contract Research Program—Fiscal Year 1948," 27 Aug. 1946; and W.H. Shapley, "Proposed Increase in the Research Contract Program of the NACA," memo for record, 29 Apr. 1948, wherein appears the term "standoffishness." For evidence of the latter, see Hunsaker to Lewis, 22 May 1944, in which the chairman raised the possibility of a suspicion in academic circles that "university cooperation with NACA needs a salesman or an inside track," even at MIT, which held more than 40 percent of the institutional memberships on NACA subcommittees. (Thomas T. Neill, "Summary of Institutional Memberships on Subcommittees and Institutional Research Funds for period 1939–1948 (Incl.)," 8 Feb. 1950.)

On proprietary information, see the policy reprinted in appendix H, originally adopted because of a dispute with one of the engine manufacturers and later expanded to include all NACA research. See minutes of Executive Committee meeting, 16 Dec. 1949, p. 6.

45. Indicative of the emphasis then being put on high-speed flight was the 4 Oct. 1945 letter to George Lewis from Brig. Gen. L.C. Craigie, chief of the Engineering Div. at Wright Field, which said in part: "This command feels that the fundamental problems of high-speed flight are of such magnitude and importance to this nation that the pertinent facilities of the NACA should not be diverted to any other purposes."
46. Richard Hallion, *Supersonic Flight: The Story of the Bell X-1 and the Douglas D-558* (New York: Macmillan, 1972).
47. Hallion, *On the Frontier: Flight Research at Dryden, 1946-1981* (NASA SP-4303, in press).
48. Clarence L. Johnson to Milton B. Ames, Jr., "Minority Opinion of Extremely High Altitude Research Airplane," 21 Oct. 1954, states in part:

1. At any given time period in which we were flying the research airplanes from the type 558-1 through the X-3, tactical airplane types were available which had better aerodynamic form and higher performance at reasonable altitudes than the research airplanes involved. For instance, wing thicknesses, wing sweep angles, and general aerodynamic design of the research airplanes were actually behind tactical aircraft designs by the time any research flights could be performed.

2. Our research airplanes have developed startling performance only by the use of rocket engines and flying essentially in a vacuum. Testing airplanes designed for transonic flight speeds at Mach numbers between 2 and 3 has proven, mainly, the bravery of the test pilots and the fact that when there is no drag, the rocket engine can propel even mediocre aerodynamic forms at high Mach numbers.

3. I am not aware of any aerodynamic or power plant improvements to air-burning engines that have resulted from our very expensive research airplane program. Our modern tactical airplanes have been designed almost entirely on NACA and other wind tunnel data, plus certain rocket model tests. The flight expenditures for one type of research airplane was, roughly, one and one-half million dollars per flight, with very little flight information obtained that is useful in future designs. Lack of suitable power plants and terrifically long development periods were responsible for such costs.

4. While a great deal of information has been developed on stability and control at high Mach numbers, this data has applied to aerodynamic forms not typical of airplanes actually designed for supersonic flight speeds.

Johnson's criticisms must be discounted for professional jealousy and the "not-invented-here" syndrome. Furthermore, the research aircraft program had begun in the second half of the 1940s, before the transonic wind tunnel was available to give researchers the mach-1 flight data they needed. Johnson was nevertheless a giant in the field, and his objections, especially about the relative cost of the program, have not been addressed in print by the supporters of the research aircraft.

Hallion paints this conflict in bolder colors in his Dryden book than in his earlier *Supersonic Flight*. The later volume relies heavily for this topic on interviews with old NACA hands still at Dryden center or in retirement, and it was perhaps from these men that Hallion derived his interpretation of what happened. The staffs at all the laboratories liked to think of themselves as more knowledgeable than the headquarters staff, and they were not above using their positions near the work to get their own way. In this regard, Lewis was and always had been fighting a losing battle. The remarkable thing is how much and how long he kept control. That he lost out on this issue is further testimony to the growing complexity of aeronautics and the NACA program and to Lewis's own failing powers.

Of course this syndrome is not unique to the NACA. Langdon Winner has observed: Research on organization communication has shown that decentralized segments of organizations use the information they possess as a resource to further their own specific purposes and thwart control by a central source. . . . Particularly in work that involves highly sophisticated expertise and the quest for results that cannot be determined precisely in advance, hierarchy and centralization are counterproductive. (*Autonomous Technology: Technics-Out-of-Control as a Theme in Political Thought* (Cambridge, Mass.: MIT Press, 1977), p. 254)

