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SPACE MEDICINE IN PROJECT MERCURY



NATIONAL AERONAUTICS AND SPACE ADMINISTRATION

NASA SP-4003

SPACE MEDICINE IN PROJECT MERCURY

By Mae Mills Link

OFFICE OF MANNED SPACE FLIGHT



Scientific and Technical Information Division

NATIONAL AERONAUTICS AND SPACE ADMINISTRATION

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Foreword

FOR CENTURIES MAN HAS DREAMED of exploring the universe. Finally an expanding rocket technology brought with it a reasonable expectation of achieving this dream, and man was quick to accept the challenge. Project Mercury was an organized expression of man's willingness to face the risks involved in exploring the new frontier of space, and of his confidence in our Nation's ability to support him technically and professionally in this exciting adventure.

Project Mercury is now legend. The story of its many activities is an important chapter in the history of our times. Its spotless record of successes is a tribute to all those who made up the Mercury team.

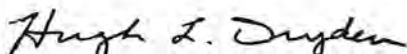
Not the least of the groups composing the Mercury team was that charged with responsibility for the health of the astronauts. This select biomedical group discharged with near perfection a variety of tasks involved in choosing and training our Nation's first space voyagers, monitoring their medical status during each flight, and finally assessing their condition after the flight.

In this volume the author sets forth a chronological account of a unique medical support program. Flavored with personal glimpses of the individuals making up this global medical organization, the chronicle portrays the manner in which scientists and technicians drawn from the three military medical services, from other agencies of the Federal Government, and from the civilian community at large were welded into a smoothly functioning team. Led by a small group of NASA physicians, the members of this team performed their tasks in a way that makes it difficult to believe that they were drawn from such widely divergent sources. Cast aside were all personal considerations and the parochialism so often found in members of traditionally competitive groups, particularly competitive professional groups.

Indeed, their performance and singleness of purpose, their dedication and professional excellence, should give pause to those who sponsor ideologies other than the ones which form the basis for our democratic way of life. Only in a society of free men could one

hope to find such an example of people banding together voluntarily to support a national goal.

The National Aeronautics and Space Administration is proud to have provided the vehicle for this demonstration of democracy in action.



HUGH L. DRYDEN
*Deputy Administrator
National Aeronautics and
Space Administration*

Author's Preface

PROJECT MERCURY WAS THE FIRST American laboratory in which man was able to test his physiological capabilities to withstand the hostile forces of the extraterrestrial environment for longer than a few seconds. Weightlessness, severe g-forces, combined stresses, radiation, potential disorientations, and toxic hazards in spacecraft were among the problems about which earthbound research had been able to supply only limited information. Indeed, from the viewpoint of environmental medicine as an applied science, Project Mercury marked the swift transition from what had come to be known as aviation medicine to what is now recognized as space medicine.

Beyond the inclusion of man as an effective system in rocket-propelled space vehicles, Project Mercury also offered the tremendous challenge of the newly available space environment to basic biology itself. From the beginning, therefore, NASA management was concerned with the entire spectrum of the life sciences, extending far beyond the biotechnology of Project Mercury. This included ecology and exobiology as well as the definition and projected application of space medicine.

The fuller history remains to be written. Also to be written is a comparative study of the American astronaut experience and that of the Soviet cosmonauts. The present study aims to provide a building block for a future life-science history recounting man's conquest of nature beyond the planet Earth.

In the preparation of this volume the author has received splendid cooperation wherever she turned. It is impossible to mention each person who gave generously of time and effort. However, special appreciation must go to Dr. Robert R. Gilruth and the Project Mercury Space Task Group; to former Surgeon General Oliver K. Niess, USAF (Ret.), and his staff, particularly Brig. Gen. Don C. Wenger (MC) and Col. Karl H. Houghton (MC) (Ret.); to the bioastronautics staff at the various centers and laboratories of the Air Force Systems Command; to Maj. Gen. Leighton I. Davis, DOD Assistant for Project Mercury, and his bioastronautics staff; to Capt. Ashton Graybiel, USN (MC),

Director of Medical Research, U.S. Navy, and his staff; to Dr. Randolph Lovelace II and his staff at the Lovelace Foundation, particularly Dr. A. H. Schwichtenberg; and to Dr. Sam F. Seeley, National Academy of Sciences-National Research Council. Special thanks go also to Brig. Gen. Don Flickinger, USAF (MC) (Ret.); to Dr. Sherman P. Vinograd, Dr. Jefferson F. Lindsey, and Walter B. Sullivan, Jr., NASA Division of Space Medicine; and to NASA historians Dr. Eugene M. Emme, Dr. Frank W. Anderson, Jr., and James M. Grimwood.

This project, initiated under the joint sponsorship of Brig. Gen. Charles H. Roadman, USAF, then Director of the Office of Life Sciences, NASA, and General Niess, was brought to completion under Dr. George M. Knauf, Acting Director, Space Medicine, Office of Manned Space Flight. The author wishes to express appreciation for the fact that they all supported her efforts to the fullest, and none ever attempted to modify her independent interpretations or conclusions. Responsibility for omissions or errors must rest wholly with the author. Comments and additional information are invited to complete the story begun in the present monograph.

MAE MILLS LINK

March 1965

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Introduction

THE DECISION OF THE UNITED STATES in 1958 to initiate a manned space flight program was based upon the confident assumption that technology could provide the life-support systems necessary for human survival in the hostile space environment. Primary responsibility for developing these flight systems obviously would rest with physical scientists and engineers. Bioastronautical experts, including flight surgeons who had long worked as a team with aeronautical engineers, believed from experience with conventional aircraft that man could sustain the combined stresses of space flight. It was believed that extension of the principles of traditional aviation medicine could provide the key to man's survival in the relatively short periods of space flight envisaged for Project Mercury. Thus, space medicine would represent basically an extension of aviation medicine.

Both inside and outside the newly created National Aeronautics and Space Administration, some scientists were concerned about specific biomedical problems of early manned space flight. Definitive biological experimentation had not yet laid a solid basis for such a mission, even though it was recognized that Project Mercury would be but a first step and would not involve the obviously novel biological hazards of extended space flight. Engineers could cope with the hardware required for orbital flight, but the astronaut was more than a mere component of a system. He also had become a symbol of the hope that man himself could perform in extraterrestrial space. The confidence of the aerospace medical community and the skepticism of the biological scientists were to come together in the working out of the first U.S. manned space flights.


NASA was charged by the President of the United States with carrying out a twofold mission in manned space flight. As a high national priority, ranking second only to national defense, NASA must at the earliest feasible time launch a man into space, provided with an environment in which he could perform effectively, and recover him safely. This was Project Mercury, with its rela-

tively limited goal. Concurrently, NASA physical scientists and engineers, with the support of the Nation's leading life scientists, must develop a capability for extended manned space flight.

Project Mercury could not define the biological and life-support problems that may be posed by extended space missions, particularly prolonged weightlessness. Mercury flight times were limited by spacecraft weights which, in turn, were restricted by the capability of available launch vehicles. The theoretical literature on such conditions as weightlessness and combined physiological stresses must necessarily await validation by future flights. The task assigned Project Mercury was to prove that man could survive and function usefully in space. That fact has now been established.

Whether or not the first U.S. manned space program, even with its limited goals, was worth the human risks involved was the subject of some debate within the scientific community. The final judgment must await the course of history. Some scientists are now seeking pilot ratings for future manned space flights, indicating their confidence in the more extensive flights that will take place in the near future.

The present document is an attempt to record the way in which the medical community in particular, and the life scientists in general, provided clinical support for Project Mercury and, as a corollary, contributed toward the evolution of the long-range manned space-flight program. It is primarily a study in management, for only through the careful planning and management of the Nation's resources—together with dedicated effort—could Project Mercury have been accomplished in such a short time. It is a record of which the Nation can be proud, for the first U.S. manned space flights were successful against great odds—odds such as any pioneering effort must always overcome.



W. RANDOLPH LOVELACE II, M.D.
Director, Space Medicine

CHAPTER I

Space Medicine: A Critical Factor in Manned Space Flight

THE U.S. SPACE PROGRAM is rooted in large part in the concepts, research, and development of Army and Air Force ballistic missile programs. These, in turn, benefited from the German rocket development that took place during World War II. The space program was also rooted in part in the experience of the National Advisory Committee for Aeronautics, which, since 1915, had been engaged in basic aeronautical research for manned flight. By 1950, rocket-powered research airplanes of the X-series as well as propulsion studies for the military brought manned flight to the edge of space. The crystallization of space exploration as a national objective in the United States resulted from the strategic surprise of the launching of Sputnik on October 4, 1957.

In the month after the launching of Sputnik, President Dwight D. Eisenhower established the President's Scientific Advisory Committee (PSAC) to provide science with a voice within the executive branch. It was headed by Dr. James A. Killian, president of the Massachusetts Institute of Technology.¹ In March 1958 the President's Committee on Government Organization, which included his scientific adviser, recommended that a new civilian agency be created to pursue an aggressive space program. The scientific reasons behind this recommendation were explained in a White House white paper released on March 26, 1958, with a statement by the President.²

This white paper listed four elements that gave "importance, urgency, and inevitability to the advancement of space technology." They were (1) the compelling urge of man to explore and to discover; (2) defense considerations; (3) the factor of national prestige; and (4) the new opportunities for scientific observation and experiment offered by space technology, which would add to man's knowledge and understanding of the earth, the solar system, and the universe.

Because the opportunities were so numerous, scientists from

many countries would want to participate, and it was suggested that the International Geophysical Year offered a model for international exploration of space. A timetable—not broken into years—listed various types of investigation under these broad headings:

1. *Early*. Physics, geophysics, meteorology, minimal moon contact, experimental communications, and space physiology.

2. *Later*. Astronomy, extensive communications, biology, scientific lunar investigation, minimal planetary contact, and human flight in orbit.

3. *Still later*. Automated lunar exploration, automated planetary exploration, and human lunar exploration and return.

4. *And much later still*. Human planetary exploration.³

In fact [it was stated], it has been the military quest for ultra-long-range rockets that has provided man with new machinery so powerful that it can readily put satellites in orbit, and, before long, send instruments out to explore the moon and nearby planets. In this way, what was at first a purely military enterprise has opened up an exciting era of exploration that few men, even a decade ago, dreamed would come in this century.⁴

The administration's bill for the establishment of a space agency was submitted to the Congress in April 1958. After lengthy deliberations on Capitol Hill, the National Aeronautics and Space Act of 1958 was enacted by the Congress and signed by the President. It became law on July 29, 1958.⁵ According to the act, space activities would be directed toward peaceful purposes for the benefit of all mankind, leaving military responsibility in space to the Department of Defense. Dr. T. Keith Glennan, president of the Case Institute of Technology, was named first Administrator of the National Aeronautics and Space Administration, and Dr. Hugh L. Dryden was named Deputy Administrator. This was in August 1958.

The organizational nucleus of the new space agency was the National Advisory Committee for Aeronautics (NACA), of which Dr. Dryden had been Director. NACA had focused upon basic aeronautical research for 43 years. During recent years the application of rocket propulsion research to manned flight had led to the development of the X-series aircraft, of which the X-15 became the best known.⁶ Through the year following Sputnik, the National Advisory Committee for Aeronautics, under the chairmanship of Dr. James H. Doolittle (who was also a member of PSAC), gave considerable attention to the problem areas that needed research to make space technology a reality.⁷

BIOLOGICAL REQUIREMENTS

In November 1957, the month in which the President's Scientific Advisory Committee was established, NACA set up a Special Committee on Space Technology under the chairmanship of Dr. H. Guyford Stever of the Massachusetts Institute of Technology.

The Stever Committee met for the first time on February 13, 1958, and established seven working groups. The group named to study human factors and training was headed by Dr. W. Randolph Lovelace II, director of the Lovelace Foundation for Medical Education and Research.⁸ This group concerned itself with the scientific and nonmilitary biomedical requirements for manned space flight, as well as other biological factors that should be part of a national space program.*

The final report was dated October 27, 1958, the month in which NASA became operational.⁹ Briefly, it considered how best to utilize man's capabilities in space exploration and outlined the means by which the new space agency should develop resources in life-sciences research. Thirteen technical areas were discussed: Program administration; acceleration; high-intensity radiation in space; cosmic radiation; nuclear propulsion; ionization effects; human information processing and communication; displays; closed-cycle living; balloon simulators; space capsules; crew selection and training; and research centers and launching sites. The report noted that because of the rapid development of rocket technology in missile programs, manned satellites and space vehicles had a potential for rapid and revolutionary progress. Concurrent biomedical and physical research and development to determine man's capabilities in space would be necessary. According to the report:

The ultimate and unique objective in the conquest of space is the early successful flight of man, with all his capabilities, into space and his safe return to earth. Just as man has achieved an increasing control over his dynamic environment on earth and in the atmosphere, he must now achieve the ability to live, to observe, and to work in the environment of space.

*Serving with Dr. Lovelace on the ad hoc committee were A. Scott Crossfield, North American Aviation, Inc.; Hubert M. Drake, High-Speed Flight Station, NACA; Brig. Gen. Don D. Flickinger, USAF (MC); Col. Edward B. Giller, USA; Dr. James D. Hardy, U.S. Naval Air Development Center; Dr. Wright Haskell Langham, Los Alamos Scientific Laboratory; Dr. Ulrich Luft, head, Physiology Department, Lovelace Foundation for Medical Education and Research; and Boyd C. Myers II (Secretary), NACA.

The Working Group on Human Factors and Training urged that crew selection, survival, safety, and efficiency be considered in all experiments. Experience and training would be the most important factors in crew selection. Experiments with man could well parallel experiments with animals. Indeed, this research could properly be considered an extension of past research in aviation and submarine medicine, but requiring an even more advanced technology.

The ad hoc committee also noted that the time schedule for manned space flight "must be realistic in both the life and physical sciences, taking into consideration the time period necessary to develop a new missile system, and to carry out an intensive laboratory and flight test program. . . . Quality assurance procedures will be required as never before." For a successful space program, a cooperative effort of life scientists and physical scientists representing diverse professional backgrounds would be required. Accumulated experience would be applied to research on vital activities at the whole-body, organ, tissue, cellular, molecular, and atomic levels. Understanding of these activities under altered environmental conditions would "result in an orderly progression of research until man shall be ready for space flight." It was recommended that the program include the Army, the Navy, the Air Force, the Atomic Energy Commission, the National Bureau of Standards, the Public Health Service, and the National Academy of Sciences, with the new space agency having primary responsibility.

Since, at the time the final report was submitted, NASA had just become operational and lacked resources in life sciences, it was recommended that NASA "develop a capability as quickly as possible," starting with contract coverage concurrent with in-house growth. The cooperation of other nations in this scientific endeavor was also envisaged. The critical goal of developing a manned satellite program would require a life-sciences committee to study the immediate problems associated with manned space flight and to "recommend specific research investigations to be undertaken by the NASA, and to exchange information on research and development in this field by government and private organizations." The membership of this committee, it was further recommended, should include not only representatives from the Department of Defense, U.S. Public Health Service, National Academy of Sciences, and Atomic Energy Commission, but also universities and foundations.

It was also recommended that a long-range space program be developed. This would require a director of life-sciences research in NASA Headquarters with responsibility for administering a life-sciences program "primarily directed toward the solution of those problems which must be solved prior to man's exploration of space."

This broad blueprint of the committee was to chart the course of the NASA life-sciences program. Although about a year would pass before NASA established a life-sciences directorate, at the time the report of the ad hoc committee was submitted a NASA Special Life Sciences Committee had already been appointed. This committee was directed to study the immediate medical problems associated with manned space flight, novel problems posed by the space environment and the bringing together of relevant experience from many disciplines and agencies.

Dr. Lovelace was appointed by the NASA Administrator to serve as chairman of this new committee, effective October 1, 1958, the date on which NASA became operational. This Special Committee on Life Sciences would, until its dissolution on March 31, 1960, serve in an advisory capacity to NASA. It included two other members of the Stever committee: General Flickinger, Surgeon and Assistant Deputy Commander for Research, Air Research and Development Command, USAF, who served as Vice Chairman; and Dr. Langham. The remainder of the committee initially included Lt. Comdr. John M. Ebersole (MC), National Medical Center; Lt. Col. Robert H. Holmes (MC), U.S. Army Research and Development Command; Dr. Robert B. Livingston, National Institutes of Health; and Dr. Orr Reynolds, Director of Science, Office of the Assistant Secretary of Defense for Research and Engineering. Capt. G. Dale Smith, USAF (VC), on duty status with NASA Headquarters, served as secretary.¹⁰ Through the next months, this committee provided invaluable professional counsel as the manned space program quickly began to take shape in Project Mercury.

THE BIOASTRONAUTICS MISSION EMERGES

On August 2, 1958, meanwhile, Dr. Detlev Bronk, president of the National Academy of Sciences-National Research Council,¹¹ had formally announced the formation of a 16-man Space Science

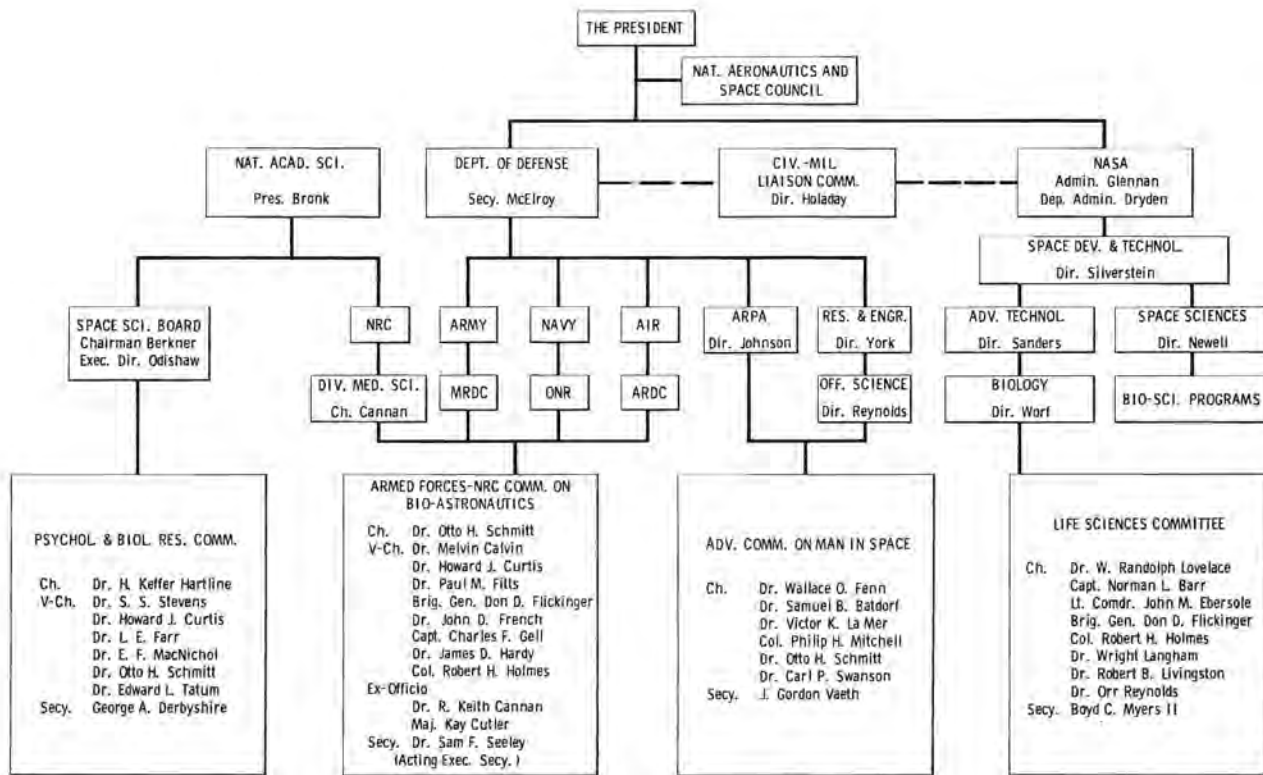


Chart 1—Organization of scientific community in behalf of space exploration, January 1959.
(See appendix A for more detail on committee members.)

Board to survey in concert the scientific problems, opportunities, and implications of man's advance into space. This group, in actual being since June, was under the chairmanship of Dr. Lloyd V. Berkner.¹² Besides acting as the focal point for all Academy-Research Council activities connected with space science research, the board would "coordinate its work with the appropriate civilian and Government agencies, particularly the National Aeronautics and Space Administration, the National Science Foundation, the Advanced Research Projects Agency, and with foreign groups active in this field."¹³ Thus, within the scientific community there already existed the organizational framework, both in the Federal Government and in civilian groups, through which basic space science research—as contrasted with applied research and technology—could be administered. This could provide the vehicle for coordination of contracts and resources with universities and with industry.

In the spring of 1958, prior to the establishment of NASA, the Department of Defense had already formally requested that the Academy-Research Council establish an Armed Forces-NRC Committee on Bioastronautics that would concern itself, as necessary, with any field of science in order to pursue its objectives. Pertinent aspects of astronautics, biology, chemistry, medicine, psychology, and related disciplines would be included. Examples of specific research problems were closed-system environments; stress; crew selection, motivation, surveillance, and control, including group dynamics; ground support facilities; weightlessness; metabolic requirements, including nutrition and water balance; cosmic and other forms of radiation; isolation and confinement; displays, controls, and communication; circulation; deceleration and vibration; escape and survival; orientation; and man-machine system problems.¹⁴

On September 22, 1958, a planning group headed by Brig. Gen. Don D. Flickinger* met to consider possible courses of action.¹⁵ The first meeting of the executive council was held in San Antonio, Tex., on November 10, 1958,¹⁶ with Dr. Melvin Calvin, University

*Other members of the group were Lt. Col. Robert H. Holmes, USA (MC); Capt. W. L. Jones (substituting for Capt. Charles F. Gell, USN (MC)); Dr. R. Keith Cannan, NAS-NRC; and the following members of the Academy-Research Council: Dr. Frank L. Campbell, Division of Biology and Agriculture; Glen Finch, Division of Anthropology and Psychology; and Herbert N. Gardner, Division of Medical Sciences. (Memorandum for Record, dated Sept. 23, 1958, Subj.: Staff Meeting re Committee on Bioastronautics.)

of California, serving as chairman.† This meeting was attended by Dr. Lovelace, Chairman of the new NASA Special Committee on Life Sciences, who noted that while the relationship of his Committee with other Government agencies was not yet clear, major functions were to be the formulation of policies and stimulation of all possible developments related to man's adaptation to space flight. He therefore welcomed liaison with the Armed Forces-NRC Committee.

Thus, by the fall of 1958 both the civilian and military scientific communities were geared to solution of the biomedical problems presented by the immediate objective of manned space flight. The interrelated efforts of the scientific community at the highest Government level in behalf of space exploration are indicated in chart 1. Through the next years, the biomedical problems of manned space flight were to be of continuing concern to the life-sciences community of the Nation.

†Other members were Dr. Howard J. Curtis, Brookhaven National Laboratory; Dr. Paul M. Fitts, University of Michigan; General Flickinger; Dr. John D. French, University of California Medical Center; Captain Gell; Dr. James D. Hardy, U.S. Naval Air Development Center; Colonel Holmes; and Dr. Otto H. Schmitt, University of Minnesota, who was subsequently to become chairman. (See app. A.)

NOTES TO CHAPTER I

¹ Other members of the original committee were: Dr. Robert F. Bacher, Prof. of Physics, C.I.T.; Dr. William O. Baker, Vice President (Res.), Bell Telephone Laboratories; Dr. Lloyd V. Berkner, President, Associated Universities, Inc.; Dr. Hans A. Bethe, Prof. of Physics, Cornell Univ.; Dr. Detlev W. Bronk, President, Rockefeller Inst. for Medical Sciences, and President, National Academy of Sciences; Dr. James H. Doolittle, Vice President, Shell Oil Co.; Dr. James B. Fisk, Exec. Vice President, Bell Telephone Laboratories; Dr. Caryl P. Haskins, President, Carnegie Institution of Washington; Dr. George B. Kistiakowsky, Prof. of Chemistry, Harvard Univ.; Dr. Edwin H. Land, President, Polaroid Corp., Dr. Edward M. Purcell, Prof. of Physics and Nobel Laureate, Harvard Univ.; Dr. Isidor I. Rabi, Prof. of Physics and Nobel Laureate, Columbia Univ.; Dr. H. P. Robertson, Prof. of Physics, C.I.T.; Dr. Jerome B. Wiesner, Director, Research Laboratory of Electronics, M.I.T.; Dr. Herbert York, Chief Scientist, Advanced Research Projects Agency, Dept. of Defense; Dr. Jerrold R. Zacharias, Prof. of Physics, M.I.T.; Dr. Paul A. Weiss, Rockefeller Inst. for Medical Sciences.

² *Introduction to Outer Space: an Explanatory Statement*, dated Mar. 9 and released Mar. 26, 1958, prepared by the President's Scientific Advisory Committee with a statement by the President. The President said: "This

is not science fiction. This is a sober, realistic presentation prepared by leading scientists."

³ *Ibid.*, p. 14.

⁴ *Ibid.*, p. 20.

⁵ See Allison Griffith, *The National Aeronautics and Space Act: A Study of the Development of Public Policy* (Washington, D.C.: Public Affairs Press, 1962).

⁶ Eugene M. Emme, *Aeronautics and Astronautics, An American Chronology of Science and Technology in the Exploration of Space, 1915-1960* (Washington, D.C.: NASA, 1961), pp. 1-100. See also Jerome Hunsaker, "40 Years of Aeronautical Research," and James H. Doolittle, "The Later Years," both in *Final Report of the NACA, 1958* (Washington, D.C.: NACA, 1959).

⁷ The NACA was composed of 15 members, including representatives of the military services. See George W. Gray, *Frontiers of Flight* (New York: Alfred A. Knopf, Inc., 1948).