49. Gray, *Frontiers of Flight*, chap. 15.

50. Russell G. Robinson wrote to George Gray 28 Mar. 1948 that "the most important technical problem in aeronautics at this time is that of retaining control of the airplane through the speed range near the speed of sound." In 59 A 2112 (10) 100 (Gray) 1947.
51. Hunsaker, NACA memorandum, "Guided Missiles, NACA Program and Facilities," 15 Dec. 1944; "Notes on Discussion at Meeting of NACA, December 18, 1944," 18 Dec. 1944. When Hunsaker appointed the special committee in January, he listed its functions:
1. To recommend most promising fields of research in support of naval and military development needs.
 2. To propose specific research projects to the appropriate NACA technical sub-committees.
 3. To exchange and evaluate information on technical developments in order to guide American research efforts.
 4. To cooperate with other Government agencies active in guided missile development.
 5. To cooperate in research with foreign representatives as may be consistent with military policy.
 6. To invite attendance of persons interested in particular problems and projects with a view to coordination of effort.
 7. To review NACA research results and to control their issue as reports. (Hunsaker to members of Special Committee on Self-Propelled Guided Missiles, 25 Jan. 1945)
52. The debate over guided missiles reveals the proliferation of technical committees advising the military and supplanting the NACA. A Committee on Guided Missiles was created in Jan. 1945 by the Joint Committee on New Weapons and Equipment of the Joint Chiefs of Staff. The Joint Research and Development Board, which replaced the Office of Scientific Research and Development in 1946, had its own Committee on Guided Missiles; when the Research and Development Board replaced the JRDB under the terms of the National Security Act of 1947, it took over that committee as well as the Guided Missiles Committee. This was the year in which the NACA abolished its short-lived Committee on Self-Propelled Guided Missiles.
53. Joseph Adams Shortall, *A New Dimension: Wallops Island Flight Test Range, the First Fifteen Years*, NASA Reference Publication 1028 (Washington: NASA, 1978). At first, only part of the land on Wallops Island was purchased; the rest was leased. In 1949 the NACA purchased the entire island.
54. Letter from Adm. Leslie C. Stevens, dated 10 Jan. 1947, quoted in minutes of Executive Committee meeting, 24 Jan. 1947, p. 11; Victory to Condon, 30 Jan. 1947; LeMay to Condon, 4 Mar. 1947.
55. Minutes of Executive Committee meeting, 24 Jan. 1947, p. 11; Condon to Hunsaker, 16 Apr. 1947. How cautiously the Committee was treading here can be inferred from a letter that J.W. Crowley sent the Cleveland laboratory on 19 Aug. 1947, titled "Laboratory progress report for period July 1-31, 1947." Crowley informed the staff that in their report he had changed "Nuclear Energy Propulsion Research" to read "Fundamental Heat Transfer Research," and he directed them to make the same change in all outstanding copies of the report. He went on:
- Because of the present unsettled conditions surrounding the Committee's research on nuclear energy, it was not considered advisable to let the report go out in its original form. . . . It is requested that until further notice, no reference be made to nuclear energy in the laboratory's progress reports.
56. Although the Collier trophy for breaking the sound barrier probably would have gone to the three contributing institutions in any event, Dryden was adamant that the NACA not promote itself alone for the award. In a letter from H.J.E. Reid to Victory, 20 Oct. 1948, forwarding material to support the award, Dryden penciled in:
- John:
- I still feel strongly that any award *for the XS-1* achievement to an individual or single group, whether NACA or outside, will in the end be very harmful to NACA and handicap further competitive effort. The best interest of NACA and the nation will be served by the joint award to NACA, Air Force, and Bell [Air-craft Corp.]. (In NA RG 255, entry 2, box 10, public information.)

One of the insights Dryden brought to the NACA was the perception that self-serving could be self-defeating.

57. See, for example, "Statement to Budget Officials by Dr. J.C. Hunsaker, Chairman, National Advisory Committee for Aeronautics," 13 Oct. 1948; *AR 1948*, p. 1; *AR 1949*, p. 1.
58. This copy of the estimates is in 64 A 518 (11), 1950.

CHAPTER 11

1. See BoB, National Security Branch (W.H. Shapley) to "Mr. Tiller," "Change in Functional Classification of N.A.C.A. Appropriations," 29 June 1949; and J.E. Reeve to "Mr. Labovitz," "Proposed Reclassification of NACA Appropriations to National Defense," 5 July 1949, from which the quotation is taken.

To the Committee on Operating Problems, formed during World War II, only the subcommittees on Aircraft Fire Prevention; Aircraft Noise, and Flight Safety were added in the postwar years, and these accounted for only a small part of the NACA research program.

2. The following excerpt from the minutes of the Executive Committee meeting of 21 September, 1950 reveals the trend of military thinking:

General Saville stated that the demands of the Air Force for research by the NACA would be nearly doubled in the next year, and the Committee's estimates for personnel and operating funds should be based on the limit of the capacities of the Committee's research facilities. He said that the fundamental defense of requests for funds for the NACA would be the responsibility of the military services—they would testify that a maximum research effort by the NACA is essential for the development of superior military aircraft required to meet the country's needs. (p. 8)

For examples of this kind of testimony, see House Committee on Appropriations, *Hearings on Independent Office Appropriations for 1952*, 82/1, 1951, pp. 358-59; *ibid.*, Subcommittee on Independent Offices Appropriations, *Hearings on Independent Offices Appropriations for 1953*, 82/2, 1952, p. 373.