⁸ Dr. Lovelace later (Mar. 20, 1964) became Director of Space Medicine, Office of Manned Space Flight, NASA Hq.

⁹ Report of the Working Group on Human Factors and Training to the Special Committee on Space Technology, Oct. 27, 1958.

¹⁰ See appendix A for final committee members.

¹¹ The National Academy of Sciences, a nonprofit organization, was established under a congressional charter signed by President Lincoln in 1863. In 1916, at the request of President Wilson, the Academy organized the National Research Council "to enable scientists generally to associate their efforts with those . . . of the Academy in service to the Nation, to society, and to science at home and abroad." Dr. Bronk was also a member of the President's Scientific Advisory Committee.

¹² Press release, Aug. 3, 1958, from the National Academy of Sciences-National Research Council; Emme, *op. cit.*, p. 99.

¹³ Academy-Research Council press release, cited above. The National Science Foundation, it should be noted, had as early as 1954 been assigned "major responsibility on pure scientific research" by Executive Order 10521, "Administration of Scientific Research of Federal Agencies," Mar. 14, 1954.

¹⁴ Minutes, Armed Forces-NRC Committee on Bioastronautics, Nov. 10, 1958, and Appendix A, "Tentative Outline of Rules," Sept. 22, 1958.

¹⁵ *Ibid.*

¹⁶ Minutes of First Meeting, Executive Council, Armed Forces-NRC Committee on Bioastronautics, Nov. 10, 1958. The Bioastronautics Committee was dissolved on Mar. 3, 1961. (See Memo for Members of the Executive Council and Panel Chairmen of the Armed Forces-NRC Committee on Bioastronautics from Sam F. Seeley, M.D., Exec. Secretary.) The historical record of the contributions of this group remains to be written.

CHAPTER II

*Aviation Medicine: Tap Root of Space Medicine*¹

BEFORE THE INTERNATIONAL GEOPHYSICAL YEAR and the launching of Sputnik there had been uncertainty as to the roles and missions of the Army, Navy, and Air Force in the exploration and exploitation of space, as well as in missile development from which space technology derived.²

In August 1958, after passage of the National Space Act, President Eisenhower assigned NASA the mission of manned space flight to be carried out as a national objective at the earliest feasible time. To accomplish this goal, NASA was to receive support from all the resources of the Nation, including military medical resources. Short of a sudden defense emergency, this reservoir of aerospace medical strength would support the NASA mission of manned space flight.

CLINICAL FACTORS: USAF AEROSPACE MEDICINE

Notwithstanding the conviction of certain leading civilian scientists that space medicine was an entirely new field, the U.S. Air Force bioastronautics community as early as 1949 had considered space medicine to be an extension of aviation medicine.³

Indeed, as early as World War I, the Army—parent of the U.S. Air Force—had trained a special kind of medical officer, the flight surgeon. This specialist, while still serving in many cases as a clinician treating sick patients, more often functioned as a medical officer concerned with healthy pilots under the unique stress of surviving in an alien atmosphere. He also worked with the design engineer on the development of equipment and instruments to help a pilot overcome the adverse environment. Thus, medicine was already wedded to flight technology. This had led to manned flight at extreme altitudes by midcentury. Ultimately, the bio-

astronautics experts believed, it would lead to manned space flight.

The U.S. Air Force (a part of the Army until 1947) had thus recognized as early as World War I that the physician was vitally important as a member of the aeronautics team.⁴ During World War I the new School of Aviation Medicine (SAM) at Mineola, Long Island, had concerned itself with the physiological problems of stress faced by man in flight, and the medical staff had concentrated on establishing physical standards necessary for military pilots. Following World War I the school had moved to Brooks Air Force Base, Tex., and subsequently to Randolph Air Force Base, where a small in-house group sponsored aviation medical research and education, the only resource of its kind in the world.⁵

After World War II the commandant, Col. Harry G. Armstrong,⁶ a pioneer in aviation medicine, gathered together certain leading German scientists in the field of aviation medicine and space science.⁷ On February 9, 1949, the first Department of Space Medicine in the world was established at the school, and Dr. Hubertus Strughold subsequently became the first professor of Space Medicine.⁸

As director of aeromedical research for the German Air Force, Dr. Strughold had been aware of the space-flight ambitions of Drs. Walter Dornberger and Wernher von Braun of the V-2 program at Peenemunde. He had himself theorized for several decades on the medical implications of space flight.⁹

Strughold and his modest SAM staff in 1949 estimated that the main medical problems of space flight could be formulated and the majority of the questions fully answered within 10 to 15 years. Hardware could be developed within 15 to 20 years. The first manned space flights thus would become feasible between 1964 and 1969.

Among the fundamental studies initiated were those in acceleration, noise and vibration, atmospheric control, weightlessness, and nutrition. Unfortunately, noted one British lecturer:

... some of the more advanced concepts and topics for discussion such as time contraction during flight near the speed of light, the ecology of the Martian atmosphere, suspended animation for interplanetary voyages, and so on, tended to lead their critics to overlook the fact that they were progressively formulating and passing on to appropriate workers clearly defined problems needing solution.¹⁰

At that time it appeared that most of the problems encountered in space flight would be logical extensions of those already encountered in aviation, and that they were not insurmountable.



Lt. Col. John P. Stapp, USAF (MC), was a pioneer in the development and use of the research sled for deceleration tests. He is shown here just before a run on the deceleration sled at Edwards AFB, Calif., with accelerometers at mouth, chest, and knee.

Two major problems of manned space flight, it was believed, were solar radiation and weightlessness.

As a first step toward solving these problems, the School of Aviation Medicine turned to the experience of the Germans at Peenemunde and in the German aeromedical laboratories. This led to the publication in 1950 of the two-volume *German Aviation Medicine—World War II*, prepared by 56 leading German aviation specialists, and translated and published by the U.S. Air Force. Such topics as the physiological fundamentals of high altitude and acceleration and the potential problems of man under gravity-free conditions were discussed.¹¹ Thus the advances of German aviation medicine in World War II became spoils of war and a part of the open literature in the field.

Meanwhile, as early as 1948, representatives of the U.S. Air Force School of Aviation Medicine and the Lovelace Foundation had held symposia aimed toward aiding the accomplishment of manned travel in the upper atmosphere, emphasis being on the concept that "one must learn to walk before one runs." Two subsequent symposia in 1950 and 1951 led to the publication of *Physics and Medicine of the Upper Atmosphere*, which provided data

cross sectioning of four scientific disciplines: Astrophysics, aeronautical engineering, radiobiology, and aviation medicine.¹² The need for cross-fertilization of scientific disciplines, as recognized by this group of the Nation's scientists, was the most important single factor with which the scientific community during the next few years must cope to meet the complex requirements of the advancing technology of manned flight and manned space flight.

By the midfifties current thinking in the Air Force was increasingly oriented toward possible manned space flight. For example, in February 1957 *The Journal of Aviation Medicine* published an article on "Selection and Training of Personnel for Space Flight," which concluded that "space flight is not drastically different from most aspects of aviation which are now familiar."¹³ This article aptly foreshadowed the pattern that was actually followed in the selection and training program for Project Mercury.

HUMAN FACTORS: USAF RESEARCH AND DEVELOPMENT

By the midthirties, advancing technology required that the skills of the flight surgeon be combined with those of the aeronautical engineer to explore the problems of "human engineering." With the establishment of the Aero Medical Laboratory at Wright-Patterson Field, Ohio, in 1934, the flight surgeon assumed a key position in the Air Force program for applied research and development of hardware. During World War II the Army Air Forces worked with NACA in developing a human-factors program, for man remained the weak link in new weapon systems that included man, plane, and missile. The basic problems of design engineering and life-support systems as defined in that period were to be pertinent a decade and a half later as the Nation embarked on its manned space-flight program.¹⁴

After the war it became increasingly apparent that aircraft operational requirements were leading man nearer to space itself. Specialists in aviation medicine, watching pilot performances at ever higher altitudes and faster speeds in the rocket-powered aircraft of the X-series, began to think of space flight as a logical extension of high-altitude flight. In October 1947, when test pilot Charles E. "Chuck" Yeager, then a captain in the Air Force, flew the rocket-powered USAF-NACA X-1 faster than the speed of sound, a new milestone had been passed.

Two months later, Lt. Col. John P. Stapp, USAF (MC), who was interested in the problems of deceleration, made his first



When space research was in its infancy, the USAF even then was pioneering in weightlessness research. The chief means of acquiring short periods of weightlessness for the research that must precede actual manned orbital flight was to fly high-speed airplanes through a high-altitude parabolic trajectory; this would afford something less than 1 minute of weightlessness as the airplane crested at the top of the parabola. Early experiments were in single-seat fighter aircraft in which the pilot attempted a few experiments. Left, Capt. Julian E. Ward, USAF (MC), tries to drink a blob of weightless water in the cockpit of his F-94C during one of the flights con-

ducted by the USAF School of Aviation Medicine. Later experiments at Wright AFB, Ohio, used transport airplanes like the C-131 (below) in which Maj. Gen. Oliver K. Niess, USAF Surgeon General, and Col. John P. Stapp, USAF (MC), float during the short period of weightlessness.



rocket-propelled research-sled ride at a speed of 90 mph. On March 19, 1954, he traveled at a speed of 421 mph on the 3,500-foot track; on August 19, at a speed of 502 mph; and on December 10, 1954, at a speed of 632 mph, which made him "the fastest man on earth" (as described in current news media). Bushnell's authoritative and highly readable history of the Air Force Missile Development Center, Holloman Air Force Base, for the period 1946-58 describes these developments, as well as the related animal experimentation program, in great detail.¹⁵

Other research efforts were also underway. As early as March 1927 Capt. H. C. Gray (U.S. Army Air Corps) had ascended to 28,910 feet in a free balloon for an unofficial altitude record. In May 1931, Auguste Piccard and Paul Kipfer made the first successful manned ascent into the stratosphere from Augsburg, Germany, and established a new world altitude record of 51,777 feet. In 1934 three Air Corps officers, Maj. W. E. Kepner, Capt. A. W. Stevens, and Capt. Orvil A. Anderson, attained a 60,613-foot altitude in an Air Corps-National Geographic Society balloon. Subsequent flights were made by both the Air Force and the Navy to study the problems of altitude. For example, in August 1957, Maj. David G. Simons, USAF (MC), a flight surgeon, remained airborne for 32 hours in the Man-High II flight. He established a manned-balloon altitude record of 101,516 feet, ascending at Crosby, Minn., and landing at Elm Lake, S. Dak.¹⁶ This was 2 months before Sputnik.

In response to the drastic upgrading of research and development in the postwar years, the U.S. Air Force organized, in January 1951, the Air Research and Development Command (later the Air Force Systems Command) to provide the best in new manned and unmanned weapon systems. Important objectives of the new command were the undertaking of scientific research and the development of applied technology to accomplish manned flight at increasing altitudes and speeds.¹⁷

The documented record of these highly significant research and development milestones that occurred in the early 1950's under the leadership of Gen. Thomas Power, then Commanding General of ARDC, has not yet appeared in the open literature. Such a history, describing the conceptual thinking at the R&D level during this period, should go far to unify the pattern of progress by Air Force scientists and engineers spreading from Kitty Hawk to the Man-in-Space R&D effort carried out later under Gen. Bernard A. Schriever.¹⁸

U.S. NAVAL RESEARCH AND DEVELOPMENT

At the U.S. Naval School of Aviation Medicine, established in 1939 at Pensacola, Fla., considerable research and development had gone forward since 1940 under joint Navy and National Research Council sponsorship. Capt. Ashton Graybiel, USN (MC), Director of Medical Research, developed a strong research and development capability in support of naval aviation. The research programs dealing with the problems of weightlessness and the vestibular function, for example, were particularly important to future NASA effort. In the pre-Sputnik period, the U.S. Naval School of Aviation undertook biological research projects for the U.S. Army. These projects, discussed later in this chapter, helped to build biological capability for manned space flight. Scientific specialties included biochemistry, biometrics, biophysics, cardiology, medical electronics, neurophysiology and acoustics, physical chemistry, physiology, psychophysiology, and personnel psychology. Among the special facilities at the school were low-pressure chambers, a low-level alpha-radiation laboratory, an electrophysiological laboratory, a slow-rotation room, and a human-disorientation device.¹⁹

The Aviation Medical Acceleration Laboratory, located at the Naval Air Development Center, Johnsville, Pa., had the largest human centrifuge in the world (with a 4,000-hp motor, a 50-foot arm, and a 40-g capability). This centrifuge was the Navy's principal tool for in-house research programs for 10 years, and was used extensively in the X-15 and Dyna-Soar programs. It was subsequently utilized in the Mercury program.²⁰

In Philadelphia, Pa., the Naval Air Crew Equipment Laboratory since 1942 had conducted basic research in biological, psychological, and human engineering aspects of aviation medicine related to personal and safety equipment. Special facilities included, among others, underwater test facilities, a complete liquid oxygen laboratory, and an escape-system recovery net capable of recovering ejected free-flight seats and capsules.²¹ This laboratory, too, was to make important contributions to Project Mercury.

PRE-SPUTNIK COOPERATIVE BIOLOGICAL EXPERIMENTATION

Following World War II, limited biological experiments had been carried out by military and university scientists. Tests had covered such factors as the effects of radiation upon living orga-



The Johnsville centrifuge, more formally known as the Aviation Medical Acceleration Laboratory of the Naval Air Development Center, Johnsville, Pa.

nisms and the behavior of animals in the absence of gravitational forces. The first of these experiments was undertaken with captured V-2 rockets at Holloman Air Base, N. Mex. In 1946-47, Harvard biologists, in cooperation with scientists from the U.S. Naval Research Laboratory, recovered seeds and fruit flies after flights at altitudes up to 160 km. This group was joined in 1948 by Dr. James P. Henry of the U.S. Air Force, and during the next few years successful flights were launched with mice and monkeys as passengers.²²

In June 1948 the first American primate, Albert I, was launched in a V-2 rocket from White Sands, N. Mex., but it died of suffocation. A year later, on June 14, a second anesthetized monkey, Albert II, was sent aloft in the same V-2 vehicle. That monkey survived the flight but was killed on impact. On September 16 a third monkey was killed when the rocket exploded at 35,000 feet. In December 1949, a fourth monkey was flown, with data on ECG and respiration successfully telemetered, but the monkey died on impact. A mouse sent aloft on October 31 was not recovered alive, although pictures were made of its behavior in a weightless state.

Aerobee rockets also were used. On April 18, 1951, Henry and his group sent aloft an anesthetized monkey and several mice. The animals were not recovered because of parachute failure. An anesthetized monkey and 11 mice sent aloft in an Aerobee rocket on September 20, 1951, were all recovered alive, although the monkey died 2 hours after impact. These mice became the first known living creatures to survive actual space-flight conditions. The following May, two anesthetized monkeys, Pat and Mike, together with two mice, were flown to a 62-km altitude. Pat and Mike were the first primates to survive actual space-flight conditions.²³ By 1952 the supply of V-2 rockets was exhausted, and biological experiments in rockets and missiles came to a halt for the next 6 years.

Paralleling these activities since 1950 were biological experiments carried out in unmanned balloon flights. On September 8, 1950, the U.S. Air Force sent white mice aloft in an "Albert" capsule to a height of 47,000 feet. They were recovered dead because of capsule depressurization and leakage 7 hours after launch. On the 28th of that month, white mice were sent aloft to 97,000 feet and recovered unharmed after 3 hours 40 minutes. On January 18, 1951, an "Albert" capsule containing mice went aloft. It was recovered after 2 hours, the balloon having burst at 45,000 feet. The following August, hamsters were sent aloft to 59,000 feet in a Minnesota capsule, but again there was a balloon failure. Data on this flight are lacking.²⁴ These experiments culminated ultimately in the Man-High experiments, in which a human subject was lifted aloft on the eve of Sputnik. These pioneering efforts were of limited value, but they laid the groundwork for biological experimentation prior to high-altitude manned flight and space flight.

Also important during this decade was the development of the X-12, X-15,²⁵ and Dyna-Soar programs, all concerned with testing human factors and all providing basic knowledge upon which the first U.S. space program would be built.

NOTES TO CHAPTER II

²³The NASA terminology *space medicine* and the U.S. Air Force terminology *aerospace medicine* are used interchangeably in the present discussion. *Bioastronautics* is the Air Force term for the total complex of scientific disciplines, including medicine, necessary to support manned flight and manned space flight, and is used in that context in the present study.

² Ballistic missiles had been given highest national priority in the race for first-generation ICBM's and IRBM's. See Eugene M. Emme, ed., *History of Rocket Technology* (Detroit: Wayne University Press, 1964).

³ See, for example, Harry G. Armstrong, *Aerospace Medicine* (Baltimore: Williams & Wilkins, 1961), successor to *The Principles and Practice of Aviation Medicine* (1st ed., 1934), the classical reference in the field. The current scientific literature in the field is systematically abstracted for *Aerospace Medicine*, successor to the *Journal of Aviation Medicine*, by Dr. Arnold Jacoblus, of the Library of Congress. The reader is referred to these two basic sources for further review of the scientific literature in the field.

⁴ Mae Mills Link and Hubert A. Coleman, *Medical Support of the Army Air Forces in World War II* (Washington, D.C.: Office of the Surgeon General, USAF, 1955), pp. 230-351.

⁵ Subsequently, to keep pace with the approaching space age, SAM in 1959 moved back to Brooks AFB, where a new complex of research and testing facilities was being constructed. SAM was redesignated the School of Aerospace Medicine.

⁶ Harry G. Armstrong, "Origins of Space Medicine," *U.S. Armed Forces Med. J.*, vol. X, no. 4, Apr. 1959, p. 392. The reader is also referred to the extensive documentation sources in the archives in the Aerospace Medical Div., Brooks AFB, Tex. The author of the present study, who was senior Air Force Medical Historian from 1951 to 1962, has used these documents extensively, as well as documents in the Office of the Surgeon General, USAF, to which the reader is referred.

⁷ This original group included Hubertus Strughold, M.D., Ph. D., who had been director of Aeromedical Research Inst., Berlin, Germany; Dr. Heinz Haber, who later became chief science consultant for Walt Disney Productions; Dr. Fritz Haber, who designed the sealed cabin for use at Randolph AFB, and later was associated with Avco Manufacturing Corp.; and Dr. Konrad Johannes Karl Buettner, a bioclimatologist from Westendorf, Germany, who later was associated with the Boeing Co. The group was joined subsequently by Dr. Hans Georg Clamann, who became research physiologist at the school, and by Dr. Siegfried Gerathewohl, who had been chief of the Psychological Testing Center of the German Air Force during World War II. Gerathewohl later joined NASA.

⁸ Office of the Secretary of the Air Force, Air Force News Service Release No. 1299, Mar. 28, 1958.

⁹ Personal communication.

¹⁰ D. I. Fryer, "The Medical Sciences and Space Flight," *R.A.E. News*, February 1964. See also, for example, Otis O. Benson, Jr., and Hubertus Strughold, eds., *Physics and Medicine of the Atmosphere and Space* (New York: John Wiley & Sons, Inc., 1960). The reader is referred to Dr. Strughold's extensive published works, particularly "From Aviation Medicine to Space Medicine," *J. Aviation Med.*, Vol. 23, no. 4, Aug. 1952, pp. 315-318.

¹¹ *German Aviation Medicine—World War II* (2 vols.), prepared under the auspices of the Surgeon General, USAF (Washington, D.C., 1950). This volume, a classic in the field, is now out of print.

¹² Clayton S. White and Otis O. Benson, Jr., eds., *Physics and Medicine*

of the Upper Atmosphere (Albuquerque: The University of New Mexico Press, 1952).

¹⁸ David H. Beyer and Saul B. Sells, "Selection and Training of Personnel for Space Flight," *J. Aviation Med.*, vol. 28, no. 1, February 1957, pp. 1-6. See also Paul A. Campbell, "Aviation Medicine on the Threshold of Space: A Symposium," *J. Aviation Med.*, vol. 29, no. 7, July 1958, pp. 485-492.

¹⁹ This program is discussed in detail in Link and Coleman, *op. cit.*, pp. 230-351.

²⁰ David Bushnell, *History of Research in Space Biology and Biodynamics, 1946-58*, AF Missile Dev. Center, Holloman AFB, N. Mex., 1958. This study is a "must" for anyone interested in gaining a true perspective of the great amount of research and development that was carried out by the Air Force in this period. Statistics supplied by Colonel Stapp, Sept. 10, 1963; Air Force Pamphlet 190-2, p. 71; and Eugene M. Emme, *Aeronautics and Astronautics, An American Chronology of Science and Technology in the Exploration of Space, 1915-1960* (Washington, D.C.: NASA, 1961), pp. 62, 68.

²¹ Emme, *Aeronautics and Astronautics*, p. 87. This was to be followed by other flights such as Man-High III. See Emme, *Aeronautics and Astronautics*, appendix C, "Chronicle of Select Balloon Flights, 1927-1961," pp. 161-165. See also David Bushnell, *Contributions of Balloon Operations to Research and Development at the Air Force Missile Development Center, 1947-58*, AF Missile Dev. Center, Holloman AFB, N. Mex., 1958. This volume is also a "must" reference. Copy on file in NASA Historical Archives.

²² When it became operational in April 1951, ARDC had four laboratories: Air Development Force at Wright Field, AF Cambridge Research Div., AF Flight Test Center at Edwards AFB, and the Holloman AFB R&D establishment (later AFMDC). Later the Arnold Engineering Development Center (Tullahoma, Tenn.), AF Armament Center (Eglin AFB, Fla.), and the AF Special Weapons Center (Kirtland AFB, N. Mex.) were added.

²³ The author has discussed this important period with key Air Force personnel including Col. George D. Colchagoff, USAF, an engineer who was on General Power's staff and was project officer for matters relating to space flight.

²⁴ "Navy Bioastronautic RDT&E Support of the NASA Manned Space Flight Program," Mar. 12, 1960, a staff paper prepared jointly by DOD and NASA. Copy on file in NASA Historical Archives.

²⁵ *Ibid.* See also, for example, NASA Project Mercury Paper No. 187, "Life System Aspects of Third Mercury Acceleration Laboratory Centrifuge Program," Space Task Group, NASA, Apr. 20, 1961.

²⁶ See note 19.

²⁷ Dietrich E. Beischer and Alfred R. Fregly, *Animals and Man in Space, A Chronology and Annotated Bibliography Through the Year 1960*, ONR Rep. ACR-64 (USNSAM Monograph 5), Dept. of the Navy, p. 53. See particularly pp. 55-90 for charts and a bibliography of animal biological experiments through 1960.

²⁸ *Ibid.*, pp. 56-57. See also Note 16.

²⁹ During the next 10 years more than 50 experiments were performed by investigators including D. G. Simons, J. P. Stapp, and others. Subjects

included hamsters, cats, dogs, black and white mice, fruit flies, goldfish, seeds, chicken eggs, and human skin. More than 80 experiments of this type were carried out in all. Beischer and Fregly, *op. cit.*, pp. 13-30.

²⁵ See Wendell H. Stillwell, *X-15 Research Results With a Selected Bibliography*, NASA SP-60, 1965.

CHAPTER III

Pre-Mercury Heritage in Biotechnology

UNTIL THE CONGRESS CLARIFIED SPACE ROLES and missions, the Department of Defense effort in missile and space affairs was variegated and geared for response to a potential military threat that had been presented by Sputnik—the demonstration of Soviet rocket technology.

On January 13, 1958, preceding the establishment of NASA under the Space Act, the Secretary of Defense, Neil H. McElroy, testified before the House Armed Services Committee that he proposed to establish within the Department of Defense an Advanced Research Projects Agency (ARPA) to be responsible for the unified direction and management of the anti-missile-missile program and for outer space projects.* The proposal was approved by the President on March 27, 1958. ARPA was directed to undertake space projects, including the launching of certain satellites and five space probes as part of the United States' contribution to the International Geophysical Year.

When NASA was declared operational on October 1, DOD responsibilities for the remaining U.S. IGY satellite probe projects were transferred to NASA by Executive order. Earlier, on September 17, 1958, a joint NASA-ARPA manned satellite panel had been established to make recommendations for a manned space flight program.¹ This would be Project Mercury.

Meanwhile, the year following Sputnik had been one in which research and development took unprecedented forward strides within the services. In that period two potentially workable satellite research concepts were emerging within the Department of

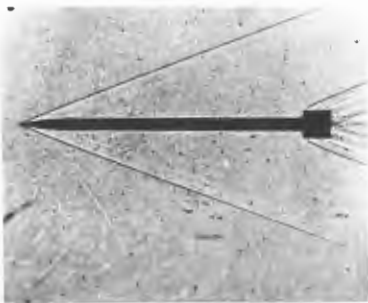
*According to "A Chronology of Missile and Astronautics Events" published in *House Report 67* (87th Cong., 1st sess.), p. 36, this plan had been announced approximately a month before, on Dec. 5.

Defense. The medical implications of each were to have significant bearing on the future Mercury program.

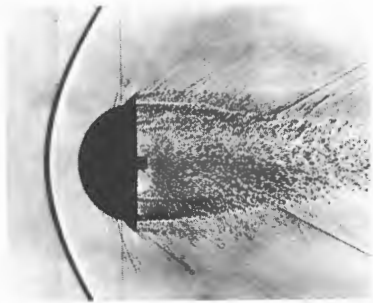
U.S. AIR FORCE MAN-IN-SPACE CONCEPT ²

In July 1957, preceding Sputnik, the U.S. Air Force Scientific Advisory Committee arranged through the Rand Corp. in Los Angeles, Calif., to hold a 2-day conference to discuss the state of the art in jet propulsion and space technology. Representatives from NACA also attended the meeting. The life-sciences agenda for the meeting was prepared by Brig. Gen. Don D. Flickinger, Command Surgeon, ARDC, and Dr. Albert Hetherington, chief scientist on his staff.