3. *AR 1950*, pp. 1-2.
4. John Stack, unsigned memo for chief of research, "NACA research potential and current and future needs," 14 Dec. 1951, with cover memo by Walter T. Bonney, "Some thoughts concerning possible manner of presentation by John Stack," 10 Jan. 1952.
5. Stack actually used speed ranges to make his point, for he wanted to impress upon his audience the complexity of aeronautical research. The top speed and the landing speed were the extremes within which a given aircraft would stay in the air. As top speeds increased, so too did landing speeds, though to a lesser degree. In the subsonic era, top speeds were between two and three times the landing speed; in the transonic era, they were five times as great. The immediate result of this (at least as Stack presented his case) was to require longer and sturdier landing fields, which in turn removed combat aircraft farther from the front lines and reduced their combat utility.
6. For example, Stack assumed that the increased speed of aircraft was a direct function of NACA funding, ignoring the work of other designers and engineers in industry, the services, and universities who contributed to American aircraft performance. He argued that an increase in the NACA budget would raise aircraft speeds, even without proportional increases in military R&D funding. This is the sort of hubris that not only blinded the NACA to its own shortcomings but also alienated many knowledgeable people in the field of aeronautics.
7. See appendix C. The House reduced the 1951 NACA appropriation more than \$6 million, most of it reportedly "to deny the NACA any increase over its current operating level." W. H. Shapley to "Mr. Ramsey," "House of Representatives Action on 1951 Estimates of NACA," 12 May, and "Effect on NACA of Senate General Reduction in 1951 Appropriations," 9 Aug. 1950.
8. *Historical Statistics of the United States, Colonial Times to the Present* (Bicentennial ed.; 2 vols.; Washington: Bureau of the Census, Dept. of Commerce, 1975), 2: 768, 966, 1116, 1120.
9. The total federal budget dropped in both 1954 and 1955, as did the military budget; however, while the latter remained more than 3 times the 1950 figures, the NACA's 1955 appropriation was only 1.3 times its 1950 level. *Ibid.*, and appendix C. The quotation is from Shapley to "Mr. Schaub," "NSC meeting on research and development," 8 May 1953.

Aeronautical R&D funding throughout the federal government went into a decline beginning in 1954 and never recovered. DoD, NASA, and Dept. of Transportation, *R&D Contributions to Aeronautical Progress* (2 vols.; Washington: Dept. of the Air Force, 1972), 1:II-5. Part of this decline must be attributed to the fact that the United States began shifting research effort from aircraft to missiles, work in which the NACA believed it had an increasing role to play.

10. Victory to Capt. Frank B. Miller, USN, 7 June 1950, in USAF Academy, Victory papers, "All JFV Correspondence, 1950."
11. See, for example, Shapley to Ramsey, "House of Representatives Action on 1951 Estimates of NACA," 12 May 1950; National Security Br. (W.H. Shapley) to Ramsey, "Additional 1951 and 1952 Budget Estimates for the NACA," 16 Oct. 1950; 64 A 518 (12), 1951.
12. Shapley to [Roger] Bounds, "Legislation in Appropriation Language—National Advisory Committee for Aeronautics," 5 May 1945; appendix A.
13. Report of the House Appropriations Committee on the 1950 Independent Offices Appropriation Bill, as quoted in minutes of NACA meeting, 21 Apr. 1949, pp. 2-3; Carl Vinson to Clarence Cannon, 16 Dec. 1949; app. A.
14. Report of the House Appropriations Committee on the 1950 Independent Offices Appropriation Bill, as quoted in minutes of the NACA meeting, 21 Apr., p. 3; Shapley to Ramsey, "NACA Organization," 14 Apr.; Victory, "A Full-Time Paid Chairman for NACA," memo for record, 15 Apr. 1949.
15. Victory, "A Full-Time Paid Chairman for NACA"; minutes of NACA meeting, 21 Apr. 1949, p. 5.
16. Participants in congressional hearings customarily receive a verbatim transcript of the testimony. Witnesses are usually allowed to edit or revise their remarks, a process that often eliminates exchanges much less damaging than this one. This quotation appears in the handwritten notes of Walter Bonney, who came upon the unedited transcript in his research. Another copy of the transcript is in the Hugh Dryden Papers at the Eisenhower Library, Johns Hopkins Univ.

Ira Abbott, who was at this hearing, reports that the exchange between Thomas and Hunsaker was far more intemperate than the version recorded here. See his description in Abbott to Monte D. Wright, 30 April 1980, encl., p. 20.

17. "Report on Survey of the National Advisory Committee for Aeronautics," forwarded by cover letter from Frank L. Yates, acting comptroller general of the U.S., to John Phillips, 20 Feb. 1953, p. 4.
18. Quotations from *ibid.*, pp. 17, 42. Thomas's comment appears in House Committee on Appropriations, *Hearings on Independent Offices Appropriations for 1952*, 82/1, 1951, p. 367. On the 1954 and 1955 audits, see Frederick H. Smith to Dryden, 24 Jan., and Dryden to Smith, 31 Jan. 1956.

Ira Abbott reports that Thomas told the NACA off the record to forget the GAO criticisms, which were misdirected and wrongheaded. Abbott to Wright, 30 April 1980, encl., p. 22.

19. Chart of "Organization of Federal Executive Departments and Agencies" as of 1 Jan. 1948 to accompany Senate Committee on Expenditures in the Executive Departments, S. Rept. 13 [80/2, 1948], in 62 A 35 (40), 010 legislation, government organization; Senate Committee on Appropriations, *Hearings on Independent Offices Appropriations*, 1951, 81/2, 1950, p. 950; W.H. Shapley to Schaub, "NACA explanation of apparent duplication in aeronautical research and development," 25 May 1953; statement by Victory before an executive session of the House Committee on Interstate and Foreign Commerce, 15 Feb. 1949, in USAF Academy, Victory papers, box 1, miscellaneous correspondence (1949 & 1951).
20. For Nixon's support of the NACA, see Ben Regan to Victory, 12 May 1952. When the NACA was seeking appropriations for a program of supersonic wind tunnels at universities, Shapley wrote:

A Subcommittee of the House Armed Services Committee[,] of which Congressman Durham is Chairman, and certain Senators on both the Senate Armed Services and Appropriations Committees have been strong supporters of this program. The principal Congressional opposition has been from the House Appropriations Committee. Apparently the situation now is that Congressman Durham has succeeded in persuading the House Appropriations Committee to take a more favorable view. (Shapley to "Mr. McCandless," "Congressional Request to NACA

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for Resubmission of Budget Estimate for Construction of Wind Tunnels at Universities," 19 July 1950.)

The same split occurred on other issues affecting the NACA.

21. "Outline of answers to questions to be posed by Charles Cordry on Joseph Young's radio program," 6 Sept. 1952, in USAF Academy, Victory papers, box 2, correspondence, July-Dec. 1952.
22. In Jan. 1950, before the Korean War, Hunsaker defended the NACA estimates for 1951 thus:

There is one factor in the establishment of research policy that must not be overlooked. There is a natural temptation, especially when the military budget is contracting, to determine the minimum materiel requirements and to approve only those research projects which have an immediate bearing on the current development projects. This is a fatal policy since it puts the cart before the horse. Research must lead and development must follow research. If the reverse is true, only mild improvement of existing weapons can result. The procurement-centered research can never produce such new developments as jet propulsion, rockets, radar and so forth. The NACA research program covered by the estimates is planned in the light of current military development projects and the current status of military and civil aviation, but it is not tied directly to the prototypes under development, except in specific instances where assistance is requested and given. The major part of the program attempts to forecast future needs and to lead rather than follow development. (House Committee on Appropriations, *Hearings on Independent Offices Appropriations, 1951*, 81/2, 1950, pp. 370-71.)

Before the end of the following year, the NACA was so deeply involved in work related to the Korean War that the Executive Committee took the unprecedented step of resolving that "the scope of research by the National Advisory Committee for Aeronautics be extended to include the aerodynamic problems associated with the control, stowage, release, and launching of aircraft armament and the integration of the airplane and its armament." Minutes of Executive Committee meeting, 12 Oct 1951, p. 12. This was a long way from fundamental problems of flight.

23. The story of air force problems with the Arnold Engineering Development Center is told in Willis Shapley, "Large Supersonic Test Facilities for Aeronautical Research and Development," an undated 14-page typescript forwarded to "Dr. Hauge" under a cover letter of 16 Apr. 1953.
24. See "Policy for Operation of Unitary Wind Tunnels on Development and Test Problems of Industry," approved by the Executive Committee on 6 May 1953, reprinted in appendix H. This policy was later extended to other NACA facilities.
25. See "Report of Facilities Panel, NACA Operation of NACA Unitary Plan Wind Tunnels," 12 Mar. 1953; "Dr. Raymond's Suggestions for Report, Facilities Panel, NACA, March 6, 1953," draft by Victory; "Dr. Dryden's proposed amendment to Dr. Raymond's suggestion for report of Facilities Panel, NACA," 11 Mar. 1943; "NACA Facilities Panel, Second Appearance of Dr. Dryden at Close of Hearings, March 6, 1953," draft by Victory; "Report of NACA Facilities Panel to NACA Executive Committee on Policy for Operation of Unitary Wind Tunnels on Development and Test Problems of Industry," draft, 19 Mar. 1953.
26. *AR 1953*, pp. 68-73; appendix B.
27. NA RG 255, entry 2, box 6, "Bouquets to NACA." The quote is from Thomas W.S. Davis to Victory, USAF Academy, Victory papers, box 2, general personal correspondence, 1953. The lengths to which the NACA would go to protect its reputation with its principal clients is revealed in NA RG 255, entry 2, box 7, "Security." Here are recorded the events surrounding an incident in which some classified papers were mishandled by the NACA and were found lying on the street in front of the Committee's offices by a reporter for the *Wall Street Journal*. When the incident was reported on the front page of that paper, the NACA took appropriate steps to ensure that the shortcomings of its security procedures were corrected, but gave the director of naval intelligence a misleading and self-serving account of what happened.
28. Papers presented to the BoB, 15 Sept. 1927, in 57 A 415 (17), 19-5, FY 1929. The quoted document is not specifically identified as Ames's statement, but it reflects his style and philosophy.