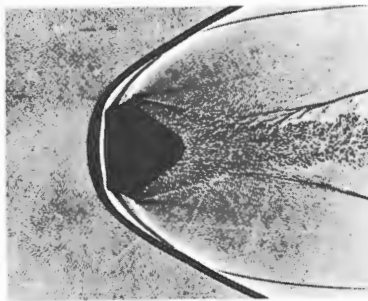
Out of the meeting came the conclusion that, given vehicular reliability, no additional life-sciences knowledge was needed for normal orbital flights. Initial testing for environmental control



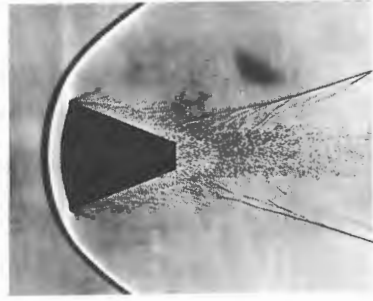
Initial concept



Blunt-body concept, 1953



Missile nose cones, 1953-1957



Manned-spacecraft concept, 1957

Aerodynamics research contributing to Project Mercury.

and other comparable factors could be accomplished within a period of 18 months. Indeed, the life sciences appeared to pose no great problem at all. Rather, the greatest problem concerned the vehicle itself: Should it be a purely ballistic type with a drag configuration for reentry, or should a "lifting body" configuration, which would reduce the reentry g-loading, be used?

Three months later, after Sputnik, Gen. Bernard A. Schriever, Commander of the Ballistic Missile Division, ARDC, brought together a group of 56 leading scientists and engineers, headed by Dr. Edward Teller, to make specific recommendations to the Air Force about its space requirements. At that time, General Flickinger recalled Dr. James P. Henry, then on duty in the USAF European Office of Research and Development, to head an ad hoc committee on life sciences of the Teller committee.

The Teller committee met in closed session at ARDC in late 1957 to complete its final report. In substance, it stated that there was no technological reason why the Air Force could not place a man in orbit within 2 years. Recognizing all the questionable aspects of manned space flight, the Teller committee did not try to specify the nature of military missions to be performed; but it did point to the fact that manned space flight should be accomplished both to add to national prestige and to advance science and technology.

After the Teller report was submitted to the Secretary of the Air Force, the Deputy Chief of Staff for Development directed that ARDC prepare an abbreviated development plan for a man-carrying vehicle which could be put into orbit with an Atlas or an Atlas plus a second-stage booster. This directive was redirected to the Wright Air Development Center at Wright-Patterson AFB, a component organization of ARDC. Because the fiscal year was drawing to a close, moneys were not immediately available and it was necessary to use available life-sciences funds to the extent of approximately \$500,000 to provide one prototype of a single man-carrying capsule within 5 or 6 months.

The contractors' proposals made in response to the hasty requests sent out by ARDC were evaluated by a board in March and April of 1958. Instead of a single contract carrying the development to a prototype, it was decided that awards should be made to the two top proposals for development programs carried only to the mock-up stage. This plan was approved by USAF Headquarters, and awards were made to North American Aviation and to General Electric, which were instructed to proceed to the mockup stage.

Meanwhile, ARDC in March 1958 made a presentation to the

Vice Chief of Staff on the complete proposed development plans for a manned space system. Subsequently, the Vice Chief of Staff directed ARDC to establish a task force which would develop plans for a manned space system under highest priority. Headed by General Schriever, the Man-in-Space task force was organized at the Ballistic Missile Division in Englewood, Calif. The working force was composed of both military and civilian personnel, including representatives from the Space Technology Laboratories. General Flickinger, who was the life-sciences spokesman for the group, noted that, with a great sense of national urgency, the task group began to accomplish "what really had to be done yesterday."

The first plan prepared was presented to ARDC Headquarters and to ARPA in May 1958. This plan, called Man-in-Space (MIS), was superseded a month later by an accelerated plan known as Man-in-Space Soonest (MISS) which proposed test programs with animal flights as early as the 1959-60 period, to be followed by the first manned flight in October 1960. Subsequent flights would lead eventually to a lunar landing by 1964.³

It was recognized that MISS would not provide for more than a 24- to 48-hour period in orbit, and this short mission would serve only as a demonstration of technological and operational capability. It was also recognized that before a lunar landing could be accomplished, there must be a better definition of the boundaries of human tolerances.

In the meantime came the decision to establish NASA. When Project Mercury was designated as the U.S. manned space flight program, the U.S. Air Force regrouped part of its program into the Bioastronautics Orbital Space System (BOSS) program. By late 1959 it had been developed into a fairly comprehensive program for subhuman exposure. By 1960, in the light of proven techniques for deorbit, the program was reworked and became known as the Bioastronautics Orbital Space Program (BOSP). In early 1961 it was accepted fully as an ongoing development program by USAF Headquarters, and was supported by NASA. (The Gagarin flight in May 1961, however, demonstrated that man could successfully orbit the earth, and NASA could no longer justify its support to the Air Force for this program.)

Among those assigned to the MISS planning group was Lt. Col. Stanley White, USAF (MC), a flight surgeon on duty at the Aero-Medical Laboratory at Wright Air Development Center, Ohio. Although no Air Force-wide medical program had yet been developed in support of the MISS concept, considerable thought was

being given to life-support hardware, and it was to this problem that Dr. White had addressed himself. It has been noted that in September 1958, following the passage of the Space Act, a joint NASA-ARPA manned satellite panel was formed to draft specific plans for a program of research leading to manned space flight. When White came to Washington to brief officials on the status of biomedical support in the projected MISS concept, he was tapped for early service with NASA. Subsequently he was to become the senior member of the aeromedical team assigned the mission of establishing criteria for selection of the Mercury astronauts.⁴

U.S. ARMY MAN-IN-SPACE CONCEPT

To meet the challenge of Sputnik, the Army in January 1958 initiated action to present a triservice man-in-space proposal to ARPA for approval. Perhaps because of its own ongoing experimental Man-in-Space program—budgeted under R&D funds and therefore requiring Air Force approval only—the Air Force did not participate.

The Army proposal as finally developed in April 1958 at the Army Ballistic Missile Agency, Ala., was designated Project Adam.⁵ The objective of the proposed project was to carry a manned, instrumented spacecraft to a range of approximately 150 statute miles; to perform psychophysiological experiments during the acceleration phase and the subsequent 6 minutes of weightlessness; and to effect a safe reentry and recovery of the manned spacecraft from the sea. Already feasible through existing hardware and recovery techniques, it would supply fundamental knowledge on human behavior during transportation by rocket, cabin design criteria, recovery techniques for manned reentry vehicles, emergency escape procedures, and data transmission techniques. In addition, as a pioneering achievement, it would enhance the technological prestige of the United States. Participating agencies of the Army-sponsored effort would be the U.S. Army Ballistic Missile Agency, the U.S. Army Medical Service, USN Task Force for Recovery Operations, and selected contractors.

The carrier vehicle would consist of a modified Redstone thrust unit and an instrument compartment as used in satellite and reentry firings. The human passenger would travel in a reclining position relative to the missile thrust axis so as to keep acceleration

effects at a minimum. The biomedical aspects would include measurement of human reactions as follows: Electrocardiogram, blood pressure, respiratory rate and depth, galvanic skin resistance, two body temperatures, and motion picture coverage of the passenger. Measurements of the spacecraft environment would include cabin pressure, oxygen partial pressure, carbon dioxide partial pressure, cabin air temperature, spacecraft skin temperature, humidity, cosmic radiation, gravitational force (for weightlessness determination), noise, and vibration.

The proposal urged that Project Adam be approved as the next significant step toward the development of a U.S. capability for the transportation of troops by ballistic missiles, and that funds in the amount of \$4.750 million be provided immediately.

In July 1958 the Director of ARPA, having studied the proposal submitted by the Secretary of the Army on May 19, stated that since it was not considered necessary for the Man-in-Space program, it would not be funded by ARPA. Through the next weeks, following the establishment of NASA, discussions were held concerning the utilization of Redstone and Jupiter vehicles for the NASA man-in-space program; but Project Adam *per se*, like the Air Force MISS, was to stop in the conceptual stage.

Now, in effect, the new team—NASA—would carry forward a man-in-space program that would draw upon the conceptual thinking of the scientific world thus far, but which yet required implementation into fact. To the new team would fall the decision-making process, including the responsibility for courses and alternative courses of action. The new phase had begun.

BIOLOGICAL EXPERIMENTS FOR PROJECT MERCURY

Three Thor-Able vehicles had been launched by the Army for re-entry tests, one each on April 23, July 9, and July 23, 1958. A mouse was carried in the nose cone of each vehicle. None of the cones were recovered, although physiological records were obtained by telemetry for Laska (passenger in the second flight) and Benji (passenger in the third flight). Limited data were obtained.⁶

The Army had also sponsored a biopack research program, carried out by the Navy, to determine the biological problems involved in ballistic flight.

The U.S. Navy through the School of Aviation Medicine, Naval Aviation Medical Center, in Pensacola, Fla., was to carry out two

biological experiments in the nose cone of the U.S. Army Jupiter missiles in late 1958 and early 1959. On December 3, 1958, a South American squirrel monkey (Old Reliable) was launched on a noninterference basis with the main mission of a Jupiter missile and carried 300 miles into space. The available volume in the nose cone was 750 cubic inches, and the weight limit was 30 pounds.⁷ The primary objective of the experiment was to demonstrate that animals could survive ballistic flights unharmed if adequate life support were provided. The secondary aim was to design, construct, and test such a system; to develop countdown and launching procedures; and to recover the specimen after flight. Particularly significant was the fact that the technical and scientific information on the physiological and behavior status of the animal was gained through telemetry. Although Old Reliable survived the flight, he was lost when a mishap occurred to the vehicle on reentry.

In the second flight, on May 28, 1959, an American-born rhesus monkey (Able) and a squirrel monkey (Baker) were recovered uninjured, although 4 days later Able died during the induction of light anesthesia for the removal of the electrodes.⁸

Working as a team, the Army and Navy visualized further research, and at the time it was announced that NASA would have the primary mission in manned space flight, plans had already been made for an imminent third flight. Thus, while the Army's proposals for developing a manned space flight program were not to come to fruition, the biological experiments that had been planned would nevertheless be carried forward under NASA leadership.⁹

THE AEROMEDICAL WORKING TEAM

The Army flight surgeon who had been associated with this program was Dr. William Augerson, a young captain then on duty with the Army Ballistic Missile Agency (ABMA) at Redstone Arsenal, Huntsville, Ala. Like Dr. White of the Air Force, he was tapped by NASA to become a member of the aeromedical team of the newly organized NASA Space Task Group. He arrived at STG, located at Langley Field, in October 1958, within a few days of Dr. White's arrival.

Capt. Ashton Graybiel, USN, a cardiologist and Director of Medical Research for the Navy since 1940, had directed the biological experimentation for Project Adam for the Army. He was



The first monkeys recovered alive from a sub-orbital flight were Able (shown above being released from his support couch) and Baker (right). Both monkeys flew to 300-mile altitude together in a U.S. Army Jupiter nose cone on May 28, 1959.



to serve in varied consultant capacities on the Project Mercury team through the next year. The Navy member of the working aeromedical team of the Space Task Group, however, was to be Dr. Robert B. Voas, a psychologist who at that time was a lieutenant in the Navy. He also joined STG in October 1958.

These three young military officers, White, Augerson, and Voas, who were to form the nucleus of the aeromedical working team that selected the astronauts for Project Mercury, were listed sim-

ply as the "Aero-Medical Consultant Staff" in the first STG organizational chart.

Thus by the fall of 1958 the course of the manned space flight program had been charted at the highest level, both in NASA and in DOD. From the military services, with their rich and varied experience, would come in large part the biomedical support for Project Mercury. Long-range plans and objectives could await future study, but now it was time for action. In the words of NASA Administrator, Dr. T. Keith Glennan, "Let's get on with it."¹⁰

NOTES TO CHAPTER III

¹ *Introduction to Outer Space: An Explanatory Statement*, dated Mar. 9 and released Mar. 26, 1958, by the White House.

² This section is based on sources including classified documents which, however, have not been quoted directly, and upon interviews with General Flickinger. Among the classified documents is *USAF Manned Military Space System Development Plan*, vols. I and II, AF Ballistic Missile Div., ARDC, Apr. 25, 1958. See also, for brief description, James M. Grimwood, *Project Mercury: A Chronology*, NASA SP-4001, 1963, p. 17.

³ Based on diary notes of General Flickinger and informal discussions between General Flickinger and the author, 1963-64. The role of General Flickinger in the MIS program is discussed in Shirley Thomas, *Men of Space*, vol. 3 (Philadelphia: Chilton Co., 1961), pp. 74-96.

⁴ Informal discussions between Dr. White and the author, 1961-63.

⁵ Manuscript sources include "Development Proposal for Project Adam," Rep. No. D-TR-1-58; "Project Adam Chronology"; DXM Journal Entries, Sept. 30 and Oct. 1, 1958; and "Agreements in Manned Satellite Project." All in NASA Historical Archives.

⁶ F.L. van der Wal and W. D. Young, "Project MIA (Mouse-in-Able), Experiments on Physiological Response to Space Flight," *ARS J.*, vol. 29, no. 10, Oct. 1959, pp. 716-720.

⁷ Because of the limited space and the uncertainties involved, some thought had been given to sending aloft a collection of plant and animal specimens, a project dubbed "Noah's Ark."

⁸ A. Graybiel, R. H. Holmes, et al., "An Account of Experiments in Which Two Monkeys Were Recovered Unharmed After Ballistic Space Flight," *Aerospace Med.*, vol. 30, no. 12, Dec. 1959, pp. 871-931. S. J. Gerathewohl, S. W. Downs, G. A. Champlin, and E. S. Wilbarger, Jr., "Bio-Telemetry in the Nose Cones of U.S. Army Jupiter Missiles," *IRE Trans. on Military Electronics*, MIL-4, Apr.-July 1960, pp. 288-302.

⁹ Interviews with Capt. Ashton Graybiel, USN (MC), Director of Research, U.S. Naval School of Aviation Medicine, Pensacola, Fla., and Dr. Dietrich Beischer, staff member who pioneered in this program, Nov. 13, 1963; interview with Dr. Donald E. Stulkin, Manned Spacecraft Center, formerly with Dr. Graybiel at the time of experiments.

¹⁰ Grimwood, *op. cit.*, pp. 27, 33.

CHAPTER IV

NASA Long-Range Life Sciences Program

FACING THE NASA ADMINISTRATOR, however, were problems that extended far beyond the immediate objective of manned space flight. Since the late 1940's when Strughold and his group had defined the biological and ecological problems of extended manned space flight, there had been a growing interest in such extended flight by the civilian academic and industrial community as well as by the military services. This long-range aspect had been overshadowed to some extent by the more pressing problems of near-earth flight as represented in the BOSS concept and the subsequent Mercury program. These latter problems could be resolved by existing technology, but the long-range problems, while defined, would nevertheless require intensive basic research.

Following the Space Act of 1958, the Stever committee had addressed itself to the need for basic research and had recommended that long-range planning for extended manned space flight and space exploration proceed concurrently with that for early manned space flight. Dr. Glennan accepted this advice. In the hectic months after the establishment of the Space Task Group, he took immediate steps to study the capabilities of space-oriented life-science research and to determine the future role of NASA in the bioscience field.

BIOMEDICAL PROBLEMS OF EXTENDED MANNED FLIGHT

The human factors involved in manned space flight are, according to Strughold, the province of space medicine. Space medicine per se is, he believes, "a logical extension of aviation medicine inasmuch as there are many interrelations between the two."¹ Since space medicine deals with the problems involved in astronautics, it is "by and large, identical with bioastronautics. . . ." Thus, space medicine includes the study of conditions on other celestial

bodies and their effect on explorers in terms of human physiology. It overlaps astrobiology, the study of the possibilities of indigenous life on other celestial bodies. The term "planetary ecology" covers both the medical and biological aspects.

Space medicine belongs in the category of industrial medicine, specifically environmental medicine. It involves the biophysics of the environment of space—the ecology of space; gravity and motions in space flight; classification and medical characterization of the various kinds of space operations; the space cabin; weightlessness as the outstanding novel environmental factor; and the medical aspects of the prospects and limitations of space flight.² In the area between space medicine and traditional aviation medicine, there are certain overlappings, such as the tolerability of high g-forces and rapid decompression.

Since the physiological effects of the space environment are the major concern of space medicine, efforts have been made to define the elusive term "space" as a physiological entity. In the early 1950's Strughold and his coworkers suggested that the atmosphere ceases and space begins at different altitudes for different physiological functions. This altitude was designated the region of *space equivalence*, or the *functional border of space*.³ While it is not the purpose of the present study to discuss the physiological problems facing man in space flight—which have been ably discussed elsewhere—they should be kept in mind by the reader, because in 1958 and in the year following the answers had not yet been found. Only actual flight into space could answer these questions.

The problems of biomedical support for the short-term Project Mercury flights were relatively simple, it was believed, and could be solved through existing technology which would provide adequate life systems for man's survival in orbital flight. This orbital path would lie below the Van Allen belt, so that radiation would pose no great problem. There were, however, other problems which would be involved both in the relatively limited Mercury mission and in extended missions.

The first of these was the problem of acceleration and weightlessness. On the basis of extrapolation from data on humans flown in Keplerian trajectories, animal experiments utilizing V-2 and Aerobee rockets, water-immersion experiments, and experiments involving sensory deprivation, it was anticipated that the principal difficulties would be in the central nervous system and organs of position sense. The chief consequences were believed

to be disorientation, hallucinations, and psychological adjustment failures, of which disorientation was the most difficult to assess.⁴ A second major problem was that of combined stresses including noise, launch, and reentry tolerance. The third was the problem of toxic hazards in the spacecraft. Fourth was the danger from ambient space radiations.⁵

These, then, were problems involving basic biological research and development, testing, and validation, as Project Mercury got underway.

NASA BIOSCIENCES REQUIREMENTS⁶

According to the report of the Committee on Aeronautical and Space Sciences, U.S. Senate, the advent of space exploration in late 1957 and the initiation of NASA's Project Mercury had "brought human problems associated with space exploration into sharp focus and thereby helped to delineate broad requirements for future activities in this area."⁷

Moreover, in interpreting the policy set forth in the National Aeronautics and Space Act of 1958, which states that "activities in space should be devoted to peaceful purposes for the benefit of all mankind," NASA had concluded that it had a twofold goal regarding the space-related aspects of biology, medicine, and psychology. The first was concerned with manned space flight and exploration, "necessitating provision of the essentials for survival in the space environment and the means which will allow effective human performance in flight and as a scientific observer." The second goal was to apply the results of studies in space environment toward further understanding of the fundamental laws of nature as they apply to biology and medicine. It was noted that the long leadtime required for necessary advances in biotechnology required continuing effort in a number of problem areas, "including man-machine integration, definition of tolerance to combined stresses, development of life support systems, radiation shielding, and provision of adequate escape and protective devices."⁸

Project Mercury, the report explained, was planned and was now being executed "as the first in a number of steps" toward manned space flight and exploration.

It was recognized [the report continued] that in order to accomplish at the earliest practicable date the assembling and testing of systems and subsystems required for successful manned orbital flight, problem areas such as reliability, tracking, communications, control, reentry, and recovery techniques had to be overcome. Research designed to acquire the basic medical

and behavioral information required to meet the physiological and psychological needs for long duration existence and effectiveness in stressful artificial environments necessitates augmentation of investigation in radiology, metabolism, cardiovascular physiology, respiratory physiology, neurophysiology, and psychology.⁹

These requirements for Project Mercury were, however, not all that was necessary. The report continued :

Basic biological studies at a cellular level—concerning the effects of space environments on living organisms and the search for extraterrestrial life—anticipate investigation of the molecular control of cellular activity and of comparative biology on the broadest possible scale. Exposure of living cells and tissues to a wide range of ionizing radiation, weightlessness, high vacuum, temperature extremes, and unusual combinations of elements to be found in remote planetary atmospheres and surfaces could lead to important scientific information.¹⁰

THE KETY COMMITTEE

On August 21, 1959, NASA announced the establishment of an ad hoc Bioscience Advisory Committee to study the capability in space-oriented life-science research and development, to outline the scope of current and future problem areas in the space bioscience field, and to recommend the future role of NASA in a bioscience program. Composed of leading scientists, this committee was under the chairmanship of Dr. Seymour S. Kety, Director of the Clinical Science Laboratory of the National Institutes of Health, and was generally referred to as the "Kety committee."¹¹ The other members were Dr. Wallace O. Fenn, Professor of Physiology, University of Rochester; Dr. David R. Goddard, Director of the Division of Biology, University of Pennsylvania; Dr. Donald G. Marquis, Professor of Psychology, Massachusetts Institute of Technology; Dr. Robert S. Morison, Director of Natural and Medical Sciences, the Rockefeller Foundation; and Dr. Cornelius A. Tobias, Professor of Medical Physics, University of California. Dr. Clark T. Randt of Western Reserve University served as secretary of the committee.

Since July the group had been in the process of organization to provide guidelines for the NASA bioscience advisory programs.¹² In this period the group had been informed of the status of existing aerospace medical facilities, programs, and personnel by representatives of the Army, Navy, and Air Force. Representatives of industry and universities also provided background information for the committee.

On January 25, 1960, the Kety committee submitted its report

to the NASA Administrator, whereupon it was dissolved.¹³ The report recommended that maximum integration of the personnel and facilities applicable to the space-oriented life sciences in the military services and other Government agencies "be arranged in the most appropriate manner indicated by the nature and extent of the specific problem at hand."¹⁴ Nevertheless, it was felt that the broad national space program should be the responsibility of the civilian agency NASA rather than the military. The Kety report stated the situation in these words:

It is altogether fitting that these matters, both of which involve man's curiosity about himself and his environment in their broadest and most fundamental sense, should be placed in the hands of an agency broadly representative of society as a whole. The military agencies which have so soundly laid the groundwork for much of existing space technology must properly give primary attention to the development of weapons systems and the national defense. Although the military effort in astronautics should not be arbitrarily restricted by narrow definitions of military relevance, the broader implications of extraterrestrial exploration demand the attention of an organization unhampered by such predetermined objectives.¹⁵

The Kety committee thus recognized the existing resources of the military services, certainly in terms of Project Mercury, but believed that over the long-term program of space exploration NASA should have its own in-house staff advisers. It was, the report continued, a matter of the NASA life-sciences facilities being considered "a public trust" in implementing national and international cooperative efforts.¹⁶

A national program in space science which does not recognize the essentiality of the human observer and does not plan to utilize him most effectively may wait indefinitely for the automatic devices to replace him or be limited to incomplete and opportunistic observations.

Putting a man into space, especially if he is to stay for long periods, is a task which involves considerable attention and effort from a wide variety of biological, psychological, and medical specialties. It will require careful planning and extensive basic and developmental research. Together with the effort in astrobiology it should constitute a substantial part of the total space research and development enterprise.¹⁷

Present and future needs were considered in three broad categories:

1. Basic biologic effects of extraterrestrial environments, with particular emphasis on those phenomena associated with weightlessness, ionizing radiation, and alterations in life rhythms or periodicity, as well as the identification of complex organic or other molecules in planetary atmospheres and surfaces which

might be precursors or evidence of extraterrestrial life.

2. Applied or technologic aspects of medicine and biology as they relate to manned space flight, including the effect of weightlessness on human performance, radiation hazards, tolerance or force stresses, and maintenance of life-sustaining artificial environment.

3. Medical and behavioral scientific problems concerned with more fundamental investigation of metabolism, nutrition, blood circulation, respiration, and the nervous system control of bodily functions and performance in space-equivalent situations.

In a section entitled "Relationship of the NASA Office of Life Sciences to Existing Programs in the Military Services," the Kety report stated that while the military medical services had been engaged in aeromedical studies since World War I and had substantial facilities and dedicated personnel, it appeared that "the military capability in aeromedicine is, at present, not fully utilized." The reasons given were several: Many of the biomedical problems of conventional high-altitude flight had been reasonably well solved; the military requirements for conventional aircraft were increasingly uncertain; there appeared to be a declining need for the use of existing aeromedical facilities for the training and indoctrination of conventional pilots; current military plans emphasized the use of unmanned ballistic missiles; and while "certain forward-looking elements at various points in the Military Establishment foresee a tactical need for manned vehicles in space," these weapons did not form a major part of current operational plans. Thus the military budgets for research were "not defended at present on the basis of a clearly defined existing military objective or requirement" but depended for the most part on the "declining momentum of the conventional aircraft program and the existence of a few experimental projects," of which the X-15 and the Dyna-Soar vehicle series were cited as examples.

On the other hand, the Kety report noted, "NASA, which does have a clearly defined mission to put and maintain men in space, has essentially no existing capability for studying the biological and medical problems involved." For Project Mercury, therefore, NASA had of necessity turned to the services which, in turn, had "responded with enthusiasm and good will to this new challenge." But, it was stressed:

In spite of the apparent success of the arrangement, the fact remains that authority for insuring the health, safety, and effective functioning of the astronauts is not firmly in the hands of the agency responsible for the suc-

cess of the project as a whole. The medical personnel were not selected by the NASA but by representatives of the military services which provided them on a loan basis for this particular task. Their continued presence in the project is as much a matter of continuing good will as it is a clear contractual agreement, and the individuals themselves must of necessity feel a primary loyalty to the services in which they have elected to develop their entire careers.¹⁸

Nevertheless, it appeared that for the "next few years, and possibly indefinitely," NASA would need to rely heavily on the military services "for help in the technology or applied aspects of aeromedicine."