29. Ira H. Abbott told Walter Bonney in 1971 that, upon graduating in aeronautical engineering from MIT in 1929, he had turned down more than fifty job offers and a postgraduate scholarship to study under Prandtl at Gottingen to take a low-paying job with the NACA. "I can say definitely that I had no idea of staying with the NACA," he said. "I was going down there strictly for what amounted to a postgraduate course in aeronautical research because I figured that was the best place in the world to get it." Transcript of interview, 28 Oct. 1971, Sandwich, N.H., pp. 1-3.
- The comparison of the aviation and petroleum industries appears in [Howard] Braithwaite to Shapley, "History of Super-grade positions: NACA/NASA," 23 Apr. 1968. Unless otherwise indicated, the following account of NACA personnel problems is drawn from this detailed and informative summary.
30. The John Victory papers at the USAF Academy provide a sense of how much time Victory devoted to personnel problems during his last decade with the Committee. For an example of similar evidence in the regular NACA files, see Victory to C.O., Redstone Arsenal, attn: Col. Tom G. Thrasher, 24 June 1952, in 65 A 953 (1), A17, 1948-1951, in which Victory asks Thrasher to stop luring away NACA employees and refutes the colonel's earlier assertion that he was only trying to make up his own losses to industry. At this time the Army arsenal had hired away 45 NACA employees.
31. The 1949 act appears in appendix A. The NACA maintained that it was supposed to have been included in the original 1947 act; see Hunsaker to Sen. Olin D. Johnston, 10 Feb. 1949. The BoB preferred that general legislation apply to all government agencies, but made no objection when NACA sought in 1949 to gain the same hiring powers as the military establishment. See A.E. Reed to Staats, "S. 2348, 'To amend Public Law 313, Eightieth Congress, to accelerate scientific research in aeronautics by authorizing the creation of fifteen additional positions in the National Advisory Committee for Aeronautics at rates of pay from \$10,000 to \$15,000 per annum,'" 16 Apr. 1948; *ibid.*, "H.R. 6695, a bill . . .," 14 June 1948; E.B. Bowers to Staats, "H.R. 6695, an act . . .," 22 Nov. 1948; Roger W. Jones to William J. Hopkins, 13 July 1949, with attachments.
32. P.L. 472 appears in appendix A. As with the NACA pay act of 1949, the BoB approved this legislation even though, as mentioned, its staff favored a general act applicable to all government agencies. See E.B. Bowers to Staats, "Draft bill, 'To authorize professional personnel of the National Advisory Committee for Aeronautics to attend accredited [graduate] schools for research and development,'" 31 Jan. 1949.
33. *AR 1955*, p. ix; minutes of NACA meeting, 22 Oct. 1954, pp. 4-6; minutes of Executive Committee meeting, 14 July 1952, pp. 13-15. Robert J. Woods of Bell Aircraft Corp. made the spaceflight proposal at the 24 June 1952 meeting of the Aerodynamics Committee.
34. Minutes of Executive Committee meeting, 14 Feb. 1952, pp. 12-15, and 14 July 1952, pp. 7-11; National Advisory Committee for Aeronautics, "Statement of Justification in Support of a Supplemental Estimate of Appropriation for the Fiscal Year 1953," 31 Mar. 1952.
35. National Security Branch (Shapley) to the director, "NACA Amendment to the 1953 Budget for Research on Aircraft Structures (Supplemental Request No. 439)," 30 Apr. 1952, with routing slip from Shapley to Veatch et al.
36. Minutes of Executive Committee meeting, 16 Sept. 1954, p. 8; Shapley to "Mr. Schaub," "Proposed NACA 1955 supplemental estimate," 14 Sept. 1954.
37. The quote attributed to Hunsaker is from Shapley memo for files, "NACA meeting with Deputy Director [of BoB] September 16, 1954," 16 Sept. 1954. The other quotes are from James R. Killian, Jr., *Sputnik, Scientists, and Eisenhower: A Memoir of the First Special Assistant to the President for Science and Technology* (Cambridge: MIT Press, 1977), pp. 75, 69, whence also the general statements about Eisenhower's strategic thinking in this period.
38. See appendix C.
39. Clarence C. (Kelly) Johnson, for one, was skeptical of the claims made for Whitcomb's work, but the Air Force was genuinely grateful for the help with the F-102, and praise for the NACA and Whitcomb was widespread. See Johnson to Dryden, 12 Aug. 1957, and Dryden to Johnson, 20 Aug. 1957, in 65 A 953 (36), A-34, 1957.
40. Hoover signed the report of the Commission on Organization of the Executive Branch of the Government, *Research and Development in the Government: A Report to Congress* (Washington, 1955), which, without making a specific recommendation on the NACA, repeated the glowing appraisal of the agency that first appeared the previous month in Commission on Organization of the Executive Branch of the Government, Committee on Business Organization of

the Department of Defense, Subcommittee on Research Activities in the Department of Defense and Defense Related Agencies, *Research Activities in the Department of Defense and Related Defense Agencies* (Washington, 1955), pp. 73-75, 90.

CHAPTER 12

1. Jerome C. Hunsaker, second annual Wings Club Sight Lecture, New York, 26 May 1965. Hunsaker's disenchantment with the course of flight development began shortly after World War II. Confronted in 1947 with a poll that showed that 26 percent of the respondents expected orbital and interplanetary flight in 10 years (a remarkably accurate expectation), Hunsaker responded that the poll indicated "that people who know about rockets like them. The same is no doubt true with regard to helicopters, alcoholic drinks and chamber music." (Walter Bonney notes on Hunsaker papers, box 8, 2 May 1972.) See also Bonney's outline for his history of the NACA, chap. 31.
2. NACA release, "Doolittle Succeeds Hunsaker as Chairman of NACA," 17 Oct. 1956; Department of Defense release, "Lieutenant General James H. Doolittle, USAFR," Jan. 1955.
3. Minutes, Executive Committee meeting, 21 Feb. 1957, pp. 7-8. For a full discussion of the origins of the Dyna-Soar program, see Richard P. Hallion, "The Path of the Space Shuttle," paper presented to the annual meeting of the American Association for the Advancement of Science, Houston, 3-8 Jan. 1979, and "The Emergence of the Lifting Reentry Concept in Aerospace Vehicle Design," paper presented to the 30th congress of the International Astronautics Federation, Munich, 21 Sept. 1979.
4. On operating problems, see, for example, *AR 1955* and minutes, Executive Committee meeting, 16 Dec. 1955, pp. 4-5. The Plum Brook facility was approved at the annual meeting 20 Oct. 1955 (minutes, p. 2), and the ground was broken on 26 Sept. 1956. The political web in which Dryden and Doolittle became entangled over the nuclear-powered airplane is neatly explained in Herbert York, *Race to Oblivion: A Participant's View of the Arms Race* (New York: Simon and Schuster, 1970), chap. 4. On Allen's blunt-body concept, see *AR 1957*, pp. 4-8.
5. See, for example, BoB, Military Div. (W.H. Shapley), "Meeting of representatives of the National Advisory Committee for Aeronautics (NACA) with the Deputy Director, September 28, 1956," memo for files, 2 Oct. 1956; minutes of Executive Committee meetings, 18 Aug., pp. 4-6, and 19 Sept. 1957, p. 14. Dryden observed in the August meeting that "the appropriations received by NACA were always less than the sums originally requested, even though the NACA always limited its requests to the amounts actually needed," and that there was "an increase in the number of kinds of problems which the Committee [was] being called upon to solve." For these reasons and others, the Committee felt it deserved to be exempted from the administration's campaign to hold 1958 expenditures to 1957 levels.
6. Victory to Reginald M. Cleveland, 29 Oct. 1956, in USAF Academy, Victory papers, box 3, general correspondence, 1956. For evidence that the BoB did not always take the NACA troubles as seriously as Victory, see Military Div. (Shapley) to Roger Jones, "NACA proposed legislation to increase the number of P.L. 167 supergrades," 22 July 1955. For a broader perspective on administration response to the NACA plight, see minutes of Executive Committee meeting, 21 May 1956, pp. 3-5.
7. *AR 1955*, pp. 2-4. Of an earlier draft of this section of the annual report, Gen. Frederick C. Crawford said: "If I were a Congressman and you came before me asking for funds with this statement I would think maybe you are selling so hard because you are not so good." (Notes on meeting of Executive Committee, of 15 Sept., dated 16 Sept. 1955.) Though the NACA did tone down the account in the annual report, it made much in the ensuing years of the advantages of the area rule. A magazine article on the subject prompted Kelly Johnson of Lockheed to write to Dryden in protest, reporting that his "studies of the data indicate that the Whitcomb area rule works primarily on aircraft involving sweep and then, generally, only on airframes which are poor to start with." Dryden agreed that the magazine article in question was "fantastic," but he gave little ground on the importance of the area rule. (Johnson to Dryden, 12 Aug., and Dryden to Johnson, 20 Aug. 1957, both in 65 A 953 (36), A-34, 1957.)
8. Hunsaker to Victory, 8 Mar.; Dryden to Hunsaker, 18 Mar. 1957; minutes of Executive Committee meeting, 21 Mar. 1957, p. 7.

9. In 1957, Dryden estimated that the NACA plant in 1940 had represented at least half the "total public investment in such facilities at the time." Though the NACA plant had tripled since then, Dryden offered no guess as to what proportion of the total it now made up. Dryden to George W. Taylor, 26 July 1957, in 65 A 953 (31), A-28, July-Dec. 1957.
10. The 50 percent figure appears in "Report by Senator Ralph E. Flanders to Committee on Armed Services . . . on Visit to the Facilities of the National Advisory Committee for Aeronautics . . . April 8 to April 13, 1955," committee print, 84/1, 1955, p. 3. Committee memberships are listed in appendix B.
11. Minutes of annual meeting, 10 Oct. 1957; Dryden to Eugene Emme, "The NACA-NASA Transition, October 1957 to October 1958," 8 Sept. 1965, p. 3.
12. Asked at a 9 Oct. 1957 news conference if Sputnik worried him, Eisenhower replied, "so far as the satellite itself is concerned, that does not raise my apprehensions, not one iota." (*Public Papers of the Presidents of the United States: Dwight D. Eisenhower, 1957* (Washington: General Services Administration, National Archives and Records Service, 1958), p. 730.) The other words were penned by Bryce Harlow and spoken by Sherman Adams; Harlow later labeled it a disservice to Adams, cute but not clever. (Harlow interview, Washington, D.C., 11 June 1974 by E.M. Emme and Alex Roland. Sherman Adams was quoted in the *New York Times*, 20 Oct. 1957; see Martha Wheeler George, "The Impact of Sputnik: Case-Study of American Public Opinion at the Break of the Space Age, October 4, 1957," NASA Historical Note 22, NASA History Office Archives.) The best published account of the Eisenhower administration response to Sputnik is James R. Killian, Jr., *Sputnik, Scientists, and Eisenhower: A Memoir of the First Special Assistant to the President for Science and Technology* (Cambridge: MIT Press, 1977).
13. Lyndon Johnson was the most prominent congressional leader to take this position. See, for example, his opening remarks in Senate Committee on Armed Services, Preparedness Investigating Subcommittee, *Inquiry into Satellite and Missile Programs, Hearings, Part I*, 85/1 and 2, 1958, pp. 1-3. Norman Cousins, the distinguished editor of the *Saturday Review*, undertook with a group of associates to place full-page ads in the country's leading newspapers under the hyperbolic title: "We Are Facing a Danger Unlike Any Danger that Ever Existed . . ." Cousins to President Eisenhower, 13 Nov. 1957.
14. Killian, *Sputnik, Scientists, and Eisenhower*.
15. In the event, the first U.S. attempt to orbit a satellite ended in flames on the launch pad; it was not until 31 Jan. 1958 that the U.S. matched the Soviet feat, and then with only 8 kilograms of payload. Constance McLaughlin Green and Milton Lomask, *Vanguard: A History* (Washington: Smithsonian Institution Press, 1971).
16. A subcommittee member, C.L. Poor, wrote to Dryden on 27 Nov. 1957:

I feel that it is more than important that the NACA have its best people, its best facilities, and its highest priorities devoted to space flight. It is essential. If the NACA does not do it, the job will not be done, or another agency will be established to do it. It would be a catastrophe if the job were not done, and done well. It would be a waste of magnificent beginnings if the job went to a new agency.