There were problem areas here, the committee continued, because while the military services "presently appear to possess a capability in excess of their own need," the situation could change in terms of long-range plans; the "apparent excess" of space medical capability available in military establishments "may be temporary."

How far the present cordial cooperativeness of military personnel is dependent on this temporary excess is difficult to determine. . . . The present situation is at best an unstable one. Either of two things may happen. The military decision to rely heavily on unmanned ballistic or guided vehicles may become more firmly established. This will lead to a further decline in military requirements for aeromedicine with concomitant budget cuts for the support of aeromedical installations. Conversely, and in the opinion of the committee more probable, present skepticism in regard to the utility of manned military vehicles will gradually disappear and the services will be provided with increased funds for research in space medicine. In either case, the excess military capability now available to NASA is likely to decline if not completely disappear.¹⁹

To meet the NASA requirements, the Kety committee therefore made the following recommendations:

1. That NASA establish an Office of Life Sciences having the responsibility and authority for planning, organizing, and operating a life-sciences program including intramural and extramural research, development, and training.
2. That a Director of Life Sciences be appointed who would be directly responsible to the Administrator of NASA in the same manner and at the same directional level as the other program directors.
3. That the internal organization of the Office of Life Sciences include assistant directors of Basic Biology, Applied Medicine and Biology, Medical and Behavioral Sciences, and the Life Sciences extramural program.
4. That an intramural life-sciences program and facility be es-

established with three sections:

- (a) Basic biology
- (b) Applied medicine and biology
- (c) Medical and behavioral sciences

5. That the Director of Life Sciences recommend advisory committees made up of consultants outside of NASA to be appointed by the Administrator.

6. That maximum integration of the personnel and facilities applicable to the space-oriented life sciences in the military services and other Government agencies be arranged in the most appropriate manner indicated by the nature and extent of the scientific problems at hand.

7. That the Office of Life Sciences assume proper responsibility for education and training in the space-oriented life sciences through postgraduate fellowships, training grants to institutions, and short-term visiting scientist appointments to be integrated with other NASA efforts in this area.

8. That the NASA life-sciences program place special emphasis on the free exchange of scientific findings, information, and criticism among all scientists.

9. That the NASA life-sciences facilities be considered a public trust in implementing national and international cooperative efforts.

OFFICE OF LIFE SCIENCES ESTABLISHED: 1960

In line with the Kety committee recommendations, an Office of Life Sciences was established on March 1, 1960, with Clark T. Randt, M.D., a member of the Bioscience Advisory Committee, as Director.²⁰

The major programs in NASA concerned with biology, medicine, and psychology obviously were manned space exploration and biological investigations in the space environment. The Senate Committee on Aeronautical and Space Sciences had noted that in the first category was the current biomedical effort in Project Mercury. It had stated:

No change in the operation of Project Mercury is anticipated. . . . These biomedical activities include the development and testing of environmental control systems and personal equipment, a training program and simulator experience for the seven astronauts, development of instrumentation for physiological and environmental monitoring, and stress tolerance studies including a series of animal experiments in flight.²¹

Currently the biomedical personnel concerned with Project Mercury included four military medical doctors and one military psychologist, all on detached service with NASA. In addition, there were 28 engineers and 3 technicians concerned with life-support systems, instrumentation for physiological and environmental monitoring, animal programs for experiments in flight, and protective equipment and devices. This would form the foundation of the life-sciences effort. For the newly established Office of Life Sciences, a total personnel complement of 32 was contemplated, of whom 8 would be professional staff members. It was further contemplated that the number would eventually be 60. "The Office is now being organized," it was reported, "to carry out the staff functions necessary for planning future operations in manned space flight missions and biological investigations."²²

Meanwhile, the reaction of the press, and later of the Congress, to the August 1959 NASA announcement of the establishment of the Kety committee and the subsequent establishment of an Office of Life Sciences was one of frank appraisal. For example, on August 21, the date of the announcement, *The Evening Star* (Washington) reported: "The civilian space agency today took the first steps in the direction of participation in space medicine in its own behalf." The *Star* observed that there were those who discerned in the appointment of this committee "a move to abandon NASA's previously stated position that the agency would leave space medicine to the military services." Nevertheless, it conceded, the shift had been "considered probable, if not inevitable, for some time." Should a space medicine section be established in NASA it would, the *Star* continued, be the U.S. Government's third major effort in that field.²³ "Exactly how the problems to be encountered in space by civilians would differ from those of the military was not immediately apparent," the *Star* concluded.

During the next months, while Project Mercury was supported by military biomedical personnel, there was in Congress a careful consideration of the pattern that future biomedical support should take. Hearings held by both the House Subcommittee on Science and Astronautics and the Senate Committee on Aeronautical and Space Sciences touched upon this problem.²⁴

Questioned by Congressman Emilio Q. Daddario of Connecticut about the respective roles of NASA and the services in providing biomedical support for manned space exploration beyond Project Mercury, Dr. Glennan, the NASA Administrator, stated:

. . . if we are going to be concerned with the explorations of space, we are going to be concerned with the life sciences in space. . . . in the broad sweep of the life sciences, I think there isn't any question but someone has to do this and we believe that we can't duck that responsibility, sir.²⁵

Congressman Daddario observed that, in view of existing military laboratories, it would represent duplication and waste for NASA to build its own in-house capability. Dr. Dryden, the Deputy Administrator, responded as follows:

Let me try to clarify this, Mr. Daddario. They [the services] are concerned with what many of us call bioengineering, the engineering problems of getting a man in space. You are talking mainly about what is called bioscience, the underlying scientific work which is applied in the bioengineering. This is not something which the present staffs of these laboratories can do. . . .²⁶

The clarification of the ultimate role and mission of the services versus in-house biomedical capability was yet to come in the spring of 1960; the subject would continue to be of some concern to the Congress and to the Nation in the following months.

Meanwhile Dr. Randt, the new Director of the Office of Life Sciences, was in the process of clarifying the roles and mission of his office in relationship to Project Mercury. On June 20, 1960, the first planning conference on biomedical experiments in extra-terrestrial environments was held, with Dr. Randt presiding. In the course of the conference he delineated the relationship of his office with that of the Space Task Group and Project Mercury:

Project Mercury is an operational program that is far along. For this reason the Life Science Office is concerned with the follow-on to the Project Mercury. However, inasmuch as Project Mercury is a top priority project, we expect to supply whatever support we may be able to provide this project. This will largely be dependent upon the personnel that we attract to our office in the near future. We expect no change in the plans or the operation of Project Mercury.²⁷

This pattern was to be followed as Project Mercury progressed, although it is generally agreed that, at the top levels of management, there was not close rapport. This was inevitable in view of the fact that the Space Task Group, mission oriented and carrying out a Presidential directive to place a man in flight, had proceeded along the guideline that existing technology and off-the-shelf equipment would be used insofar as possible. The Office of Life Sciences, on the other hand, was geared not to the immediate problems of engineering and technology involved in early manned flight, but to the orderly development of a long-range space exploration program, of which Project Mercury was

but the first primitive step. The concern of the entire life-sciences community of the Nation, in the universities, in research institutions, and in industry, would be reflected in this office. Man was important both as traveler in space and as visitor upon other planets. Life itself, and not its instrument, technology, was the concern of the Office of Life Sciences. Within the broad mandate of the Space Act, the missions of Project Mercury and of the Office of Life Sciences were equally important.

At the moment, however, Project Mercury held top priority, as it had since that day in early October 1958 when it became the symbol of the most ambitious concerted peacetime research and development effort known to man.

NOTES TO CHAPTER IV

¹ Hubertus Strughold, "Space Medicine," ch. 31 in Harry G. Armstrong, *Aerospace Medicine* (Baltimore: Williams & Wilkins, 1961), p. 595.

² *Ibid.*, p. 596.

³ H. Strughold, H. Haber, K. Buettner, and F. Haber, "Where Does Space Begin?: Functional Concept of the Boundaries Between Atmosphere and Space," *J. Aviation Med.*, vol. 22, no. 5, Oct. 1951, pp. 342-349, 357; H. Strughold, "Atmospheric Space Equivalent," *J. Aviation Med.*, vol. 25, no. 4, Aug. 1954, pp. 420-424.

⁴ The literature in the field is voluminous. For the Project Mercury account, see J. P. Henry, W. S. Augerson, et al., "Effects of Weightlessness in Ballistic and Orbital Flight," *J. Aerospace Med.*, vol. 33, no. 9, Sept. 1962, pp. 1056-1068. See also, for example, (1) E. R. Ballinger, "Human Experiments in Subgravity and Prolonged Acceleration," *J. Aviation Med.*, vol. 23, no. 4, Aug. 1952, pp. 319-321, 372; (2) S. Bondurant, W. G. Blanchard, N. P. Clarke, and F. Moore, "Effect of Water Immersion on Human Tolerance to Forward and Backward Acceleration," *J. Aviation Med.*, vol. 29, no. 12, Dec. 1958, pp. 872-878; (3) E. L. Brown, "Zero Gravity Experiments," abstracted in *J. Aviation Med.*, vol. 30, no. 3, Mar. 1959, p. 177, under title "Research on Human Performance During Zero Gravity"; (4) P. A. Campbell and S. J. Gerathewohl, "The Present Status of the Problems of Weightlessness," *Texas State J. Med.*, vol. 55, no. 4, Apr. 1959, pp. 267-274; (5) B. Clark and A. Graybiel, "Human Performance During Adaptation to Stress in the Pensacola Slow Rotation Room," *Aerospace Med.*, vol. 32, no. 2, Feb. 1961, pp. 93-106; (6) O. Gauer and H. Haber, "Man Under Gravity-Free Conditions," in *German Aviation Medicine—World War II*, vol. I, ch. VI (Washington, D.C.: 1950), pp. 641-644; (7) S. J. Gerathewohl and H. D. Stallings, "Experiments During Weightlessness: A Study of the Oculo-Agravic Illusion," *J. Aviation Med.*, vol. 29, no. 7, July 1958, pp. 504-516; (8) D. E. Graveline and B. Balke, "The Physiologic Effects of Hypodynamics Induced by Water Immersion," USAF SAM Rep. No. 60-88, Sept. 1960; (9) A. Graybiel, F. E. Guedy, W. Johnson, and R. Kennedy, "Adaptation to Bizarre Stimulation of the Semi-Circular Canals as Indi-

cated by the Oculagyal Illusion," Rep. No. 53, USN School of Aviation Medicine, July 27, 1960; (10) H. J. Von Beckh, "Experiments With Animals and Human Subjects Under Sub and Zero-Gravity Conditions During the Dive and Parabolic Flight," *J. Aviation Med.*, vol. 25, no. 3, June 1954, pp. 235-241; (11) J. E. Ward, W. R. Hawkins, and H. D. Stallings, "Physiologic Responses to Subgravity—I. Mechanics of Nourishment and Deglutition of Solids and Liquids," *Aerospace Med.*, vol. 30, no. 6, June 1959, pp. 151-154; "Physiologic Responses to Subgravity—II. Initiation of Micturation," *Aerospace Med.*, vol. 30, no. 8, Aug. 1959, pp. 572-575; and (12) G. D. Whedon, J. E. Deitrick, and E. Shorr, "Modification of the Effects of Immobilization Upon Metabolic and Physiological Functions of Normal Men by Use of an Oscillating Bed," *Am. J. Med.*, vol. 6, no. 6, June 1949, pp. 684-711.

³ For discussion of these latter three topics, see, for example, Harry G. Armstrong, *Aerospace Medicine* (Baltimore: The Williams & Wilkins Co., 1961), particularly ch. I, Armstrong, "The Atmosphere"; ch. 13, Richard W. Bancroft, "Medical Aspects of Pressurized Equipment"; ch. 15, Armstrong, "Vertigo and Related States"; ch. 16, Ralph L. Christy, "Effects of Radial and Angular Accelerations"; ch. 17, John P. Stapp, "Effects of Linear Acceleration"; ch. 18, Horace O. Parrock, "Effects of Acoustic Energy"; ch. 19, Paul Webb, "Temperature Stresses"; ch. 22, Lawrence E. Lamb, "Cardiovascular Considerations"; and ch. 25, John E. Byson, "Toxicology in Aviation." See also Otis O. Benson, Jr., and Hubertus Strughold, eds., *Physics and Medicine of the Atmosphere and Space* (New York: John Wiley & Sons, Inc., 1960); Ursula T. Slager, *Space Medicine* (New York: Prentice-Hall, 1962); and M. P. Lansberg, *A Primer of Space Medicine* (Amsterdam: Elsevier Publishing Co., 1960). See also Charles H. Roadman, "Aerospace Medical Support of Manned Space Flight," *USAF Medical Services Digest*, vol. XIII, no. 9, Sept. 1962, pp. 2-9, 25.

⁴ This topic has not yet been treated in detail in a formal monograph.

⁷ *Space Research in the Life Sciences: An Inventory of Related Programs, Resources, and Facilities*, report of the Committee on Aeronautical and Space Sciences, U.S. Senate (86th Cong., 2d sess.), July 15, 1960, p. 25.

⁸ *Ibid.*

⁹ *Ibid.*, p. 26.

¹⁰ *Ibid.*

¹¹ *Ibid.*, p. 29.

¹² *Ibid.*

¹³ "Report of National Aeronautics and Space Administration Bioscience Advisory Committee, Jan. 25, 1960," generally referred to as the "Kety report" and published in *Space Research in the Life Sciences*, *op. cit.*, pp. 37-58.

¹⁴ *Ibid.*, p. 38.

¹⁵ *Ibid.*, p. 39.

¹⁶ *Ibid.*, p. 57.

¹⁷ *Ibid.*, pp. 40-41.

¹⁸ *Ibid.*, pp. 53-54.

¹⁹ *Ibid.*, pp. 54-55.

²⁰ NASA Release No. 60-135. Dr. Randt was an eminent neurologist who came to NASA from Western Reserve Univ.

²¹ *Space Research in the Life Sciences*, *op. cit.*, p. 27.

²² *Ibid.*

²³ *The Evening Star* (Washington) noted that the U.S. Air Force already had a "vast network of medical facilities interested in conditions in outer space," and the Navy had "ample facilities" for studying "closed system" conditions such as would be common to both submarines and spaceships. In addition to these two major capabilities, *The Star* continued, there was the small space medicine activity headed by Dr. Siegfried Gerathewohl at Redstone Arsenal in Huntsville, Ala.

²⁴ See, for example, *To Amend the National Aeronautics and Space Act of 1958 and NASA Authorization for Fiscal Year 1961—Part I*. See also *Hearings Before the Special Investigating Subcommittee on Science and Astronautics, U.S. House of Representatives* (86th Cong., 2d sess.), July 15 and 16, 1960.

²⁵ *Space Research in the Life Sciences, op. cit.*, p. 191.

²⁶ *Ibid.*

²⁷ *First Planning Conference on Biomedical Experiments in Extraterrestrial Environments* (held under the auspices of Office of Life Science Programs, NASA Hq., June 20, 1960), NASA TN D-781, 1961, p. 62. Meanwhile, as one step toward bringing about closer rapport between the Office of Life Sciences and the STG, James P. Nolan, an engineer graduated from MIT, was assigned as liaison officer to Dr. Randt's office in Washington, D.C.

CHAPTER V

Medical Aspects of Astronaut Selection and Training

SPECIFICALLY, THE DATE HAD BEEN October 8, 1958. On that date the Space Task Group was unofficially established at Langley Field, Va., where the NACA Langley Laboratory (now the NASA Langley Research Center) had been located since 1917. Robert R. Gilruth, who had headed the former NACA Pilotless Aircraft Research Laboratory at Wallops Island, Va., was named Project Manager, and Charles J. Donlan, Technical Assistant to the Director of the Langley Laboratory, was made Assistant Project Manager. Thirty-five key staff members of the Langley Laboratory, who had worked closely with the Wright-Patterson Laboratory personnel on the Man-in-Space plan, were transferred to the new Space Task Group, as were 10 other persons from Lewis Research Center, Ohio. These 45 persons were to form the nucleus of the work force for the manned satellite program with headquarters at Langley. On November 14 the highest national priority procurement rating was requested for the manned spacecraft project (although it was not granted until April 27, 1959). On the 26th, the manned satellite program was officially designated "Project Mercury."¹

Between Washington and Space Task Group headquarters at Langley—an hour's flight by small plane—there was now an almost hourly exchange of information as plans began to crystallize. It was a period of test to determine whether national leadership and the democratic system could pursue such a vast undertaking without the impetus of a threat to national survival.

Of immediate concern was the type of individual who would function most effectively as an astronaut. What should be his professional qualifications? His training and experience? By what physical and mental criteria should he be judged? Who should determine his physical fitness? These problems would re-

quire the attention of both engineering and medical professions in the Space Task Group.²

CRITERIA FOR SELECTION

The aeromedical team composed of Drs. White, Augerson, and Voas, together with other representatives from the Space Task Group, NASA Headquarters, and the Special Committee on Life Sciences described in chapter I, were now to evolve a crew-selection procedure.³ This group was to labor almost around the clock during the next few weeks as plans were made, modified, and finally accepted. Among the group was Dr. Allen O. Gamble, a psychologist from NASA Headquarters, who later described the initial planning as including first a "duties analysis" of what was expected of the astronaut.⁴

As finally decided, his duties were:

1. To survive; that is, to demonstrate the ability of man to fly in space and to return safely
2. To perform; that is, to demonstrate man's capacity to act usefully under conditions of space flight
3. To serve as a backup for the automatic controls and instrumentation; that is, to add reliability to the system
4. To serve as a scientific observer; that is, to go beyond what instruments and satellites can observe and report
5. To serve as an engineering observer and, acting as a true test pilot, to improve the flight system and its components⁵

The next step was to determine qualification requirements. These included environmental stress capacity, toughness, and resilience; motor skill; perceptual skill; age maximum of 35, changed later to 39 because too few men could meet the other qualifications if the age were too low; education (an engineering or scientific degree because of the technical job to be accomplished); and a height no greater than 5 feet 11 inches, because of the limited dimensions of the capsule.

Space Task Group personnel then explored categories of professions to determine which could furnish individuals best qualified to serve as astronauts. While a courier was carrying from Langley to Washington a set of plans for one particular category, a senior staff member from NASA Headquarters might be on the phone suggesting yet another category. All told, the categories considered were aircraft pilots, balloonists, submariners, deep-sea divers (particularly scuba divers who used underwater breathing

apparatus), mountain climbers, Arctic and Antarctic explorers, flight surgeons, and scientists including physicists, astronomers, and meteorologists. It was finally decided that test pilots were the most appropriate group from which to choose. An important factor was their demonstrated capability of meeting threatening situations in the air with accurate judgment, quick decisions, and motor skill.

By December 3 the team had drawn up a set of proposed Civil Service standards, and on that day the Director of Personnel for NASA, Robert J. Lacklen, requested authority from the U.S. Civil Service Commission to appoint "40 scientific specialists who will be engaged in special research activities for the Space Task Group" It was noted that there were compelling reasons why information concerning these men would be restricted and therefore they could not be recruited by open competitive examination.⁵

It was contemplated that representatives from the services and industry would nominate 150 men by January 21, 1959, from which 36 would be selected for further testing. These tests would reduce the number to 12, and by the end of a 9-month training period a hard core of 6 men would remain. The next day the U.S. Civil Service Commission approved the request, and on December 9 the notice was published in the *Federal Register*.⁷ By the end of the month, however, this plan had been rejected. It had been decided at the White House level that military test pilots only would be used.⁸

Meanwhile, the Space Task Group was faced with the problem of determining the most appropriate facility to conduct medical examinations of the astronauts. The staff members involved in making this decision, according to Dr. White, were Gilruth, Donlan, George Low, Warren North, Dr. Voas, Dr. Augerson, and himself. As they developed their plans, they kept the Special Committee on Life Sciences informed of their day-to-day progress.

Initial planning favored selection of a facility in the Washington area, with top consideration being given to three Federal institutions: The National Institutes of Health, the Army's Walter Reed Medical Center, and the Bethesda Naval Hospital. As planning progressed, however, STG redirected its thinking toward the choice of a non-Government facility with a national reputation. This seemed particularly desirable after the White House decided in December that only military pilots could qualify as astronauts. Since they would be volunteering, it was believed

only fair that the results of the stringent medical examinations be known only to NASA. Thus the military careers of unsuccessful candidates would not be jeopardized if some anomaly were discovered.

EVALUATION OF POTENTIAL CANDIDATES

The decision to utilize only military test pilots proved to be a sound one. According to Dr. Gamble:

They were a good, solid group, largely preselected, and preexperienced. And also, their records were available in Washington for preliminary screening, which was not true of industry, or civilian test pilots. Furthermore, they had, most of them, graduated from the military test pilot schools where there are high standards for entrance and even higher requirements for graduation. And their job is very nearly similar to that of an astronaut during the first flights. Furthermore, they were familiar with the full-pressure suits and complex cockpits. And we had one thought that perhaps many of you might not have considered; they would then be a homogeneous team, including their wives.⁹

The decision having been reached to utilize only military personnel, the selection committee added two requirements. The candidates must have been graduated from a test pilot school and they must have had at least 1,500 flying hours and be fully qualified in top-performance jet aircraft.

By January 1959 the selection committee was ready to review records of possible candidates, including all test pilots on active duty. This work was done by the "Phase I" group, whose names are indicated in the following paragraphs. Full cooperation was given by military officials in this work, which required several weeks. More than 500 names were selected for further consideration, including over 200 Air Force test pilots and 200 Navy pilots, 23 Marine pilots, and 40 Army pilots. NASA announced on January 28, 1959, that 110 had met all the basic requirements.¹⁰

On Monday, February 2, 1959, 69 reported to Washington under special military orders. On that day and the following Monday, they attended briefings that included a detailed technical explanation of the problems involved. Later in the day they came back for individual interviews during which they were asked to volunteer or decline. No record was kept on those who declined.¹¹

There were several types of measurement for those who volunteered. First was a joint technical interview by Charles J. Donlan, Assistant Director of Project Mercury (an engineer); Warren North of the Space Flight Program (a former test pilot); and

Dr. Gamble, the Manpower Evaluation Development Officer (an industrial psychologist). During these sessions further technical details of Project Mercury were made available to the candidates, including engineering drawings and specifications, and the individual pilots were encouraged to inquire in depth in areas of their interest. This yielded valuable clues concerning motivations and technical backgrounds.

The second test was a psychiatric evaluation by two psychiatrists who were Air Force officers, Dr. George E. Ruff and Dr. Edwin Z. Levy. Each recorded his independent conclusions; they compared notes, and then they reported to the committee. The third test was a detailed review of the medical records and a medical interview by the flight surgeon, Dr. Augerson. In addition, Dr. Voas gave the candidates a battery of written tests including the Miller Analogies Test (a graduate-school-level test), the Minnesota Engineering Analogies Test, and the Doppelt Mathematical Reasoning Test. Others who helped conduct Phase I were Dr. White, Dr. William F. O'Connor, and Dr. David K. Trites, a Navy officer.

Thirty-two pilots were chosen for Phase II, which was to be carried out at the Lovelace Clinic, Albuquerque, N. Mex. Factors in the choice of this facility were the work it was doing for the USAF Air Research and Development Command (later Systems Command) on selection techniques for the Man-in-Space program and the fact that it had recently completed development of machine cards for recording all medical and related information from the Lovelace Foundation and Clinic and from the Aero-Medical Laboratory stress and related tests at Wright-Patterson AFB.

MEDICAL TESTING

The physical evaluation program was thus carried out for NASA by the Lovelace Clinic in Albuquerque, N. Mex. The 32 volunteers were divided into 5 groups of 6 men each and 1 group of 2. This was the rate at which they could be handled by the clinic and by the Wright-Patterson Laboratory. One group at a time reported for an exhaustive series of examinations while the other men remained at their home stations. The first group entered the Lovelace Clinic on February 7, 1959, and the others entered on succeeding Saturdays. Each candidate spent 7½ days and 3 evenings at the Lovelace facility.

The Senate report that described Project Mercury in detail

noted that since all those examined were active test pilots, it was not anticipated that any would be disqualified as physically unfit. "Rather," it was explained, "degrees of physical soundness were obtained and evaluation was dependent upon a comparison of each man to his fellow candidates."¹²

The comprehensive program of examination and evaluation procedures for determination of the physical, mental, and social well-being of the candidates was under the direction of Dr. A. H. Schwichtenberg, a retired general officer in the Air Force, who had joined the Lovelace Foundation as head of the Department of Aerospace Medicine. So as to establish a comparative yardstick, the following program was carried out:

1. History, aviation and medical
2. Physical examination
3. Laboratory tests
4. Radiographic examinations
5. Physical competence and ventilatory efficiency tests
6. Final evaluation

The routine clinical examinations were given under normal conditions with the subject resting. Special consultations were provided as necessary. The clinical examination is described below.¹³

The medical history of each astronaut was taken by Dr. Schwichtenberg and his staff. This included a conventional medical history together with a family history; the attitude of the immediate family toward hazardous flying; the subject's growth, development, and education; recent travels to areas where parasite diseases are endemic; and any disorders precluding pressure inflation of the ears, sinuses, or lungs. The Cornell Medical Index Health questionnaire was used.

The aviation history included information about the pilot's total flying hours in various aircraft and about military experience in peace and wartime including details of combat missions, accidents, bailouts, use of the ejection seat, explosive decompressions, and altitude indoctrination and operational experience with partial- or full-pressure suits.

The physical examinations were made by an internist and flight surgeon, Dr. R. R. Secrest. The candidates were also examined by an ophthalmologist, Dr. E. H. Wood; an otolaryngologist, either Dr. H. W. Meredith or Dr. D. E. Kilgore, Jr.; a cardiologist, Dr. J. K. Conrad; a neurologist, Dr. B. T. Selving; and a surgeon, Dr. W. R. Lovelace II or Dr. A. McKinnon, Jr.

At the Lovelace Clinic, the medical selection process was long and comprehensive. At right, Astronaut Candidate John Glenn undergoes a modified caloric test to check on his balance mechanism. Cool water is run into the ear and the effect on eye motions (nyctagmus) is measured.



The eye examination included refraction, visual fields, extra-ocular muscle balance, red lens test, tonometry, depth perception, slit lamp, dark adaptation, and dynamic visual acuity. Finally, a color photograph of the conjunctival and retinal vessels was made. The otolaryngological tests included visual inspection, indirect laryngoscopy and nasopharyngoscopy, audiometric thresholds, speech discrimination, and labyrinth function by the standard caloric method.

Examination by a cardiologist included electrocardiograms and ballistocardiograms. A tilt-table test was done, in conjunction with the physiology section, to acquire information on the stability of the pressor-reflex mechanisms and the effectiveness of vasomotor control by the autonomic nervous system. (This test also may help in the detection of relative coronary insufficiency from electrocardiographic changes.) The Lee and Gimlette procedure was employed by an expert to detect congenital abnormal openings between the right and left sides of the heart.

The neurological examination included testing the reflexes and coordination, determining the normalcy of cerebellar function, and determining proprioception and other senses. Dr. L. D. Amick ascertained the conduction velocity of the right ulnar nerve between the elbow and the wrist. An electroencephalogram was done, including a determination of the effects of hyperventilation.

Additional examinations were made by specialists where indicated. Proctosigmoidoscopy was performed by a surgeon.

Laboratory tests under the direction of Drs. T. L. Chiffelle and P. V. Van Schoonhoven included complete blood count and special hematology smear, hemoglobin, hematocrit, sedimentation rate, fasting blood sugar, cholesterol, blood grouping, sodium, potassium, carbon dioxide, chloride, urea clearance in blood and urine, blood urea nitrogen, catecholamine, protein-bound iodine, protein electrophoresis, blood volume (Sjöstrand's carbon monoxide method), total body water determination by the tritium dilution method of Pinson and Langham (tracer dose of 1.5 millicuries of tritiated water used), bromsulphalein-dye liver function test, gastric analysis, urine analysis including colorimetric determination of 17-ketosteroids, throat cultures, stool examination, and sperm count. The amount of potassium 40 was determined in the whole body counter at Los Alamos by Langham and Anderson. The results of the laboratory tests in consolidated form are shown in table I.

TABLE I.—Laboratory Tests¹⁴

Test	Astronaut candidates (31)		Astronauts selected (7)	
	Mean	Range	Mean	Range
*Hemoglobin, gm/100 ml...	16.0	14.5-17.9	16.6	14.5-16.2
Total circ. hemoglobin, gm...	756.5	565-1,127	857.2	674-1,120
*Leukocytes, 1,000/mm ³ ...	8.1	4.7-15.3	7.7	5.0-10.0
*Sedimentation rate, mm/hr.....	5	0-32	4	2-6
*Cholesterol, mg/ml.....	225	150-320	238	184-280
*Sodium, meq/l.....	142	139-147	143	141-144
*Potassium, meq/l.....	4.6	3.4-5.5	4.7	4.0-5.5
*Chlorine, meq/l.....	105	103-110	10.5	103-108
*Carbon dioxide, meq/l.....	26	22-30	26	23-30
*Sugar, mg/100 ml.....	102	84-112	100	88-108
*Protein bound iodine, µgm/100 ml.....	5.8	4.2-10.4	5.5	4.9-6
*Bromsulphalein, % reten- tion (45 min).....	3	0-7	3	2-4
17-ketogenic steroids, mg/24 hr.....	19.1	8.8-29	18.3	11.1-23
17-ketosteroids, mg/24 hr..	13.7	8-22.6	13.3	9.9-17.5

*Fasting specimen.

In the radiographic examinations, appreciable reduction in radiation exposure was accomplished by the use of supersensitive intensifying screens and shielding plus the use of ultrafast X-ray film. Under the direction of Dr. J. W. Grossman, roentgenograms were made of the teeth, the sinuses, the thorax posteriorly-anteriorly in inspiration and expiration, and right laterally (searching especially for bullae), the esophagus, the stomach, the colon, and the lumbosacral spine, and cineradiograms were made of the heart (searching for preclinical evidence of arteriosclerosis).

Physical competence tests were administered by Dr. U. C. Luft to provide an estimate of the candidate's general physical condition and cardiopulmonary competence. Graded work was done on v. Döbeln's bicycle ergometer, increasing the load from 300 mkg/min to around 1,200 mkg/min under electrocardiographic monitoring for possible abnormalities at maximum effort. The test proceeded until the heart rate reached 180 beats/min or until signs of approaching overload were evident. The heart rate, blood pressure, respiratory volume, and respiratory gas exchange were measured each minute. The oxygen consumption attained during the highest workload was the criterion of aerobic work capacity. Each individual was rated with regard to standard values based on age, height, and weight.

Measurements were made of the total lung capacity and its various subdivisions by direct and indirect spirometry, and the efficiency of ventilation was determined by continuous recording of the dilution of nitrogen while the subject breathed 100 percent oxygen. The timed vital capacity, maximal breathing capacity, and ventilatory response to light exercise (walking at 2 mph for 3 minutes) were determined. With these tests it was possible to detect any restrictive or obstructive impairment and to estimate the efficiency of breathing at rest and during mild exercise.

Density of the body was determined by weighing the nude body in water after maximal inspiration followed by exhalation of a measured amount of air. There was close correlation between the lean body mass calculated from the above results and from the K^{40} determinations.

A summary of the pertinent physiologic data is given in table II.

A final evaluation of each candidate in terms of physical, mental, and social well-being was made at the conclusion of the week-long examinations. The evaluation board was composed of the examining flight surgeons and a physiologist, all with extensive high-

TABLE II.—Physiologic Data¹⁵

Test	Astronaut candidates (31)		Astronauts selected (7)	
	Mean	Range	Mean	Range
Height, cm.....	176	167-180	177	170-180
Weight, kg.....	73.4	61-87	75.3	70-87
Body surface area, m ²	1.9	1.7-2.1	1.9	1.8-2.1
Lean body mass, kg.....	63.9	55-71	66.8	59-71
Total body potassium, gm.....	168.6	142-204	175.4	167-199
Total body water, liters.....	41.3	36-47	41.5	37-45
Blood volume, liters.....	4.92	3.33-6.91	5.40	4.35-6.91
Total circ. hemoglobin, gm.....	756.5	565-1,127	857.2	674-1,120
Total lung capacity, liters.....	6.82	5.36-8.19	7.02	6.34-8.02
Functional residual capacity, liters.....	3.22	2.25-4.23	3.41	2.96-4.23
Vital capacity, liters.....	5.49	4.35-6.91	5.54	5.11-6.02
Residual volume, liters.....	1.32	0.83-2.00	1.48	1.13-2.00
Maximum breathing capacity, liters.....	180	149-247	191	156-247
Nitrogen clearance equivalent.....	11.1	9.3-13.0	10.9	9.2-12.0
Final O ₂ uptake during exercise, l/min.....	2.41	1.90-2.84	2.60	2.07-2.84

altitude and operational experience. A summary of the findings was prepared and, together with a copy of the machine record cards, was forwarded to the Aerospace Medical Laboratory at Wright-Patterson Air Force Base.¹⁶

STRESS TESTING¹⁷

The Air Force Research and Development Command (later the Air Force Systems Command) provided the next part of the program for selection of the astronauts for Project Mercury. Brig. Gen. Don Flickinger, Command Surgeon and also a member of the NASA Special Committee on Life Sciences, worked closely with the Space Task Group to provide the general direction of this phase of the astronaut selection program. Begun on February 16, 1959, and completed on March 27, 1959, this testing for NASA was performed under Project No. 7164, "Physiology of Flight," and Task No. 71832, "Physiological Criteria for Extended Environments."

Colonel Stapp, USAF (MC), was at that time chief of the Aero Medical Laboratory at Wright Air Development Center (redesignated the Aerospace Medical Laboratory later that year, on August 1). Supervising the tests under his direction were Lt. Col. William R. Turner, USAF (MC), chairman of the Candidate Evaluation Committee, and Capt. Charles L. Wilson, USAF (MC), Candidate Evaluation Program task officer. The following personnel participated in this program: 1. *Acceleration tests*—Capt. Evan F. Lindberg, USAF (MC), Principal Investigator; Capt. Alvin S. Hyde, USAF (MC); Capt. Neil Cherniack, USAF (MC); 1st Lt. Lawrence M. Berman, USAF; Mrs. Julia Pettitt; 2. *Anthropological measurements*—Charles E. Clauser, Principal Investigator; Capt. Robert S. Ziegen, USAF; Kenneth W. Kennedy; 3. *Biological acoustical tests*—Capt. Ronald G. Hansen, USAF, Principal Investigator; Maj. Jack E. Steele, USAF (MC); Donald J. Baker; Dr. Rolf R. Coermann; Capt. Edward B. Magid, USAF (MC); 4. *Thermal tests*—Capt. Joseph Gold, USAF (MC), Principal Investigator; Johannes W. Polte; 5. *Physical fitness tests*—Capt. Charles L. Wilson, USAF (MC), Principal Investigator; Capt. Edmund B. Weis, Jr., USAF (MC); S/Sgt. Joseph Young, USAF; 6. *Psychological tests*—Capt. George E. Ruff, USAF (MC), Principal Investigator; Capt. Victor H. Thaler, USAF; Dr. Mildred B. Mitchell; Capt. Edwin Z. Levy, USAF (MC); Capt. John K. Jackson, USAF; 1st Lt. Gilbert E. Johnson, USAF.

Having completed their examinations at the Lovelace Foundation on a Saturday morning, the 32 candidates, carrying with them their complete records, departed for Dayton, Ohio, arriving near midnight. After being billeted in a single house, they reported at 10 o'clock the following morning for a briefing by the laboratory coordinator, the administrative assistant, the task officer, the investigator from the Physical Fitness Test Unit, and an investigator from the Psychology Test Unit.

The tests to be administered had been devised to determine the candidate's psychological makeup and to estimate his ability to cope with stresses. As reported in WADC Technical Report 59-505, the examinations were in the following areas, with data recorded on machine record cards:

1. Psychiatric evaluation, psychological testing, anthropometric studies

2. Stress tolerance determinations from thermal flux, acceleration forces, low barometric pressures, pressure-suit protection,

isolation, and confinement

3. Final clinical appraisal of suitability

Specific stress tests were as follows:

1. *Harvard step test*: Subject steps up 20 inches to a platform and down once every 2 seconds for 5 minutes to measure his physical fitness.

2. *Treadmill maximum workload*: Subject walks at a constant rate on a moving platform which is elevated 1° each minute. Test continues until heart reaches 180 beats per minute. Test of physical fitness.

3. *Cold pressor*: Subject plunges his feet into a tub of ice water. Pulse and blood pressure are measured before and during test.

4. *Complex behavior simulator*: A panel with 12 signals, each requiring a different response, measures ability to react reliably in confusing situations.

5. *Tilt table*: Subject lies on steeply inclined table for 25 minutes to measure ability of the heart to compensate for an unusual position of the body for an extended time.

6. *Partial pressure suit*: Subject is taken to simulated altitude of 65,000 feet for 1 hour in an MC-1 partial pressure suit. Measure of efficiency of heart systems and breathing at low ambient pressures.

7. *Isolation*: Subject goes into a dark, soundproof room for 3 hours to determine his ability to adapt to unusual circumstances and to cope with the absence of external stimuli.

8. *Acceleration*: Subject is placed in a centrifuge with the seat inclined at various angles to measure his ability to withstand multiple gravity forces.

9. *Heat*: Subject spends 2 hours in a chamber with the temperature at 130° F. Reactions of heart and body functions to this stress are measured.

10. *Equilibrium and vibration*: Subject is seated on chair which rotates simultaneously on two axes. He is required to maintain the chair on an even keel by means of a control stick with and without vibration. The subject is tested both with and without a blindfold.

11. *Noise*: Subject is exposed to a variety of sound frequencies to determine his susceptibility to tones of high frequency.

The psychological tests administered at WADC had two objectives: To determine personality and motivation, and to determine intelligence and special aptitudes. The first was accomplished through the following: Interviews, Rorschach (ink blot), themat-

Astronaut selection continued with stress testing at Wright - Patterson AFB, Ohio, after the clinical tests at the Lovelace Clinic. In the well-equipped Air Force laboratories, Astronaut Candidate Carpenter underwent a physical fitness test on the treadmill (right), Slayton experienced the isolation test (below, left), and Grissom (below, right) took a ride in the equilibrium chair.



ic apperception (the stories suggested by pictures), draw-a-person, sentence completion, self-inventory based on 566-item questionnaire, officer effectiveness inventory, personal-preference schedule based on 225 pairs of self-descriptive statements, preference evaluation based on 52 statements, determination of authoritarian attitudes, peer ratings, and interpretation of the question, Who am I? The second objective was accomplished through administration of the Wechsler Adult Scale, Miller Analogies, Raven Progressive Matrices, Doppelt Mathematical Reasoning Scale, engineering analogies, mechanical comprehension, Air Force Officer Qualification Test, Aviation qualification test (USN), space memory, spatial orientation, Gottschaldt Hidden Figures, and Guilford-Zimmerman Spatial Visualization.

Unless the candidates so wished, none of the medical, psychological, or performance records were included in their personal records. The reason for this exclusion of Project Mercury records from Department of Defense pilot medical records was "to guarantee that any episode of syncope (which might occur, for example, on the human centrifuge, the MC-1 test, or the Tilt Table test) would not be a threat to the pilot's flying status."¹⁸

It was noted in WADC Technical Report 59-505 that since the beginning, in 1952, of the U.S. Air Force program relating to man in space, ARDC had envisioned a program to be used in selecting crew members for future projects which, ideally, would include these characteristics:

1. Individuals must be medically acceptable and technically capable before they are considered as potential candidates.
2. Those tested must be actual project candidates.
3. The test profile must simulate all aspects of the stresses anticipated during the actual project, and these stresses must be combined in the same relationship and intensity as would occur during a project.
4. A battery of nonsimulating but relevant tests must be included in the testing program.
5. In the final recommendation of candidates, the investigators must interpret subject performance on the simulating tests only.
6. All candidates must enter the project.
7. Upon completion of project, all participants must be graded on effectiveness of their performance.
8. Investigators must then seek significant correlation between subject performances on various simulating and nonsimulating tests and successful mission performance.



The seven military test pilots finally selected as the Project Mercury astronauts: left to right, Lt. Malcolm S. Carpenter (USN); Capt. Leroy G. Cooper, Jr. (USAF); Lt. Col. John H. Glenn, Jr. (USMC); Capt. Virgil I. Grissom (USAF); Lt. Comdr. Walter M. Schirra, Jr. (USN); Lt. Comdr. Alan B. Shepard, Jr. (USN); and Capt. Donald K. Slayton (USAF).

9. Nonsimulating tests bearing significant correlation with successful mission performances may then be used in selection of future subjects from an identical population for identical projects.

The Project Mercury candidate evaluation program was necessarily based upon factors which contributed toward making it less than the ideal program envisioned, the report continued, because of such factors as time limitations, accelerated schedules, and unforeseen changes.

FINAL EVALUATION

For the final selection of astronauts, representatives met at NASA's Langley Research Center, Va. Included were representatives of both medical and technical fields from NASA, the USAF Aerospace Medical Laboratory, and the Lovelace Foundation.

On April 2, 1959, NASA announced that seven astronauts had been chosen for Project Mercury. They were: Lt. Malcolm S. Carpenter, USN; Capt. Leroy G. Cooper, Jr., USAF; Lt. Col.

John H. Glenn, USMC; Capt. Virgil I. Grissom, USAF; Lt. Comdr. Walter M. Schirra, Jr., USN; Lt. Comdr. Alan B. Shepard, Jr., USN; and Capt. Donald K. Slayton, USAF.¹⁹ Within the next 24 months these names were to become household words throughout the world—names that symbolized the dreams and hopes of mankind throughout the free world that space would truly be explored for the benefit of all mankind.

According to the Lovelace report :

The seven ultimately selected were chosen because of their exceptional resistance to mental, physical, and psychological stresses, and because of the particular scientific discipline or specialty each presented. . . . Their average age was 34.1, with ages ranging from 32 to 37. All of these men were married.²⁰

Senate Report 1014 gave substantially the same information :

Data from the Lovelace and WADC examinations were compiled and forwarded to the NASA Langley space flight activity, for the fourth and final step in the selection process. At Langley, a group representing both the medical and technical fields evaluated the previous examinations. The seven ultimately selected were chosen as a result of physical, psychological and stress tolerance abilities and because of the technical experience each represents.²¹

THE ASTRONAUT MEDICAL PROGRAM

There were to be five main objectives for continuing the medical phase of the astronaut program. These were :

1. Constant and continuing medical observation which required the assignment of a flight surgeon to this particular responsibility
2. Continuing observations on intangible problems such as morale and motivation
3. Periodic, more intensive, medical evaluation to insure a continuing good state of general health
4. Reevaluation of all physiological and psychological testing procedures on which selection was based to insure continuing high-caliber performance
5. Continuing evaluation of the entire program in relation to the physiological and psychological demands to be placed on the individuals and correlation with their demonstrated qualities.²²

MEDICAL ASPECTS OF TRAINING

On April 27, 1959, Project Mercury was assigned the highest national priority. Two weeks later, on May 12, NASA announced a training program for the seven astronauts "to provide them with

the technical knowledge to pilot the nation's manned orbital capsule." By the end of the year the training of the new astronauts was well underway. It had included, among other activities, a visit to Wright Air Development Center for general pressure-suit indoctrination and for a 3-day check of low-residue diets. It included, too, a visit to the Naval Medical Research Institute at Bethesda, Md., for (1) a determination of basal metabolic rate, cutaneous blood flow rate, and sweat rate at environmental temperatures of 95° F and 114° F, and (2) familiarization with the effects of excessive carbon dioxide.

Skindiving training was carried out at the Navy's Little Creek Amphibious Base to simulate the weightless state and to maintain physical fitness of the astronauts. Acceleration studies with centrifuges were accomplished at Johnsville, Pa. There were fittings for pressure suits at the contractor's (Goodrich) plant, and trips to Cape Canaveral and to Edwards Air Force Base (for briefings on the X-15 research airplane). Future training would include, among other things, survival techniques, disorientation and communications training at Pensacola, Fla., and flights for practice in eating and drinking in the weightless state.²³ Certain phases of the training are discussed in greater detail in subsequent chapters of the present study.

Meanwhile, on April 1, 1959, Dr. William K. Douglas, an Air Force career officer holding the rank of lieutenant colonel, was detailed for duty as the personal physician for the astronauts.²⁴ A flight surgeon, he had been on duty with the Office of the Surgeon General, USAF. He was to serve as the astronaut's physician through the next 3 years—the normal tour of duty for an Air Force officer—at which time he would be reassigned to Patrick Air Force Base for duty in the Office of the Assistant for Bioastronautics, Air Force Missile Test Center. At that time he would be succeeded by Dr. Howard Minnows, a civilian physician; but now, in April 1959, Dr. Douglas was to begin a 3-year tour of duty unique in the annals of medical history. His daily pattern of life would simulate that of the seven astronauts; many of the tests would also be taken by him; he was, in a very true sense of the word, the eighth astronaut.

Through the next high-keyed months that were a prelude to the first suborbital manned flight in May 1961, the seven astronauts were to embark upon a compressed training schedule that required every ounce of their energy and dedication. This training program was divided into six areas: (1) Vehicle operations

Once chosen, the seven Mercury astronauts quickly became occupied with an intensive training and conditioning program. Two of the many phases are shown here. At right, in the Gulf of Mexico off the U.S. Navy School of Aviation Medicine, Pensacola, Fla., Astronaut Grissom practices egress from the narrow neck of a Mercury cabin.



Some weeks later the astronauts (center) found themselves in the bleak desert country near Stead AFB, Nev., undergoing the USAF Survival School. Each astronaut was taken out into the desert and left for 4 days with a mockup of a Mercury spacecraft, a parachute, and a set of survival problems. At bottom, Astronaut Shepard is in his parachute-tent and attempts to carve some homemade sandals.



during launch, orbit, and reentry; (2) management of the on-board systems; (3) vehicle attitude control; (4) navigation; (5) communications; and (6) research and evaluation.²⁵

From the medical viewpoint, this training program involved responsibility by the Space Task Group for monitoring and controlling the exposure of the individual astronaut to acceleration, weightlessness, heat, vibration, noise, and disorientation. These were medical problems that would be of concern to Dr. White and his aeromedical group, which now formed part of the Life Systems Division within STG, and particularly to Dr. Douglas. Moreover, the astronaut must prepare himself personally for the stresses he would encounter, and to this end each one undertook a physical fitness program tailored to his own needs. The physical fitness of the astronauts was also a primary concern of their personal physician.

NOTES TO CHAPTER V

¹ James M. Grimwood, *Project Mercury: A Chronology*, NASA SP-4001, 1963, pp. 31-32.

² *Project Mercury: Man-in-Space Program of the NASA*, S. Rept. 1014, 86th Cong., 1st sess., Dec. 1959, p. 6. See also W. Randolph Lovelace II, A. H. Schwichtenberg, Ulrich C. Luft, and Robert R. Secrest, "Selection and Maintenance Program for Astronauts for the National Aeronautics and Space Administration," *Aerospace Med.*, vol. 33, no. 6, June 1962, pp. 667-684.

³ Paul E. Purser, Spec. Asst. to Dir., Project Mercury, Memo for Files, Subj.: General Background Material on Project Mercury, Mar. 23, 1959. This memorandum places the date of official assignment as Nov. 3, 1958.

⁴ Personal interviews with Dr. Allen O. Gamble, 1961-63.

⁵ Allen O. Gamble, "The Astronauts and Project Mercury," a lecture delivered on Apr. 24, 1961, during the Space Education Inst., Mar. 6-May 8, sponsored jointly by the Univ. of Maryland and the Martin Co. in cooperation with the Maryland Sec., American Rocket Soc. See also "Operations Part of the Mercury Technical History," an undated draft copy prepared by Robert Voas, in MSC archives.

⁶ Robert J. Lacklen, Director of Personnel, NASA, Ltr to U.S. Civil Service Commission, Dec. 3, 1958.

⁷ *Federal Register*, vol. 23, no. 239, Dec. 9, 1958, pp. 95-103.

⁸ White House statement, cited by Dr. Gamble. See also Grimwood, *op. cit.*, p. 33.

⁹ See note 5.

¹⁰ *Ibid.* Also personal discussions with Drs. Voas and Gamble by the author.

¹¹ According to Dr. Gamble, advance estimates by the Committee had been that the rate of volunteers would range from 5 to 50 percent. Actually it was more than 75 percent ("The Astronauts and Project Mercury," *op. cit.*).

¹² *Project Mercury: Man-in-Space Program of the NASA*, *op. cit.*, p. 42.

¹³ Lovelace et al., *op. cit.* Also, additional information supplied by Drs. Lovelace and Schwichtenberg.

¹⁴ *Ibid.*

¹⁵ *Ibid.*

¹⁶ Lovelace et al., *op. cit.*, p. 680. See also A. H. Schwichtenberg, D. D. Flickinger, and W. R. Lovelace II, "Development and Use of Medical Machine Record Cards in Astronaut Selection," *U.S. Armed Forces Med. J.*, vol. 10, no. 11, Nov. 1959, p. 1324-1351.

¹⁷ The following discussion is based on Charles L. Wilson, ed., *Project Mercury Candidate Evaluation Program*, WADC Tech. Rep. 59-505, Dec. 1959, U.S. Air Force, and on *Project Mercury: Man-in-Space Program of the NASA*, *op. cit.*, pp. 44-45.

¹⁸ Wilson, *op. cit.*

¹⁹ *We Seven* (New York: Simon & Schuster, Inc., 1962), written by the astronauts, recounts their personal experiences, including their reactions to the medical tests performed.

²⁰ Lovelace et al., *op. cit.*, p. 681.

²¹ *Project Mercury: Man-in-Space Program of the NASA*, *op. cit.*, p. 43.

²² This concept is described succinctly in Lovelace et al., *op. cit.*, p. 681. In addition, the report lists the routine medical examinations to be performed.

²³ *Project Mercury: Man-in-Space Program of the NASA*, *op. cit.*, pp. 40-49. Interviews with Capt. C. P. Phoebus, USN, and Capt. Frank Vorhis, USN.

²⁴ Special Orders A-1157 (DAF) Apr. 1, 1959 (EDCSA). Special Orders AA-150, June 20, 1962, "Agreement Between the Departments of Defense, Army, Navy and Air Force and the NASA Concerning the Detailing of Military Personnel for Service with NASA," signed by T. Keith Glennan for NASA on Feb. 24, 1959, Donald A. Quarles for DOD on Apr. 3, 1959, Wilber M. Brucker for the Dept. of the Army on Mar. 12, 1959, Thomas S. Gates for the Dept. of the Navy on Mar. 12, 1959, James H. Douglas for the Dept. of the Air Force on Mar. 24, 1959, and approved by President Eisenhower on Apr. 13, 1959. This document would implement Sec. 203(b)(12) of the National Aeronautics and Space Act of 1958 (P.L. 85-568). The individual would be notified by NASA as soon as accepted. The military departments would assign the members detailed to NASA to appropriate military units for purposes of providing rations, quarters, and medical treatment. Normally the tour of duty with NASA would be 3 years, although in the case of ROTC graduates the tour could be shorter. At the request of the NASA Administrator, military personnel could be recalled prior to the end of the normal tour of duty. Likewise, the military department could recall any person detailed to NASA, should the Secretary so indicate.