For an indication of how quickly the NACA program could be made to look applicable to spaceflight, see the Committee's "NACA Research Into Space," a confidential document published in Dec. 1957.
17. Minutes of Executive Committee meeting, 21 Nov. 1957, pp. 6-7; H. Guyford Stever interview, Washington, 7 Feb. 1974, by Emme and Roland; NACA release, "NACA Space Technology Committee Holds Organization Meeting," 14 Feb. 1958; John L. Sloop, *Liquid Hydrogen as a Propulsion Fuel, 1945-1959* (NASA SP-4404; Washington, 1978), p. 181. By the time the Stever committee held its final meeting and submitted its recommendations, the NACA was no longer in existence. See minutes of meeting of the Special Committee on Space Technology, 27-28 Oct. 1958, and "Recommendations Regarding a National Space Program" by the NASA Special Committee on Space Technology, 28 Oct. 1958.
18. Dryden, "The NACA-NASA Transition, October 1957 to October 1958," pp. 4-5, with annotations by Walter T. Bonney; Sloop, *Liquid Hydrogen*, p. 181.
19. Minutes of Executive Committee meeting, 16 Jan. 1958, pp. 7-10. The only change made in the staff study was the inclusion, at the suggestion of Detlev Bronk, of mention of the role of the National Academy of Sciences.

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20. "NACA Research Into Space," 10 Feb. 1958, p. 2; minutes of Executive Committee meeting, 14 July 1952, p. 15.
21. Killian, *Sputnik, Scientists, and Eisenhower*; York, *Race to Oblivion*, chap. 6; Andrew J. Goodpaster interview, Washington, 22 July 1974, by Emme and Roland; and James R. Killian interview, Cambridge, Mass., 23 July 1974, by Emme and Roland.
22. Homer E. Newell, *Beyond the Atmosphere: The Early Years of Space Science* (NASA SP-4211; Washington, 1980), chap. 8.
23. "Spearhead of Progress," *Aviation Week*, 5 Nov. 1956, p. 21; "NACA, the Logical Space Agency," *ibid.*, 3 Feb. 1958, p. 21; Newell, *Beyond the Atmosphere*, pp. 6-39, 10-47; W.H. Pickering to Killian, 9 July 1958.
24. Dryden, "The NACA-NASA Transition," p. 2; Killian, *Sputnik, Scientists, and Eisenhower*; Victory to Vice Adm. Donal B. Duncan, USN, 20 Feb. 1958, in USAF Academy, Victory papers, box 3, general correspondence, 1958.
25. Shapley to "Mr. Veatch," "Status of Amendment to Executive Pay Act proposed by NACA to increase the salary of the Director of NACA," 14 Aug. 1951, with attached note, Finan to RCA, 7 Sept. 1951; National Security Branch (Shapley) to "Mr. McCandless," "NACA Appropriation Language to Increase the Salary of the Director to \$17,500," 8 Oct. 1951.
26. Doolittle to Killian, 24 Mar. 1958.
27. Reliable accounts of how the space act came to be can be found in Alison Griffith, *The National Aeronautics and Space Act: A Study of the Development of Public Policy* (Washington: Public Affairs Press, 1962); Enid Curtis Bok Schoettle, "The Establishment of NASA," in Sanford Lakoff, (ed.), *Knowledge and Power: Essays on Science and Government* (New York: Free Press, 1966), pp. 162-270, and Mary Stone Ambrose, "The National Space Program, Phase I: Passage of the 'National Aeronautics and Space Act of 1958,'" MA thesis, American University, 1960.
28. "The ultimate potentialities of spaceflight cannot now be fully grasped," Eisenhower wrote to the secretary of defense and the chairman of the NACA on 2 Apr. 1958, the same day he sent the space bill to Congress. Though he made clear in this letter that he intended the new NASA to be the nation's lead space agency, he did state that "the new Agency [would] continue to perform for the Department services in support of military aeronautics and missiles programs of the type now performed by the National Advisory Committee for Aeronautics and also provide similar services with respect to military space programs."

At a White House meeting on space on 3 Feb. 1958, Donald A. Quarles, deputy secretary of defense and a former member of the NACA, said that in the space area, the "NACA should perform its 'classic' role of research." (Undated notes, apparently prepared by Willis H. Shapley of the Bureau of the Budget from the debriefing given him and others by Maurice Stans, director of the BoB, who attended the White House meeting.)
29. ARPA was created in Feb. 1958, in part to remove the development of new weapons systems from the interservice rivalry in the Pentagon that had spawned the "missile mess" and threatened to spill over into the realm of military space activities, and in part to provide an interim agency to carry on the nascent space program while the administration decided where that program would finally be lodged. The story is told by ARPA's first chief scientist in York, *Race to Oblivion*, pp. 115-20. See also minutes of the Executive Committee meeting, 15 May 1958, pp. 4-5; Hugh L. Dryden to Eugene Emme, "The 'signed' agreement of April 11, 1958, on a Recoverable Manned Satellite Test Vehicle," 8 Sept. 1965.
30. Senate Special Committee on Space and Aeronautics, *Hearings on S. 3069, a Bill to Provide for Research into Problems of Flight within and outside the Earth's Atmosphere, and for Other Purposes*, part I, 85/2, 1958, pp. 6-7.
31. Alison Griffith, *The National Aeronautics and Space Act*.
32. See, for example, his 16 Apr. 1958 statement in House Select Committee on Aeronautics and Space Exploration, *Aeronautics and Space Exploration, Hearings on H.R. 11881*, 85/2 1958, pp. 401-19.
33. *Ibid.*, pp. 74, 117, 420.
34. Dryden believed that the NACA-USAF agreement was canceled because the Department of Defense wanted ARPA to be the defense space agency. (Letter to Eugene Emme, "The 'signed' agreement of April 11, 1958, on a Recoverable Manned Satellite Test Vehicle," 8 Sept. 1965.) BoB documents make it clear that Killian was at the heart of all administration decisions on space. See, for example, Military Div. to director, "Meeting with Dr. Killian on