²⁵ Robert B. Voas, "Project Mercury Astronaut Training Program," presented to the USAF Symposium on Psychophysiological Aspects of Space Flight in San Antonio, Tex., May 26-27, 1960. See also Voas, "A Description of the Astronaut's Task in Project Mercury," *Human Factors*, vol. 3, no. 3, Sept. 1961, pp. 149-165. The reader is also referred to B. D. Goodman, "Psychological and Social Problems of Man in Space—A Literature Survey," *ARS J.*, vol. 31, no. 7, July 1961, pp. 863-872.

CHAPTER VI

Biomedical Aspects of Life-Support Systems

THE STEVER COMMITTEE REPORT had recommended that, in the development of a manned satellite program, the various types of necessary research and development go forward concurrently. This was in fact the way the Mercury program began to take shape in the winter and spring of 1959. In the course of their training the astronauts were able to provide vitally needed information for the development of life-support systems. As this research and development advanced, it was possible to test the systems through animal flights prior to actual manned ballistic and orbital flights.

Preliminary specifications for a manned spacecraft were distributed to industry in early November 1958, and a contractor's briefing was held by the Space Task Group at Langley Field, Va., for some 40 potential bidders. Detailed specifications were prepared, and on November 14, 1958, were distributed to about 20 manufacturers who had stated their intentions to bid. By mid-December, proposals for constructing the spacecraft had been received from 12 manufacturers or manufacturing teams, and in January 1959 the McDonnell Aircraft Corp. was selected as the contractor. Negotiations were completed on January 26, 1959, and the detailed contract was signed on February 6, 1959.¹

EARLY SPACECRAFT RESEARCH AND DEVELOPMENT

The development of specifications and negotiation of the contract was the end result of NACA research and development which had been in progress since early 1952, with close cooperation between military and industrial specialists. In June of that year, a small working group had been established "to analyze available information on space flight and to arrive at a concept of a suitable

manned test vehicle which could be constructed within two years."²

As a result of the recommendation by the NACA Committee on Aerodynamics that the problems of manned and unmanned flight at altitudes above 15 miles be considered, the Langley Aeronautical Laboratory began preliminary studies. Several problem areas were immediately identified, including those of aerodynamic heating and the achievement of stability and control at very high altitudes and speeds. For the next 4 years personnel at the NACA Langley and Ames Laboratories were engaged in research on aerodynamic characteristics of reentry configurations. They also contributed to the military missile program (which is not pertinent to the present discussion).

As a result of studies conducted the previous year, Maxime Faget, later the Assistant Director for Engineering and Development at the Manned Spacecraft Center, and his associates at the Langley Aeronautical Laboratory prepared a ballistic shape in November 1957 for a manned satellite development project. In January 1958 he and Paul E. Purser, later Special Assistant to the Director, MSC, conceived a solid-fuel design for the launch vehicle to be used in the research and development phase of a manned satellite project. Designated "Little Joe," this launch vehicle was used extensively in the early testing stages of Project Mercury. A report entitled "Preliminary studies of Manned Satellites—Wingless Configuration, Non-Lifting," completed by Faget, Benjamin Garland, and James J. Buglia in March 1958, was later to become the working paper for the Project Mercury development program.³

In the various research projects preceding Project Mercury, considerable attention had been given to the problems of acceleration and reentry forces of manned space flight. Indeed, these may be said to have been the last remaining major obstacles to manned space flight.

Both the German Air Force prior to World War II and the U.S. Army Air Forces had considered various techniques such as traveling in a prone position.⁴ As early as 1932, H. von Diringshofen pointed out that man's "g" tolerance would be markedly enhanced if the force were directed perpendicular to the axis of the large (great) blood vessels, as in the prone or supine position. In 1936, L. Bührlen, from considerations based upon centrifuge experiments on supine human subjects, recommended the use of a seat which at 4 to 5 g automatically tilted backward to the horizontal. H. Wiesehofer in 1939, presumably motivated by these earlier sug-

gestions of a tilting seat, actually flight tested a g-actuated tilting seat in a Heinkel-50 two-seated airplane, in which five passengers withstood 7g for 15 seconds without visual symptoms. In this installation, however, no flight tests were made in which the pilot utilized the tilting seat. In the *Compendium of Aviation Medicine*, S. Ruff and H. Strughold (1939) alluded to the work of Wiesehofer and similar observations, declaring that the g-actuated tilting seat had been shown to be "entirely practical."

Several American investigators later considered and designed g-actuated tilting seats for pilots of highly maneuverable aircraft. F. P. Dillon in 1942 patented a hydraulic g-actuated seat, and J. J. Ryan and B. H. T. Lindquist in 1943 described a spring-controlled g-actuated seat, not unlike the one von Diringshofen had described a decade and a half earlier.

W. G. Clark, J. P. Henry, D. R. Drury, and P. O. Greeley at the University of Southern California in the early 1940's were able to relate the positioning of the body and limbs quantitatively about the g-vector to the change in human g-tolerance. In the same period, E. H. Wood, C. F. Code, and E. J. Baldes studied the Ryan-Lindquist seat in detail for g protection provided when the seat was oriented at 45° from the horizontal.

In 1948, H. T. E. Hertzberg of the USAF Aero Medical Laboratory, Ohio, fabricated and tested on the centrifuge a "prone position bed" on which the human subject was easily able to withstand 12g. As an outgrowth of this and the earlier work of others, in 1949 he constructed, and in early 1950 tested, a net seat in which the supporting material was nylon raschel net which in the unloaded condition hung slack on the frame. This "slack net" was tested and was found to be extremely comfortable. It also was believed to provide lateral support to the postero-lateral aspects of the trunk.

In the period 1957-1960, J. I. R. Bowering, RAF, on duty at Wright-Patterson Air Force Base, Ohio, also constructed a net seat, based largely on the work of Hertzberg. His design departed from that of Hertzberg mainly in that he used as a support a raschel net material stretched taut over the seat frame. This supine seat did not display the same degree of subjective comfort as the slack net seat. It was also demonstrated that the taut net seat was unable to attenuate certain vibrational resonances of interest to human occupants.

Faget and his associates in April 1958 suggested the idea of using a contour couch to withstand the high g-loads in Mercury flights.⁵

In May 1958, fabrication of test-model contour couches was started in Langley shops. The couch proved to be feasible on July 30 when a subject withstood a 20-g load on the Navy centrifuge at Johnsville, Pa.⁶

Except in this one area, however, engineers and bioastronautics experts had yet to define the life-support criteria for manned space flight. Insofar as possible they would draw upon Air Force and Navy experience in the development of hardware for high-speed, high-altitude flight.

Three major factors had to be considered in the planning for the human operation of a spacecraft: (1) the stresses the astronaut would encounter, (2) the functions he would perform, and (3) the phases of the mission in which these factors would be encountered.⁷

Four categories of stresses could be expected: (1) Those caused by motions or forces, or their absence; (2) those caused by the space environment itself; (3) those caused by the spacecraft environment; and (4) those caused by the mental and physical activities required of the astronaut. Stresses caused by motions or forces included acceleration, weightlessness, noise and vibration, and oscillatory motions. Those caused by the space environment itself included radiation, micrometeoroid impact, and illumination. Those caused by the spacecraft environment included the atmosphere of the spacecraft, isolation, nutrition and waste factors, and other comfort factors. Finally, those stresses caused by the mental and physical activities of the astronaut included orientation ability, task complexity, and psychological factors.

Normally these stresses did not occur simultaneously and they were critical only during specific phases of the mission. According to Charles W. Mathews, Chief, Spacecraft Research Division, NASA Manned Spacecraft Center, in an address before the International Space Science Symposium: "We are interested not only in whether the astronaut can complete the mission without undue stress, but also whether he can perform certain critical functions at the same time."⁸ During the flight mission, critical stresses would occur at different points in time as different phases of the mission were in progress including powered flight, free flight, space maneuvers, operations in atmosphere, terminal flight, and surface operations.

The Mercury program—which was an experiment to test the



One of the major contributions of NACA/NASA research on manned space flight was the development, testing, and construction of the contour couch. Designed to withstand several times the maximum g-loads anticipated during reentry of the Mercury spacecraft into the earth's atmosphere, the contour couch as conceived by Maxime Faget and associates at Langley Research Center was individually tailored to each astronaut. Each one "sat" for a mold of his body (above) from which the contour couch was then cast in plastic (left).



After the plastic mold had hardened, it was finished with fibrous material (above). Then the contour couch was clamped to the metal seat and fitted with harness and restraining straps (below) in preparation for installation in Mercury spacecraft.



ability of a man and machine to perform in a controlled but not completely known environment—was to start with a series of design experiments for which there were few criteria. Design philosophy based upon experiments changed as the program progressed—for example, the shape of the spacecraft itself.⁹

Because man's capabilities to perform in space were unknown, early design philosophy was based upon automatic systems to perform the critical functions, with man riding along as a passenger and observer. Later this philosophy changed as it was increasingly demonstrated that man could effectively operate the manual controls and thereby provide a redundancy in case the primary systems failed.¹⁰

Design of a life-support system for Project Mercury could be accomplished by engineering and technology, but, according to Christopher Kraft, Jr., of the NASA Manned Spacecraft Center, "we cannot redesign the man who must perform in space."¹¹ Biomedical experiments would therefore have to answer one question: Could a man adapt to an environment which violates most of the laws under which his earth-oriented body normally operates?

Mercury objectives were to be in two areas: (1) scientific, and (2) engineering and technological. The scientific concern, involving all disciplines of the life sciences, was to determine man's capabilities in a space environment and in those environments associated with entering and returning from space. The engineering and technological problem was to place a manned vehicle safely into flight and effect a safe recovery of both man and vehicle from orbit. This total scientific and engineering-technological mission would require a life-support system that could sustain the astronaut throughout his total mission time including launch, orbit, and recovery. Dr. Stanley C. White and his deputy, Richard S. Johnston, an engineer, were to provide the focal point within the STG Life Systems Division for integrating the biomedical aspects of the life-support system within the total configuration.

LIFE SUPPORT SYSTEM DESIGN

According to Johnston, "one of the most complex development problems, if not the most complex problem, to be resolved in manned space flight is the life support of man in space for prolonged periods."¹² Life-support requirements for manned space flight include food, water, and atmosphere at a satisfactory pressure and composition to maintain blood-oxygen levels. To main-

tain a livable environment, the metabolic products of carbon dioxide, heat, and water must be controlled. Systems must be provided to collect, store, and treat human body wastes. Adequate protective systems must be devised to enable the astronaut to withstand the flight stresses—stresses expected in routine operations and those imposed by complex emergency situations.

For all system development, including life systems, certain design requirements existed, the prime one being to provide the necessary equipment in the minimum volume with the minimum weight. System reliability had to be provided in terms of the total mission reliability factor. As mission time increased, the system required revision to permit crewmen to "troubleshoot" malfunctions and to make in-flight system repairs. The systems had to be designed to withstand both the natural and the induced environmental conditions including vacuum, acceleration, heat, and radiation. Finally, they had to be revised to integrate with other spacecraft systems to allow usage of common supplies and to serve dual purposes.¹³

These were the problems that faced design engineers in the fall and winter of 1958-59 as they began the development of the Mercury life-support systems.

ENVIRONMENTAL CONTROL SYSTEMS

The environmental control system developed in Project Mercury could be considered as two subsystems, the cabin system and the pressure-suit control system.

The primary function of the environmental control system was to provide a livable gaseous environment for the astronaut. A basic requirement was to provide a 28-hour flight capability based on an oxygen consumption of 500 cc/min at standard temperature and pressure (STP) and a maximum cabin leakage rate of 300 cc/min STP. Four pounds of oxygen were needed to meet this requirement, although actually the Mercury system was to be supplied with 8 pounds to provide for complete redundancy. The next requirement was a cabin pressurization level of 5 pounds per square inch absolute (psia) with pure oxygen atmosphere. This pressure level was chosen as the best compromise to provide (1) necessary oxygen partial pressure, (2) efficient use of supply for emergency modes of operation, (3) a pressure offering small differential change during cabin decompression emergencies, and (4) a level for which decompression sickness would be minimal.



The astronaut's single-piece, 5-psi pressure suit was, like the contour couch, individually tailored and fitted to each astronaut.

A closed-type environment was selected to conserve oxygen and thus reduce the oxygen weight and volume required. The astronaut at all times would wear a full-pressure suit to provide emergency decompression protection. The cabin system controlled the pressure between 4.0 and 5.5 psia. The heat-exchanger system was designed for an astronaut metabolic heat production of 500 British thermal units per hour (Btu/hr).

The decision to use a 100-percent oxygen atmosphere at 5 psia was based upon both engineering and physiological considerations. From the engineering viewpoint, the system incorporated the factors of simplicity, minimal weight, and reliability. Physiological considerations involved the requirement to prevent bends in the event of emergency decompression, and maintenance of an adequate oxygen partial pressure. The pressure suits would operate at a pressure of 4.6 psia following cabin decompression.

Originally it was contemplated that the pressure-suit system would be maintained with pure oxygen and that the cabin would be enriched with oxygen at launch to provide a cabin atmosphere of approximately 66 percent oxygen and 33 percent nitrogen. This was to allow the visor of the pressure suit helmet to be opened in flight. One of the major reasons for selecting the oxygen-nitro-

gen mixture was the fire-prevention consideration. During the early ground tests of the system, however, it was found that nitrogen gas could concentrate in the pressure-suit circuit since the flow of oxygen into the suit was initiated by a slight negative pressure on a demand regulator. Consequently, cabin atmosphere was changed to 100 percent oxygen and special emphasis was placed on material selection and quality control to eliminate the potential fire hazard.¹⁴

The pressure suit was a backup system to the cabin atmosphere. Oxygen was forced into the suit at a torso connection by a battery-powered electric blower. In the suit, body cooling took place and a mixture of carbon dioxide, water vapor, and oxygen was produced. This gas mixture left the suit by a helmet connection and entered a physicochemical treatment cycle. Odors were removed by activated charcoal, carbon dioxide was removed by the chemical absorption of lithium hydroxide, and heat was removed by a water-evaporative heat exchanger. The water vapor condensed in the heat exchanger was removed by mechanical separation. Oxygen pressure was maintained in the pressure suit by a demand regulator which metered oxygen from a 7,500-psi oxygen supply. The operation time for the system would be dependent upon the system consumables: oxygen, coolant water, lithium hydroxide, and electrical power. The design was based on a carbon dioxide production rate of 400 cc/min.¹⁵

A closed-type environmental control system meeting these requirements was developed by the AiResearch Manufacturing Division of the Garrett Corp. (under a McDonnell Aircraft Corp. sub-contract). This system was located under the astronaut support couch, and the astronaut was clothed in a full-pressure suit to provide protection in the event of a cabin decompression. The cabin and pressure suit were maintained at 5 psi in normal flight with 100 percent oxygen atmosphere. Although the system was designed to control the environmental conditions automatically, manual controls were provided for use in the event of automatic-control malfunction.¹⁶

The manned development tests for the cabin system were conducted in December 1959 at the AiResearch Manufacturing laboratories. By that time the Mercury pressure suit and the environmental control suit functioned as a unit. In October 1960, a pressure-suit control system was installed in the Johnsville centrifuge, and tests were made under both manual and emergency conditions. At that time it became apparent that the system

would support the astronaut in orbital flight.¹⁷ This phase is discussed later in the chapter.

The pressure-suit circuit provided breathing oxygen, maintained suit pressurization, removed metabolic products, and, through positive ventilation, maintained gas temperatures.

The single-piece pressure suit itself was developed by the U.S. Navy, NASA, and the B. F. Goodrich Co. The Navy Mark IV was chosen as the basic suit, with modifications as requirements were clarified.

ASTRONAUT PARTICIPATION IN ENGINEERING DESIGN AND TESTING

By the spring of 1959 it had become apparent that as the design and construction of the manned spacecraft proceeded, considerable coordination of Space Task Group effort would be required to monitor the McDonnell contract adequately. A Capsule Coordination Office and Capsule Review Board were established by STG. These held frequent meetings at the management level.¹⁸

A mockup spacecraft had been completed by March 1959. The Mockup Board recommended no major changes except in the cockpit area, and it was further recommended that these changes await the selection and initial orientation of the Mercury astronauts.

Between May and August 1959, the astronauts gave considerable attention to the cockpit area, as did other NASA personnel. Among the factors considered were:

1. The operational procedures which the astronaut must follow during routine and emergency flight.

2. The anthropometric dimensions of the seven astronauts, which demonstrated several additional inadequacies in the placement of switches and controls of the earlier layout.

3. Studies of the dimensions of the astronauts while wearing a full-pressure garment, in both the routine unpressurized state and the pressurized state. These factors provided the basis for the spatial and geographic layout within the spacecraft so the astronauts could reach any control under both routine and emergency conditions. This layout, when correlated with the visual fields of the astronauts, demonstrated additional limitations of the initial layout.¹⁹ Several cockpit changes were made on the basis of this information, all of which would be effective for all the manned orbital flights and for all the manned ballistic flights except the first.

Other design studies which would directly affect the comfort and safety of the astronaut included egress studies that resulted in a quick-release side door for rapid access to the astronaut and for emergency exit.

Although many minor changes were made in spacecraft equipment, only a few major changes were necessary. For example, the originally specified extended-skirt main parachute for landing was found to be unsafe for operation at altitudes above 10,000 feet, and was replaced by a similar size "ring sail" parachute. In June 1959, considerations of parachute loads and deployment during large oscillations or tumbling of the parachute led to the elimination, and then reinstallation, of the drogue parachute. Finally, the initial concept of an impact bag was eliminated, only to be reinstated because of the hazards of wind-induced loads and the possibility of land impacts after early aborts.

In the fall of 1959 the astronauts spent a period of indoctrination at the Navy Air Crew Equipment Laboratory, Philadelphia. Their activities included:

1. Initial dressing, fitting, and routine ground-level pressurization of the individual suits
2. Altitude-chamber runs consisting of 1 hour in unpressurized suit with chamber at 5 psia, pure oxygen, and 1 hour in chamber pressurized to 1 psia with suit at 4.75 psia
3. Simulated reentry with temperature, pressure, and ventilation of normal Mercury reentry and landing
4. Work-space orientation using Mercury console mockup (referred to in the previous section)

The principal difficulty thus far encountered in the indoctrination program appeared to be that of obtaining the proper suit fit for each astronaut. L. N. McMillion, of the Space Task Group, reported in November 1959 that four of the astronauts had thus far participated in the indoctrination.

Schirra and Carpenter have received acceptable suit fits; however, Glenn's suit still does not fit even after two retailoring efforts, and Cooper's suit, which fit well initially, seems to have stretched more than normal during the factory run heat pressure tests.²⁰

He added, however, that "Goodrich intends to keep tailoring each suit until the wearer is content; they are actively investigating the problem of stretching during the heat pressure tests." This was done for each astronaut.

Throughout the Mercury project a continuing developmental



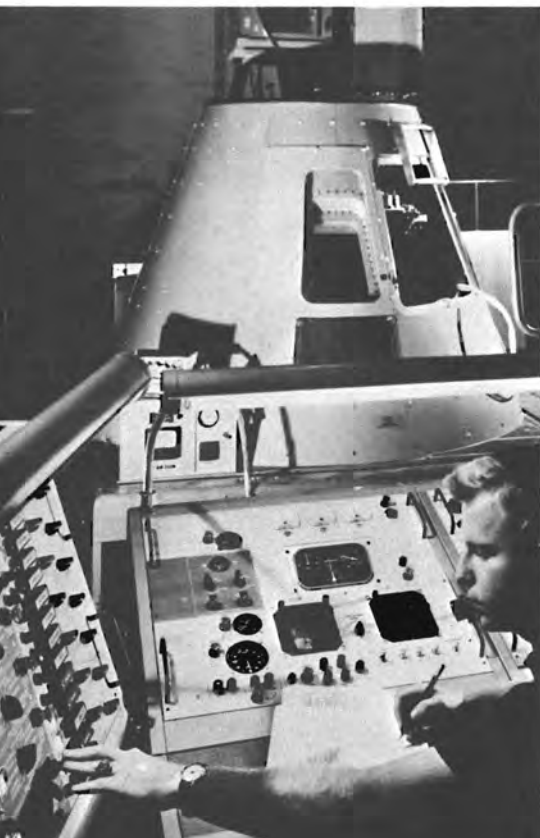
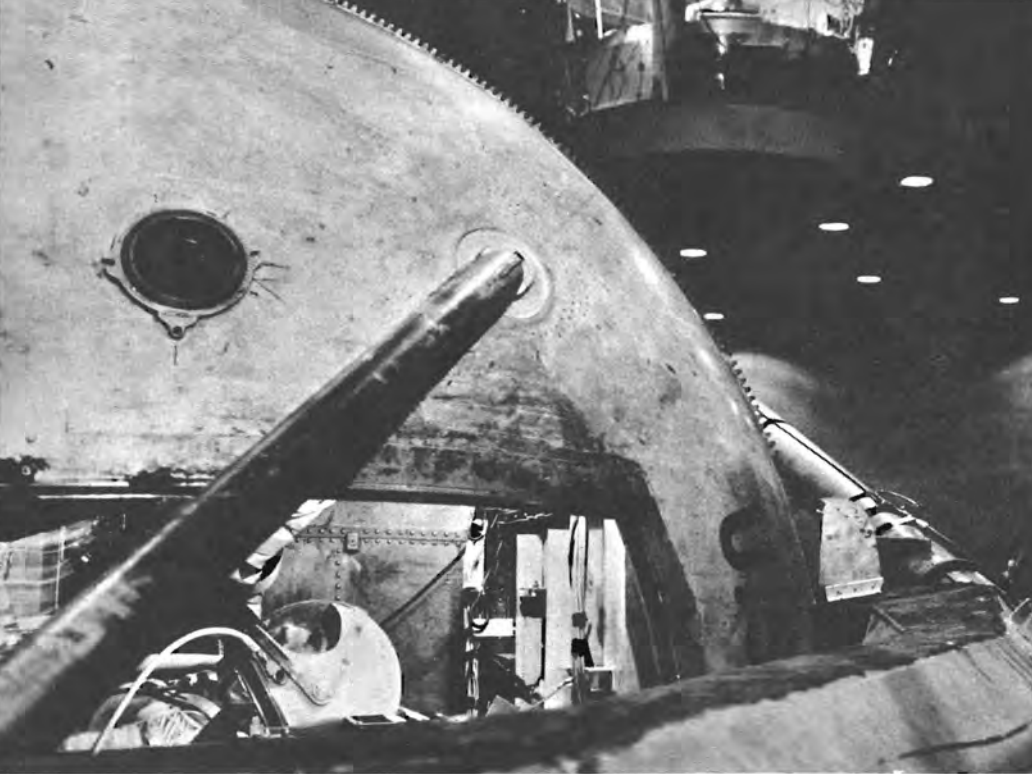
Not only was the development of the original pressure suit a slow and difficult process, but the improvement and modification of the suit continued throughout the duration of the Mercury program. Each suit was fitted individually, as shown above where Astronaut Cooper is being fitted by women from the laboratory of the suit contractor, Goodrich Rubber Co. Components of the suit were subjected to exhaustive tests, as the helmet (below, left) being tested under pressure for leakage. Complexity of the suit is indicated by these gloves of Astronaut Glenn, showing the four fingertip lights that would be used during orbit on the dark side of the earth.



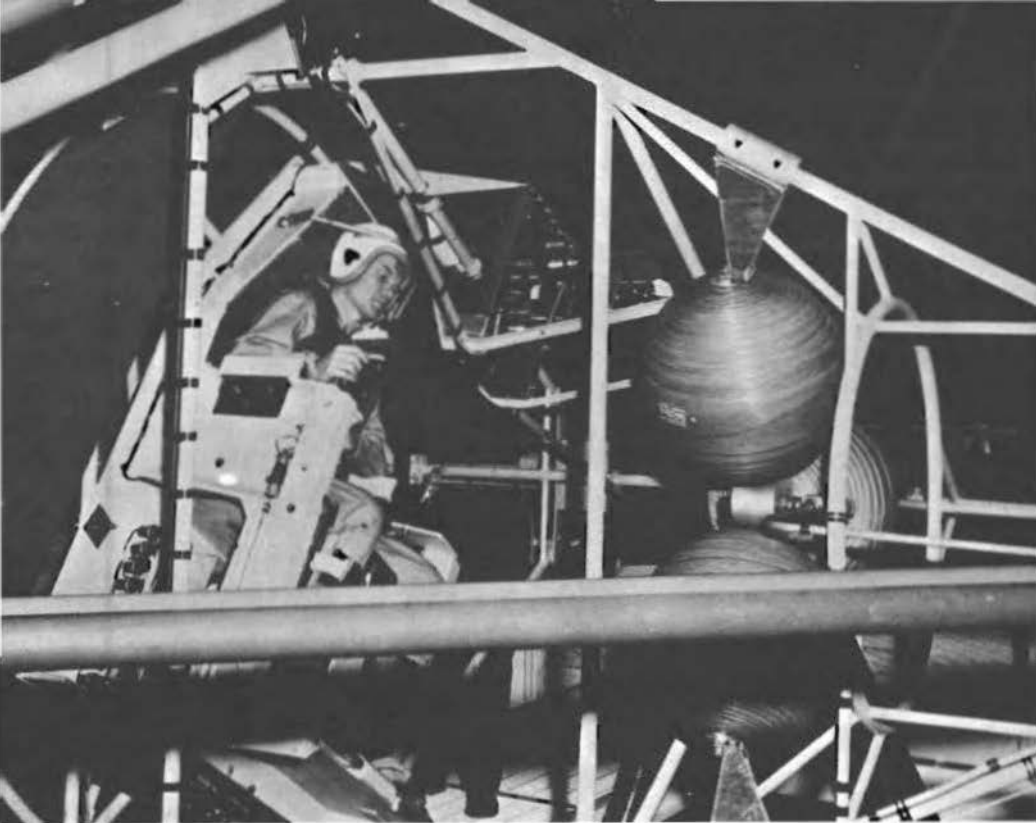
program was conducted to utilize the latest technological advances compatible with the constraints imposed by the spacecraft configuration and mission. This included, for example, such features as glove lights to illuminate the instrument panel, a urine collection and transfer system, improved shoulder construction of the suits to provide increased upper-torso mobility, and a mechanical visor seal.²¹

NASA was able to draw upon the resources of the Air Force, the Navy, industry, and academic and private research institutions to develop life-support systems to protect man against the stresses of launch, orbit, reentry, and impact. As has already been noted, in April 1958 Maxime A. Faget had suggested the idea of a contour couch to withstand the high g-loads imposed by acceleration and reentry forces of manned space flight, and such a couch was subsequently developed for the Mercury astronauts. It should, in addition, be emphasized that since World War II extensive research had been carried out for the Air Force and Navy by the services, by industry, and by academic and private research institutions.²² Particular mention should also be made of the concurrent work by C. F. Gell, H. N. Hunter, P. W. Garland, and others at the Naval Research Laboratory, and by J. P. Stapp, S. Bondurant, N. P. Clarke, W. G. Blanchard, H. Miller, R. R. Hessberg, E. P. Hiatt, Eli Beeding, and others in the services.²³ The literature in the field was extensive and experimentation applicable to high-speed flight was going steadily forward, particularly with the X-15.²⁴

In the fall of 1959, the seven astronauts began intensive testing of their life-support systems as well as intensive training and indoctrination in the use of life-support systems. Part of this testing and indoctrination was accomplished on the centrifuge at the AMAL in Johnsville. Three programs were carried out, one each in August 1959, April 1960, and October 1960. The program held October 3-14, 1960, is described in some detail because this was the period in which the Life Systems Division of STG not only evaluated the astronauts' personal equipment such as harness, couch, and pressure suit, but also evaluated the effectiveness of the bioinstrument sensors for monitoring of biomedical data during actual flights (discussed in the following chapter). The objectives of the program were "to train the astronauts for the Mercury-Redstone mission, and to obtain basic medical data to be used to monitor the astronauts' well-being during flights."²⁵ This was 6 months before the Shepard flight.



For such a radically difficult environment as space, simulators and trainers of many kinds were essential, both for testing life-support equipment and for conditioning astronauts to the sensations, problems, and responses that would be part of space flight. One of the key conditioning devices was the centrifuge, especially the big Navy centrifuge at Johnsville, Pa. (above). Representative simulators shown here are: Procedures trainer, NASA Langley Research Center, for instrument training (left); Multiple Axis Space Test Inertia Facility (MASTIF) trainer, Lewis Research Center (above, right), for three-axis flight control using six gas jets; Air Lubricated Free Attitude (ALFA) trainer, Langley Research Center, where an astronaut, on his contoured couch mounted on an air bearing and sighting through instrument panel at model of earth, could practice dynamic flight control as compared with instrument control in the procedures trainer; analog flight simulator, McDonnell Aircraft Corp., St. Louis, Mo.



The astronauts followed as closely as possible the procedures that would be used for the actual mission. To illustrate the kind of teamwork required, the detailed assignments of the STG group are described below. Dr. C. P. Laughlin would record, process, and analyze the physiological stress information about the astronauts including pre- and post-training physical examination; monitoring and tabulation of pulse, respiratory rate, body temperature, and electrocardiogram; pre- and post-training vital capacity; pre- and post-training nude weight; and pre- and post-training volume and specific gravity of urine. The major part of the physiological stress information would be gathered by personnel of the National Institutes of Health and Dr. J. P. Henry of STG. Fluid loss and vital capacity measurements would be under the direction of Dr. William S. Augerson. Insertion of the astronauts into the spacecraft would be done by one of two teams: Dr. William K. Douglas and Joe W. Schmitt, or Dr. C. B. Jackson and Harry D. Stewart. Drs. Douglas and Jackson would also evaluate the effectiveness of the biosensor performance. The pressure suit and urine bag would be evaluated by Lee N. McMillion. William H. Bush would be responsible for the electronic part of the biomedical recording, and Morton Schler would be responsible for procurement, installation, and monitoring of the environmental control system. The couch and restraint harness would be evaluated by Gerard J. Pesman.²⁶

Most of the astronauts considered their couches "reasonably comfortable." As a result of earlier studies which indicated that the astronaut needed to be able to release his harness more quickly, minor modifications were made so that the harness could be released in four simple movements.

The reliability of the components of the Mercury environmental control system (ECS) was "completely satisfactory."

The astronauts' pressure suits, which had been delivered in September, received their first intensive use in this period. The leakage rates for the new suits ranged from 80 to 300 cc/min, small rates compared with those of previous suits. The bioinstrumentation connector was a modified Bendix plug attached on top of the right thigh of each suit. The new connector was reliable and a definite improvement over the snap patch previously used. The latching device for securing the inside connector to the suit "operated with some difficulty," although it was believed the suit would be acceptable for operational use. Meanwhile, B. F. Goodrich Co. would continue to investigate improved latching methods.²⁷



Astronauts had to learn to live with and operate in their life-support equipment. Above, Astronaut Shepard lies on a contour couch in his MC-IV pressure suit and practices navigation on the Langley Research Center simulator. Astronaut Cooper (right) is lifted in his pressure suit into a prototype net couch in Hangar S at Cape Canaveral, Florida.



Still another concern for the Life Systems Division had been the establishment of procedures and timing for astronaut insertion into the spacecraft as well as for postflight debriefing. It was concluded that although insertion techniques presented no major problems, insertion procedures should be practiced and should be conducted with a properly itemized checklist.

The October 1960 program had as one of its objectives the obtaining of basic medical data to be used to monitor the astronaut's well-being during flights. During the program simultaneous measurements were made of the emotional state, metabolism of adrenal medullary and cortical hormones, and control performance during the training program. Blood and urine samples

were taken before and after repeated exposure to acceleration.

This program was directed by Dr. G. E. Ruff of the University of Pennsylvania (who, during his tour of duty with the Air Force, had participated in the astronaut-selection stress tests at WADC). Urine samples were analyzed at the National Institutes of Health, Bethesda, Md., and blood samples by Dr. Kristen Eik-Nes, University of Utah. Dr. Ruff also interviewed all the astronauts at least once. All the astronauts took simple pencil and paper tests for evaluation of their emotional state.²⁸

Through the remaining months before the Shepard flight, the astronauts would continue their intensive training pace at Langley and at Cape Canaveral. Up to the last moment, advances in technology would be incorporated into the life-support systems to the degree possible under the constraints imposed.

NOTES TO CHAPTER VI

¹ Paul E. Purser, Spec. Asst. to Dir., Project Mercury, Memo for Files, Subj.: Additional Background Material on Project Mercury, May 11, 1960. See also, "Agenda: Briefing NASA—Space Task Group, November 7, 1958." Participating in this briefing were: Robert Gilruth, "General Background of NASA Manned Satellite Program"; Maxime A. Faget, "Description of Development and Qualification Program and Discussion of Various Missions"; Alan B. Kehlet, "Configuration Requirements and Details"; Aleck C. Bond, "Present Status of Heat Protection—Heat Sink Versus Ablation"; André Meyer, "Structural Requirements"; Robert G. Chilton, "Stabilization Control Requirements"; Jack C. Heberlig, "Human Support System, Environmental Control System, Landing System, and Recovery System Requirements"; Howard P. Kyle, "Communications"; Clifford H. Nelson, "Instrumentation"; and Charles H. Zimmerman, "Bidding Information."

² *Project Mercury*, NASA Fact Sheet 195, Manned Spacecraft Center, July 1963, pp. 2-3.

³ *Ibid.*, p. 3.

⁴ The literature in the field is extensive. See for example: (1) W. G. Clark, "Effect of Changes in the Position of the Body and Extremities on Seated Man's Ability to Withstand Positive Acceleration," Unpublished National Research Council Monograph, 1946; (2) W. G. Clark, "Tolerance of Transverse Acceleration with Especial Reference to the Prone Position," Unpublished NRC Monograph, 1946; (3) Personal communication, Walter B. Sullivan, Jr., with H. T. E. Hertzberg, C. E. Clauser, and F. W. Berner, Aeromedical Laboratory, Wright-Patterson AFB, Ohio; J. P. Henry, M.D., Dept. Physiology, USC; William G. Clark, Veterans Administration Hospital, Sepulvada, Calif.; E. J. Baldes, Ph.D., Department of Defense; Mr. Harvey Holder, Engineering Directorate of Defense and Transport System; Mr. Richard Peterson, Research and Technology Division, Wright-Patterson AFB, May 1965.

⁵ *Project Mercury*, NASA Fact Sheet 195, Manned Spacecraft Center, July 1963, p. 3.

⁶ *Ibid.*

⁷ Charles E. Mathews, "United States Experience on the Utilization of Man's Capabilities in a Space Environment," in R. B. Livingston, A. A. Imshenetsky, and G. A. Derbyshire, eds., *Life Sciences and Space Research* (New York: John Wiley & Sons, Inc., 1963).

⁸ *Ibid.*, p. 144.

⁹ Christopher C. Kraft, Jr., "A Review of Knowledge Acquired From the First Manned Satellite Program," NASA Fact Sheet 206, Manned Spacecraft Center, circa Aug. 1963.

¹⁰ Edward R. Jones, "Man's Integration into the Mercury Capsule," presented at the 14th Annual Meeting, American Rocket Soc., Washington, D.C., Nov. 16-19, 1959. See also Robert B. Voas, "Project Mercury: The Role of the Astronaut in Project Mercury Space Flights," presented at the VPI-NSF-NASA Conference on Physics of the Solar System and Reentry Dynamics, Blacksburg, Va., Aug. 10, 1961.

¹¹ Kraft, *op. cit.*

¹² R. S. Johnston and E. L. Michel, "Spacecraft Life Support Environment," NASA Fact Sheet 115, Manned Spacecraft Center, Dec. 1962. See also C. F. Gell, E. L. Hayes, and J. V. Correale, "Developmental History of the Aviator's Full Pressure Suit in the U.S. Navy," *J. Aviation Med.*, vol. 30, no. 4, Apr. 1959, pp. 241-250.

¹³ Johnston, *op. cit.*

¹⁴ *Ibid.*

¹⁵ Johnston reported (*ibid.*) that these oxygen consumption and carbon dioxide production rates originally established for Mercury had not been exceeded, and that flight data had been determined grossly at 360 cc/min.

¹⁶ See, for example, Stanley C. White, Richard S. Johnston, and Gerard J. Pesman, "Reviews of the Biomedical Systems Prior to the MR-3 Ballistic Flight," an undated manuscript circa winter 1959-60. See also Richard S. Johnston, "Mercury Life Support Systems"; Anton A. Tamas, "Toxicological Aspects of Closed Atmospheric Systems"; William R. Turner, "Regenerative Atmosphere Systems for Space Flight"; and E. L. Hayes and Roland A. Bosee, "Development and Evaluation of Bio-Astronautic Life Support Systems," all in *Life Support Systems for Space Vehicles*, SMF Fund Paper No. FF-25, IAS, Jan. 1960.

¹⁷ See also William S. Augerson, James P. Henry, *et al.*, "Project Mercury. Life Systems Aspects of Third Mercury-Aviation Medical Acceleration Laboratory Centrifuge Program," NASA Project Mercury Working Paper No. 187, Apr. 20, 1961.

¹⁸ This section is based on Purser, Memo for Files, *op. cit.*

¹⁹ *Ibid.*, p. 3.

²⁰ L. N. McMillion, Life Systems Br., Memo for Chief, Flight Systems Div., Subj.: Trip Report, Nov. 20, 1959.

²¹ Richard Johnston, Edward L. Hayes, and Lawrence F. Dietlien, "Crew Systems Development In Support of Manned Space Flight," an undated manuscript circa summer 1963.

²² The reader is referred particularly to the following references: Ralph L. Christy, "Effects of Radial and Angular Accelerations," including 33 foot-

note references; John Paul Stapp, "Effects of Linear Acceleration," with 10 footnote references; Paul Webb, "Temperature Stresses," with 26 footnote references; James B. Nuttall, "Escape, Survival and Rescue," with 54 footnote references; Lawrence E. Lamb, "Cardiovascular Considerations," with 13 references; and Hubertus Strughold, "Space Medicine," all in Harry G. Armstrong, *Aerospace Medicine* (Baltimore: Williams & Wilkins, 1961). See also *Human Acceleration Studies*, Publication 913, NAS-NRC. This includes an excellent bibliography by George Bates, a proposed physiological acceleration terminology with a "Historical Review" by Carl C. Clark and Richard J. Crosbie, and a discussion by Rufus R. Hessburg, "Acceleration Environments Pertinent to Aerospace Medical Research." See also Carl C. Clark and Dennis Faubert, "A Chronological Bibliography on the Biological Effects of Impact," Martin Engineering Rep. 11953, Sept. 1961, and additions prepared by Dr. Clark as a result of the Symposium on Impact Acceleration Stress held under the auspices of the Man-in-Space Committee of the Space Science Board, National Academy of Sciences-National Research Council, at San Antonio, Tex., Nov. 27-29, 1961. See also Ashton Graybiel, "Significance of Vestibular Organs in Problems of Weightlessness"; R. Grandpierre and F. Violette, "Contribution à l'Étude des Effets de l'Apésanteur sur le Système Nerveux Central du Rat"; U. V. Parin and O. G. Gazonko, "Soviet Experiments Aimed at Investigating the Influence of Space Flight Factors on the Physiology of Animals and Man"; all in Livingston *et al.*, *Life Sciences and Space Research*, *op. cit.*

²³ See, for example, C. F. Gell and P. W. Gard, "Problem of Acceleration," NAVPERS 10839-A, Navy Dept., 1955. See also S. Bondurant, N. P. Clarke, *et al.*, "Human Tolerance to Some of the Accelerations Anticipated in Space Flight," *U.S. Armed Forces Med. J.*, vol. 9, no. 8, Aug. 1958, pp. 1093-1105.

²⁴ The principal human centrifuges throughout the world included those in the United States at the Mayo Clinic, Rochester, Minn.; Wright-Patterson AFB, Ohio; the University of Southern California; the Naval Air Station, Pensacola, Fla.; The Naval Air Development Center, Johnsville, Pa.; in Canada, the Canadian Air Force, Toronto; in England, the Royal Air Force, Farnborough; in France, the French Air Force, Bretigny Flight Test Base; in Germany, the Institute of Aviation Medicine, Bad Nauheim; in Sweden, the Swedish Air Force, Stockholm; and in Japan. Others were under construction.

²⁵ Augerson, Henry, *et al.*, *op. cit.*

²⁶ *Ibid.*, p. 21.

²⁷ *Ibid.*, pp. 7-9.

²⁸ *Ibid.*, p. 7.

CHAPTER VII

Biomedical Planning for Launch, Tracking, and Recovery

WHILE THE ASTRONAUTS were in the midst of their training and indoctrination program in the summer of 1959, plans were underway to develop testing facilities for both manned and unmanned vehicles. NASA had turned for assistance to DOD, which controlled the Atlantic Missile Range, including the Cape Canaveral Missile Test Center, Cape Canaveral, Fla. Since 1951 this range had been used to test missiles.¹

The Executive Agent for DOD was the USAF, with its Air Force Missile Test Center at Patrick Air Force Base, a few miles inland. Organizationally, the Test Center was a part of the Air Force Research and Development Command. Maj. Gen. D. N. Yates was Commander of AFMTC and Col. George M. Knauf, USAF (MC), was staff surgeon at AFMTC, Patrick AFB. These two officers were to play an increasingly important role in the development of NASA's Project Mercury.

On August 10, 1959, the Secretary of Defense designated General Yates the Department of Defense Representative for Project Mercury Support Operations.² There would be a Naval deputy to assist in recovery operations for Project Mercury.³ As DOD Representative for Project Mercury Support Operations, General Yates would be responsible for the preparation and submission for review and approval of top-level plans and requirements in support of Project Mercury, including appropriate recommendations for implementation. (During development, these plans would be coordinated as appropriate with the Director of Defense Research and Engineering, office of the Secretary of Defense. Completed plans would be forwarded by DDR&E to the Joint Chiefs of Staff who in turn would review them and provide comment and recommendation for final approval by the Secretary of Defense.) General Yates would direct and control DOD facilities, forces, and assets assigned for support of Project Mercury.

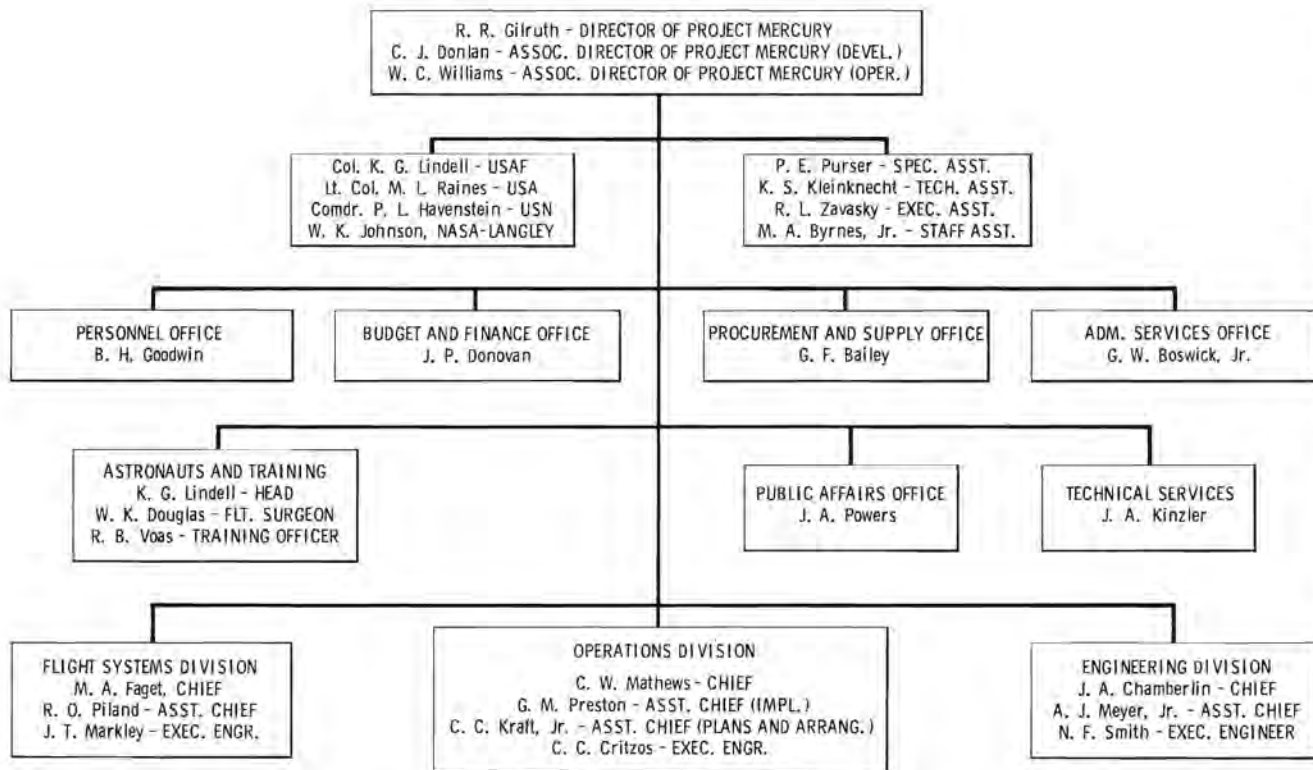


Chart 2—Organization of Space Task Group, January 1960.

DOD performance of specific missions assigned for support of Project Mercury was also his responsibility, although budget aspects of DOD participation would conform with policies and procedures of the Office of the Comptroller and Director of Public Affairs.

In the basic memorandum of August 10, the Deputy Secretary of Defense clarified policies and procedures:

It is desired that use of existing organizations be made. Accordingly, while General Yates is authorized such staff as may be required for the execution of his duties and as approved by the Secretary of Defense, it is expected that he will make maximum utilization of the existing agencies in the Department of Defense and military departments. He is authorized to have direct access to and communication with any elements of the military department, unified and specified commands, and other DOD agencies, and other appropriate departments and agencies of the Government performing functions related to those of Project Mercury over which he exercises direction and control.⁴

For the next 11 months General Yates would serve both as Commander, AFMTC, and as DOD representative for support of Project Mercury. On July 9, 1960, he was succeeded by Maj. Gen. Leighton I. Davis, USAF.⁵ Meanwhile, on December 1, 1959, General Yates officially designated his staff surgeon, Colonel Knauf, as his Assistant for Bioastronautics.⁶ He served in this capacity for the next 25 months.⁷

MEDICAL MONITORS

As early as October 29, 1959, Dr. Stanley C. White, STG, had noted in a memorandum for the Project Director that as Mercury moved into actual manned operations, there would be "fairly considerable requirements for additional medical support in monitoring recovery, and post-flight research and support."⁸

A plan of action was offered which envisaged using medical personnel from the various Federal medical services, particularly the Department of Defense. Basic assumptions were that appropriately trained personnel from all branches of the service would be used; that Mercury was sufficiently important as a national effort to justify unusually extensive medical support; that most personnel would be obtained for training and duty on a temporary basis; that whenever possible, personnel would be assigned at or near their normal duty station; that although Space Task Group, NASA, would prefer to request certain persons by name, this was not always practical; that STG should reserve the right



Medical support for manned flights in Project Mercury was a large and complex requirement involving a truly national effort. Medical observers would be required at all stations in the tracking network (above). Larger medical teams would be required at Cape Canaveral (right). Mercury astronauts are shown in the Mercury Control Center at the Cape, together with Christopher C. Kraft, Jr. (fourth from left), of Mercury Operations Div.



to review records and qualifications and to interview persons to be assigned in direct support of Mercury; that STG would supervise training, with the right to delegate much of the work; that monitoring personnel would be responsible to the Project Manager; and that wherever possible, Mercury would attempt to accomplish other national objectives as a byproduct of the mission.

The following day, October 30, a detailed plan for medical monitoring of Project Mercury was forwarded to the Project Director by Dr. Augerson, then on duty with the Life Systems Branch, of which Dr. White was Chief. The purpose of the medical monitors for Project Mercury would be to preserve the health of the pilot by providing remedial advice during the flight, evaluating the current medical status of the pilot, and correlating spacecraft data and physiological data with the mission profile. The medical monitors also would provide medical advice to flight directors, station directors, and recovery commanders as appropriate; provide preventive medicine advice and medical care for personnel at remote sites; gather research information in space medicine; and train personnel for support of future space projects. A schedule was outlined for individual and team training.

By mid-November 1959 these preliminary discussions were in the process of being formalized. On the 13th of that month the newly appointed Associate Director of Project Mercury (Operations), Walter C. Williams, who had been designated the single point of NASA-DOD operation contact, requested that General Yates assist in making the necessary arrangements for obtaining medical support for Project Mercury.⁹

Recognizing that it would not be feasible to detach medical personnel from their present duty station and assign them full time to Project Mercury, the Associate Director of Project Mercury suggested that they be assigned on temporary duty for training and actual operations.

Requirements for recovery medical personnel, it was noted, would have to await a more detailed analysis of the recovery system. It was contemplated, however, that the Department of Defense would be asked to deploy one or two field medical units or to augment certain existing facilities. Capt. Ashton Graybiel, USN (MC), Director of Medical Research for the Naval School of Aviation Medicine, was mentioned as being "eminently desirable" as head of the medical recovery and research program.

A summary of the monitor plan was enclosed in William's letter to General Yates. (See app. B.) Certain questions, however, remained to be answered. For example, the Associate Director of Project Mercury asked if it would be feasible to train and deploy physicians on a temporary duty basis. How would medical support be controlled and administered? What additional personnel in excess of NASA requirements would be trained? What were the estimates of the cost? Could it be assumed that NASA would be



Col. George Knauf (third from left), Assistant for Bioastronautics to DOD Representative for Project Mercury and in charge of DOD medical support of Project Mercury, and Astronauts Shepard and Schirra (left and right), brief Gen. Bernard Schriever, Commander, Air Force Systems Command, on Mercury procedures.

required to pay only the travel and per diem allowances of assigned officers? Could some assignments be integrated with other Service medical plans and assignments? Would it be possible for NASA to express a particular interest in certain personnel by name? These and other details had yet to be worked out.

On December 11, 1959, a little more than a week after Dr. Knauf was officially designated the Assistant for Bioastronautics for DOD support of Project Mercury, the STG aeromedical team met with DOD representatives, including him, to brief them on the medical requirements for Project Mercury. Earlier concepts were clarified. The medical monitors, it was reiterated, would preserve the health of the pilot by giving remedial advice during the flight, evaluating the current medical status of the pilot, and correlating spacecraft data on physiological data with the mission. They would provide medical advice to the flight director, station director, and recovery commander as appropriate. They would also

provide preventative medical advice and medical care for personnel at remote sites, gather research information in space medicine, and train personnel for future space project support.¹⁰

Medical monitors obviously would require a detailed knowledge of the Project Mercury mission and spacecraft. They would also require personal knowledge of the astronauts and their physiological responses in stressful training. Further, they would need experience with Mercury monitoring equipment as well as experience in missile or other analogous monitoring. Finally, they must have the professional capability to correlate psychological, environmental, and physiological changes indicated by instrumentation. A list of qualified military medical personnel to be used was proposed by the Space Task Group. In addition, it was proposed that entire classes from the USAF School of Aerospace Medicine, Texas, assist in the monitoring operation so as to provide more depth for continuing space flight operations.