- 'Space' responsibilities," 16 May 1958, and Military Div. to director, "Pending agreement on 'space' responsibilities," 12 May 1958.
35. As early as 3 Feb. 1958, Herbert York and Donald Quarles had agreed that "the only military value [of space] was for reconnaissance." (Shapley, undated "Notes on Mr. Stans' 'debriefing' after White House meeting on 'space' Monday morning, February 3, 1958")
 36. The Eisenhower bill submitted along with the space act became the Defense Reorganization Act of 1958.
 37. BoB, Military Div. to the director, "Status report on 'Space' program and budgetary problems," 10 June 1958.
 38. BoB, Military Div. to the director, "Actions needed to resolve pending questions on 1959 'Space' programs," 1 July 1958; *ibid.*, "Further information for 'Space' meeting, Thursday, July 10, 1958," 9 July 1958; *ibid.*, "Air Force 1959 funds and programs to be considered for transfer to and interaction with NASA program," 15 July 1958. On the ARPA attempt to circumvent the intent of the administration, see BoB, W.E. Gathright to "Mr. Veatch," "ARPA million-pound thrust engine development," 18 Aug. 1958, which brought "into question the whole basis of the recent settlement and, in effect, raise[d] again the question of whether it [would] be possible to draw any workable line (or any line at all) between the space programs of Defense and NASA."

See also, Military Div. to the director, "Current status of 'space' problem, 25 July 1958," in which Shapley commented:

It seems clear to us that these discussions have degenerated into a bureaucratic struggle for survival as a "space" agency on the part of ARPA. The [Defense] Secretary's main problem seems to be to get a settlement that will keep ARPA happy. The position Dr. York keeps taking makes it unlikely that ARPA will be satisfied unless they get everything they wanted in the first place.
 39. Robert Rosholt, *An Administrative History of NASA, 1958-1963* (NASA SP-4101; Washington, 1966), pp. 37-48.
 40. See Alex Roland, "Defining Aeronautical Progress," paper presented to the Southern Association for History of the Sciences and Technology, Lexington, Ky., 7 Apr. 1979.
 41. Transcript of interview of Victory by Alfred F. Hurley, Colorado Springs, Co., 29 June 1962, p. 2-11.

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- Hall, R. Cargill, *Project Ranger: A Chronology* (JPL/HR-2, 1971, multilith).
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- Roland, Alex F., *A Guide to Research in NASA History* (NASA HHR-50, 7th, ed., 1984, available from NASA History Office).
- Skylab: A Chronology* (NASA SP-4011, 1977).
- Van Nimmen, Jane, and Leonard C. Bruno, with Robert L. Rosholt, *NASA Historical Data Book, 1958-1968*, vol. 1, *NASA Resources* (NASA SP-4012, 1976).
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HISTORIES

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- Swenson, Loyd S., Jr., James M. Grimwood, and Charles C. Alexander, *This New Ocean: A History of Project Mercury* (NASA SP-4201, 1966).

REFERENCE WORKS

- Aeronautics and Space Report of the President*, annual volumes for 1975-1982.
- The Apollo Spacecraft: A Chronology* (NASA SP-4009, vol. 1, 1969; vol 2, 1973; vol. 3, 1976; vol. 4, 1978).
- Astronautics and Aeronautics: A Chronology*, annual volumes 1961-1976 with an earlier summary volume, *Aeronautics and Astronautics, 1915-1960*.
- Dickson, Katherine M., ed., *History of Aeronautics and Astronautics: A Preliminary Bibliography* (NASA HHR-29, 1968, multilith).
- Hall, R. Cargill, ed., *Essays on the History of Rocketry and Astronautics: Proceedings of the Third through the Sixth History Symposia of the International Academy of Astronautics* (NASA CP-2014, 2 vols., 1977).

- Hall, R. Cargill, *Project Ranger: A Chronology* (JPL/HR-2, 1971, multilith).
- Looney, John J., ed., *Bibliography of Space Books and Articles from Non-Aerospace Journals, 1957-1977* (NASA HHR-51, 1979, multilith).
- Roland, Alex F., *A Guide to Research in NASA History* (NASA HHR-50, 7th, ed., 1984, available from NASA History Office).
- Skylab: A Chronology* (NASA SP-4011, 1977).
- Van Nimmen, Jane, and Leonard C. Bruno, with Robert L. Rosholt, *NASA Historical Data Book, 1958-1968*, vol. 1, *NASA Resources* (NASA SP-4012, 1976).
- Wells, Helen T., Susan H. Whiteley, and Carrie E. Karegeannes, *Origins of NASA Names* (NASA SP-4402, 1976).

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