There would be two types of monitoring stations for Project Mercury: The purely monitoring stations which could make medical recommendations to the pilot or assist the control center in decisions, and the command stations which, together with certain launch and control central positions, were to be regarded as key sites. The monitors there should be the most familiar with Mercury operations. Assignments of the "key site" medical officers would be as follows:

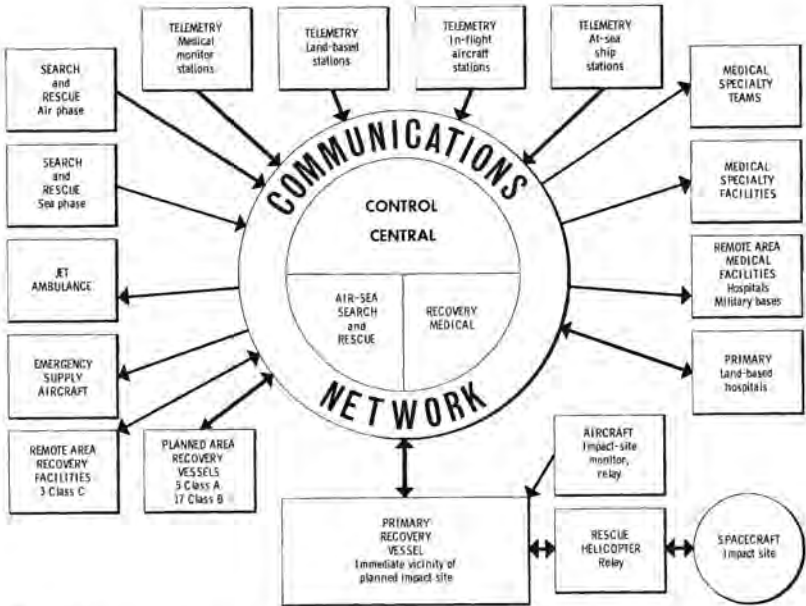
1. The astronaut flight surgeon would be with the astronaut to provide preflight examination, preparation and installation of the astronaut in the spacecraft, and emergency medical coverage near the launch pad. Following successful launch, he would fly down-range to the normal recovery base.

2. The blockhouse monitor would monitor the countdown, serve as tower rescue physician (should there be prelaunch difficulty in the gantry), coordinate the medical aspects of near-pad aborts, and relieve or assist the control central monitor.

3. The control central flight surgeon would be in the Command Control Room.

These requirements were already clear, STG reported. Still to be determined were the medical requirements for the Bermuda station, the normal retrofire command station, and possibly the Canary Island station.

It was noted that, by the time manned operations were begun, five Air Force officers and one Army officer would have detailed knowledge of the astronauts and Project Mercury, and it was rec-



The elaborate real-time communications net established for Project Mercury operations had provision for medical communications at each key point in the network and a focal point of medical communications in Control Central, Cape Canaveral.

ommended that they be considered key Space Task Group personnel. Already detailed to STG were three Air Force officers: Dr. White, now chief of Crew Systems Branch, STG; Dr. Douglas, Flight Surgeon, assigned to the astronauts; and Dr. Henry, on duty with Dr. White (as coordinator of the animal program). There was also Dr. Augerson, of the Army, who had been one of the original aeromedical consultants for Project Mercury. In addition, Dr. Knauf, the assistant for Bioastronautics, and Dr. Rufus Hessberg, an Air Force colonel assigned to Holloman AFB but working intimately with the Space Task Group in support of the animal program, should be considered part of STG at the time of launch. This was later to become fact.

It was suggested that three cardiologists serve as consultants: Dr. Larry Lamb, on duty in a civilian status at the School of Aviation Medicine; Dr. Per Lanjoen, cardiologist at the William Beaumont Army Hospital in California; and Dr. Samuel M. Sandifer, Chief of Cardiology, Tripler Army Hospital, Hawaii. Alternate personnel included Dr. Clyde Kratochvil, a USAF flight surgeon holding a doctorate in physiology, and Drs. Charles Berry and

William R. Turner, both USAF flight surgeons and Board certified in Aviation Medicine. Finally, a tentative list of other proposed medical monitors was attached. (See app. B.)

Training and indoctrination for the medical monitors envisaged a 5-day tour of duty during which the monitors would become acquainted with the astronauts. Also, they would be briefed on such topics as the Mercury spacecraft mockup, environment, monitoring equipment, full-pressure suit, recorded reviews of simulated missions, systems, and research objectives. They would visit the Navy installations at Johnsville and at Philadelphia as well as Holloman AFB (where the Air Force was carrying out the Mercury animal program for NASA). Team training would follow individual training, and shortly before an actual mission there would be an extensive team drill at Cape Canaveral.

Following this briefing, DOD representatives and the NASA Space Task Group consolidated a suggested list of military personnel for submission to the Associate Director, Project Mercury. The individuals named—military and civilian—were those suggested by the three military service representatives¹¹ at the close of the Space Task Group briefing on the medical requirements for Project Mercury support.

During the next few days the Space Task Group considered these individuals in the light of the background material submitted by the Service representatives. Also, STG attempted to correlate, insofar as possible, the professional and technical skills of the individuals concerned with the type and magnitude of the medical responsibilities envisaged for each global range station at which it was planned to conduct aeromedical monitoring during Project Mercury flight operations.¹² By late December 1959, STG had completed its review of the list of recommended medical personnel.¹³ It was planned that the proposed training program would get underway by March 1, 1960.

Since the medical monitors would be receiving telemetered information from the astronaut in flight, they had to be indoctrinated in the techniques to be used. Special mention should be made of the four 3-day refresher courses that were subsequently given at the USAF School of Aerospace Medicine by Dr. Larry Lamb, who was to serve as a consultant to STG. Since a major portion of the medical monitoring would consist of the interpretation of telemetered information from the astronauts in orbital flight, NASA requested that he develop a course to train monitors in the electrocardiographic and cardiovascular aspects of space flight.

In September 1960, as a first step, he recorded important biological variables of the seven astronauts. Together with information gained through aeromedical evaluations of the Air Force flying population over a period of years, this information formed the basis for the courses given to medical monitors in December of that year.¹⁴ Mention should also be made of the 59-page guidebook entitled "Medical Problems at Tracking Stations Supporting Project Mercury" prepared by Col. Harold V. Ellingson, USAF (MC), for use by monitors stationed at telemetry and tracking stations for Project Mercury.¹⁵

STG-DOD MEDICAL ADVISORY BOARD

In early April 1960, Dr. Douglas, the astronauts' personal physician, initiated action through Dr. Knauf, the Assistant for Bioastronautics to the DOD representative, to organize and coordinate a joint STG-DOD Medical Advisory Board. The board, which would meet at the request of STG, would review medical operational plans to insure that all aspects of the astronauts' preflight physical examination, in-flight medical monitoring, and postflight examination and debriefing had been adequately considered. The Board would operate on a continuing basis, studying all pertinent medical data from each successive flight with a view toward taking corrective action prior to the next flight.

At the first meeting, held at the Aviation Medical Acceleration Laboratory, WADC, Johnsville, Pa., on April 13, 1960, members were asked to determine in their own fields what types of biological measurements should be made on the astronaut and on the vehicle itself.¹⁶ Both the Space Task Group representative, Dr. Douglas, and the DOD representative, Dr. Knauf, wanted to obtain the assistance of a select group of specialists from within the military services to review the proposed postflight medical support. Such a review would, it was believed, lead to a final medical support plan that would be adequate in the light of the national significance of Project Mercury, yet would not commit critically short medical resources unnecessarily. On May 2, therefore, the Assistant for Bioastronautics forwarded a letter to the Bureau of Medicine and Surgery and to the Office of the Surgeon General, USAF, stating that STG/NASA had requested him to provide a selected group of medical officers to assist in reviewing Project Mercury medical operational plans to insure that all objectives of the astronauts' preflight physical examina-

tion, inflight medical monitoring, and postflight examination and debriefing had been adequately considered and provided for. Two Navy medical officers, Capt. Ashton Graybiel and Capt. Edward L. Beckman, and two Air Force medical officers, Lt. Col. David G. Simons and Capt. James Roman, were selected.

DOD MERCURY CONSULTANT PROGRAM

Meanwhile, it had become increasingly clear that the nature and scope of biomedical requirements would demand the detailed knowledge of physicians in the various specialties. The concept of a consultant service in addition to the STG-DOD Advisory Board was gradually taking shape. In a letter to the Surgeons General of the three services dated April 16, 1960, Dr. Knauf, the Assistant for Bioastronautics, requested that each Surgeon General nominate from his service the individual most eminently qualified to render consultant service in each of the following specialties: General surgery, orthopedic surgery, pathology, neurosurgery, plastic surgery, internal medicine, and anesthesiology.¹⁷ From this total list it was proposed to select a committee made up of a single representative of each specialty as a principal member, with the remainder of the nominees acting as alternate committee members. Colonel Knauf and Captain Graybiel would act as cochairmen of the committee.

On June 1, 1960, all the nominees met with the cochairmen in Washington, D.C.¹⁸ Following a briefing on the potential biomedical problems facing the Mercury astronauts, the chairmen requested that the medical officers in each specialty from each of the three services meet as a group and determine which of them would serve as principal consultant for Project Mercury. The other two would serve as alternate or backup members.¹⁹

The group defined their objectives as follows:²⁰

(1) To insure that the basic plan for postflight medical support was adequate and professionally sound, and that it provided an appropriate level of medical competence at each location where it had been determined that medical forces would be deployed.

(2) To take appropriate steps to insure that there be proper and sound employment of professional resources.

With the organization of this Professional Advisory Committee, which had absorbed the members of the original STG-DOD Medical Advisory Board, planning could go steadily forward. In late June the committee gathered at Patrick Air Force Base,

Fla., for a 2-day meeting. On June 28 the committee inspected various facilities at the 6550th USAF Hospital at Patrick AFB, giving special attention to surgery, central supply, recovery room, clinical laboratory, and the X-ray department. The members proceeded to Cape Canaveral where they inspected facilities for possible use as a forward medical station. Time was growing short and problems had yet to be resolved.

At a roundtable discussion at Cape Canaveral, the committee directed its attention toward the possible integration of Patrick Air Force Base Hospital into the Mercury Medical Support System, and concluded that the hospital could be used to perform the support mission contemplated in connection with Project Mercury medical recovery operations. It was their opinion that the professional staff at Patrick AFB Hospital should include at the time of manned launches the following additional personnel: neurosurgeon, general surgeon (qualified in thoracic surgery), orthopedic surgeon, plastic surgeon (traumatologist), internist, anesthesiologist, pathologist, radiologist, urologist, nurse (qualified in neurosurgery), neurosurgical technician, orthopedic technician, urological technician, and an officer trained in clinical chemistry. In addition, the committee recommended that certain selected items of equipment be added.

Besides increasing the medical resources at Patrick AFB Hospital for recovery purposes, the committee strongly recommended that a forward medical facility be located on Cape Canaveral to render emergency care in the event of injury to an astronaut. This facility would be prepared to treat shock and to provide any other care that might be necessary to prepare the astronaut for transport to Patrick Air Force Base Hospital.

Although the STG staff had originally proposed that a team be organized to function as the first echelon of medical care—a mobile unit transported by helicopter—the committee now recommended that the forward medical station be designed to support these activities. Seeking a facility located in a permanent or semipermanent structure which would have electrical power, potable water supply, and air conditioning, the committee recommended that this forward medical station be housed in the Ground Air Transmitter Building or an equivalent building equally accessible to the skid strip. If such a building were not available, it was recommended that it be constructed. Trailers and tents would be the last resort. To staff this forward medical station, the following professional and subprofessional personnel were to

be assigned: one traumatologist, two anesthesiologists, and two independent-duty technicians.

By the summer of 1960 plans were completed, and in late June 1960 the Professional Advisory Committee visited Grand Bahama Island and Grand Turk Island in an effort to develop a better understanding of the medical parameters of Project Mercury manned flight operations. As a result of this visit, the committee recommended that the medical facilities on Grand Bahama Island and Grand Turk Island include at least 1,200 square feet and be comparable to those at Patrick AFB. It was suggested that quonset huts equipped with one operating room be utilized. No additional space for debriefing would be needed, since this could be conducted in the medical facility. It was contemplated that the astronaut would ordinarily not be held on these islands for more than 48 hours, with 72 hours as a maximum. No convalescent period was foreseen.

The committee also considered other vital points of medical support.

In summary, the following recommendations were made:

1. The medical facility on Grand Bahama Island would be backed up by staff at Patrick AFB and Cape Canaveral.
2. On all destroyers there should be a technician capable of performing laboratory duties.
3. All physicians selected should be certified by their specialty board or the equivalent.
4. An oral surgeon and a group of consultants should be on call the day of launch.
5. The space required at Cape Canaveral for medical facilities would be 1,000 square feet, and not 2,000 square feet as originally planned.

Thus did the large-scale medical complex for support of Project Mercury manned flight begin to take shape.²¹

On July 6, 1960, following this meeting, the Associate Director of Project Mercury, Walter C. Williams, summed up the STG medical requirements for launch, flight, and recovery in a letter addressed to the DOD Representative, Project Mercury Support Operations:

For each phase of operation, Launch, Flight, and Recovery, certain steps have been taken by the Space Task Group and the Department of Defense to provide the necessary medical service. Launch Operations are supported by a combined team of Space Task Group and AFMTC medical personnel making use of AFMTC and special facilities. Network and Flight Control

Operations are supported by a team of medical monitors in response to the STG request. . . .²²

The level of acceptable medical care was to be in two categories: Emergency Surgical Care and Specialty Care. The Associate Director of Project Mercury described each:

(a) Emergency Surgical Care consists of personnel and equipment to be available on each major recovery vessel assigned to the planned landing areas and on Cape Canaveral for the Launch Site Recovery Area. The personnel suggested by the study are, a surgeon and anesthesiologist supported on the ships by the pharmacists mates and at the Cape by Air Force medical personnel. The equipment is expected to be portable and brought aboard by the Emergency Surgical Team. If it can be shown that an injured astronaut and Emergency Surgical Team can be brought together reliably and quickly by transfer, in certain areas, this requirement can be appropriately reduced. The embarkation of personnel and equipment will probably have to be coordinated by the Recovery Task Force Commander.

(b) Specialty Care consists of mobile team of medical specialists and facilities to support them. The suggested team would include an internist, neurosurgeon, thoracic surgeon, orthopedic surgeon, general surgeon, burn specialists, and a pathologist, each with the necessary assistants. The facilities would include a base hospital, advanced base hospitals, transportation, and communications. The suggested base hospital is Patrick Air Force Base where the Specialty Team would be gathered prior to launch. The suggested advance base hospitals are at Cape Canaveral, Bermuda, Canary Islands, Grand Turk Island, and Grand Bahama Island. The latter two would serve as routine debriefing facilities as well as Specialty Care facilities for Atlas and Redstone flights respectively. The advanced base facilities would be existing military or civilian facilities augmented with portable specialty equipment. The debriefing facilities may require some prior augmentation for debriefing purposes which may include some medical equipment. Transportation should be available between the base hospital and the advanced base hospitals, if required. Communications for specialty consultation can be provided by planned network and recovery communication systems through the Mercury Control Center, if required. The coordination of this Specialty Team will probably have to be done in conjunction with STG medical personnel at Cape Canaveral.

With respect to Recovery Operations, it was noted that STG had requested a study by Captain Graybiel to determine the desirable medical services. This study now having been completed, STG desired to implement certain of its conclusions by a request for necessary aeromedical support of recovery operations.

PLANS FOR RECOVERY OPERATIONS

Because the Mercury concept included water landing of the spacecraft, the problems of search and recovery were to be given considerable attention. As early as the winter of 1958-59, the

Space Task Group, with the assistance of the Launch Officer assigned to STG, had developed a basic recovery plan. In early spring of 1959, a joint NASA-DOD working group was established to develop these plans in more detail. This resulted in Navy responsibility for recovery being assigned to the Atlantic Fleet, and in turn to Destroyer Flotilla Four (DesFlotFour). When General Yates became the DOD representative for Project Mercury in August 1959, the earlier joint NASA-DOD working group was superseded; Capt. J. G. Franklin, USN, became Naval Deputy to General Yates, and recovery became the responsibility of the Project Mercury Support Planning Office. According to Paul E. Purser, Special Assistant to the Director of Project Mercury, "Because of the excellent progress already made and the excellent working relationships which had been established, DesFlotFour remained responsible for the details of the recovery operation."²³

During the spring and summer of 1959, the Space Task Group furnished several boilerplate spacecraft which were used by DesFlotFour in developing detailed recovery techniques.

Following the appointment of General Yates, in August 1959, as the DOD Representative for Project Mercury Support operations and his designation of Dr. Knauf in December 1959 as his Assistant for Bioastronautics, plans for recovery of the astronaut had received new impetus. The earlier planning of Dr. Graybiel and his group (as requested by STG) was now reoriented to the DOD-STG effort at the Air Force Missile Test Center. Tentative plans began to develop for the medical care and maintenance of the astronaut following impact.²⁴

On January 9, 1960, Dr. Knauf met with Dr. Graybiel and his group to exchange ideas about the course of this planning. Dr. Knauf noted that General Yates did not accept the premise that a medical officer should be involved in actual recovery operations, and that the position and function of the medical officer in primary operations areas was as yet unclear. It appeared that only major medical problems should be treated by the recovery teams, with no definitive care aboard the destroyer. Existing hospital facilities along the path of orbit should be alerted, and the astronaut should be taken to the nearest shore hospital with dispatch.²⁵

Through the next 6 months, the Naval School of Aviation Medicine worked intensively to prepare a plan for the recovery of the astronauts at sea. The dimension of this planning is apparent in the fact that the primary eight planned impact areas had an average width of 33 miles and a combined length of 2,747 miles. When



Recovery of the astronaut after reentry and water landing was exhaustively studied by Mercury medical staffs. Shown here are the flotation collar (left), developed by Dr. Stullken of the U.S. Navy, with which the pararescue men could lift and stabilize the reentered spacecraft; and the survival gear (be-



the first orbital flight was made, there were in fact 24 ships including 3 carriers deployed, with 13 Marine helicopters, 1 Navy aircraft, and 15,000 Navy personnel involved in recovery operations alone.

In early 1960, however, the medical aspects of this program were as yet under study, and not until June 1960 was the final report submitted to NASA.²⁶ This plan, sent from the DOD Representative for Project Mercury Support to the Space Task Group, was eventually to become the NASA Recovery Plan.

low, left) as fully developed for the Schirra flight. Recovery techniques were exercised in such events as the helicopter recovery of the chimpanzee Ham (MR-2, January 31, 1961) (right) and ship (U.S.S. Decatur) recovery of the unmanned spacecraft that orbited September 13, 1961 (MA-4).



Animal Recovery Plans

On July 7, 1960, STG forwarded the Animal Recovery Plan to General Davis, the DOD Representative, Project Mercury Support Operations.²⁷ On the same day, Walter C. Williams, Associate Director of Project Mercury, informed him that if the proposed animal recovery plan were put into effect, it would be necessary for veterinary personnel to be assigned to duty both on vessels and at the Aeromedical Field Laboratory at Holloman Air Force

Base to receive training in the routine and emergency handling of animals.²⁸ Initial requirements were as follows:

	<i>Veteri- narians</i>	<i>Techni- cians</i>
Little Joe 5.....	1	1
Redstone 2.....	2	6
Atlas 4.....	2	16
Atlas 5.....	7	22

(Subsequently the requirements for Redstone 2 were doubled, and requirements for Atlas 5 were set at 12 veterinarians and 20 technicians.)²⁹

It was understood by STG that the Department of Defense could meet this requirement and that selection of personnel would be under the guidance of Maj. Walter E. Brewer, USAF (VC). Training schedules would be established by the Aeromedical Field Laboratory in consultation with Major Brewer.

Astronaut Recovery Plans

Although the Commander, AFMTC, was the DOD representative responsible for recovery, the responsibility for recovery of the Mercury astronaut and spacecraft in preplanned high-probability areas and contingency areas in the Atlantic Ocean was assigned to CINCLANT, who designated the Commander, Destroyer Flotilla Four, as his executive agent in this matter. This was outlined in NASA Project Mercury Working Paper No. 162, "Project Mercury Medical Recovery Operation." Task Force 140 was established in the Atlantic Fleet of the U.S. Navy and designated the Project Recovery Force for the Atlantic Command area. U.S. unified and specified commands were directed to support the Project Mercury operation "to the maximum consistent with primary responsibilities for national defenses."

The manned spacecraft would be inserted into orbit through use of the Atlas launch vehicle and its associated radio-inertial guidance system. The launch would be from AFMTC, Cape Canaveral, Fla., a site that would enable an eastward launch over water, to take advantage of the earth's rotation. The launch azimuth would be slightly north of east to obtain an orbit inclination of approximately 32.5°; with this inclination, all orbits would cross the continental United States and would avoid unfriendly territory. Since the spacecraft landing was planned for a water area, every effort was to be made, in the event of an emergency, to land the spacecraft in water.

The planning of Air Rescue Service was to be guided by this premise, although it was recognized that land recovery must also be considered, particularly for the North American and African continents. It was, therefore, envisioned that Air Rescue Service forces, along with other forces of the unified and specified commands, would be deployed to preselected sites to permit location of the spacecraft within 18 hours after notification of the predicted landing point. The expected lifetime of spacecraft search aids was 24 hours, so they could not be depended upon after that elapsed time.

On March 7, 1961, the Assistant for Bioastronautics requested CINCUSAFE, ARS, CINCPAC, CINCLANT, and CINCEUR to examine the requirements placed upon them by NASA Project Mercury Working Paper No. 162, which dealt with "Project Mercury Medical Recovery Operation."³⁰ Each addressee was requested to derive an operational procedure for providing medical support as an annex to its "Contingency Area Operations Plan." Since the several search and rescue areas varied widely in geographical character and in availability of local resources, the medical annex was to be coordinated among the various agencies involved. In summary, the annex provided that search and rescue forces including an appropriate number of pararescue teams trained in Project Mercury spacecraft emergency procedures would be responsible for search, location, and retrieval of any Project Mercury spacecraft or astronaut that might land in any of the designated regions except the part of the Atlantic Ocean included in Project Mercury planned landing areas 1 through 9.

During Project Mercury manned flight operations each aeromedical monitor assigned to a tracking station on the Project Mercury global range would exercise emergency medical surveillance over the area for which he had been assigned responsibility. These areas of responsibility were as follows:

<i>Aeromedical monitor site</i>	<i>Longitude boundaries of area of responsibility</i>
Bermuda.....	80° W. to 60° W.
Atlantic Ocean ship.....	60° W. to 30° W.
Canary Islands.....	30° W. to Meridian of Greenwich
Kano, Nigeria.....	Meridian of Greenwich to 30° E.
Zanzibar.....	30° E. to 60° E.
Indian Ocean ship.....	60° E. to 100° E.
Muchea, Australia.....	100° E. to 130° E.
Woomera, Australia.....	130° E. to 170° E.
Canton Island.....	170° E. to 160° W.

Hawaii.....	160° W. to 140° W.
Pacific Missile Range.....	140° W. to 120° W.
Guaymas, Mexico.....	120° W. to 100° W.
Corpus Christi, Tex.....	100° W. to 80° W.

In the event of an emergency landing in his area, the aeromedical monitor concerned would assume full responsibility for the medical care of the astronaut. The theater surgeon concerned would, in coordination with the designated aeromedical monitor, assume medical administrative responsibility for the initial hospital care of the astronaut. The STG was to be prepared to airlift to any point agreed upon by the theater surgeon concerned and the medical director of Project Mercury such professional medical specialty support as might be required to provide the desired medical care for the astronaut when a comparable level of medical competence was not available locally. The various areas of responsibility and the procedures involved were clearly defined.

DETAILED RESPONSIBILITIES

The NASA Space Task Group on September 9, 1960, requested that the supply and resupply of equipment in support of Project Mercury recovery operations be the responsibility of the Assistant for Bioastronautics, Office of the Department of Defense Representative. Specifically the DOD Representative for Bioastronautics should take necessary steps to procure medical equipment as listed in the "Medical Annex, Medical Recovery Operations, Project Mercury," which had been revised on September 9, 1960, "and such other medical supplies and resupplies as deemed necessary." The use of this equipment and supplies would be on a no-cost basis to NASA for items returned to DOD. NASA would pay the cost of nonreturned items. Upon termination of the mission, control of medical resources would revert to the Assistant for Bioastronautics, Office of the DOD Representative, Patrick AFB. NASA would bear the cost of transportation of medical resources in the implementation of the medical recovery operation of Project Mercury.³¹

Meanwhile, as the months had passed, the responsibility of DOD for support of Project Mercury in other areas had become clarified. For example, details of carrying out the astronaut preflight feeding program at Cape Canaveral came under study during early 1960. On February 18, 1960, Walter C. Williams, Associate Director for Project Mercury, requested that DOD personnel at

Patrick AFB be responsible for the 3-day low-residue diets prior to each manned shot, as well as for feeding prior to practice count-down. Technical and operational advice would be provided by the Space Task Group.³² Specifically it was suggested that Miss Beatrice Finkelstein, research nutritionist and dietitian in the Aerospace Medical Laboratory at Wright Air Development Center, supervise the program in the kitchen and dining facilities available near NASA Hangar S at Cape Canaveral. Colonel Knauf and Miss Finkelstein agreed with this suggestion, and on July 21, 1960, she submitted an organizational plan for the pre-flight feeding of astronauts participating in Project Mercury.³³

In substance, the plan called for a high-protein, low-residue diet for 72 to 96 hours prior to takeoff so as to preclude defecation during flight. This precaution was taken because the protective clothing worn by the astronaut could not without danger be removed in flight, and performance of this physiological function would be difficult. The diet had to be prepared and served under rigidly controlled conditions. Because of the stringent demands placed upon the astronaut in his preflight activities, it was recommended that a small food-preparation facility be added to the readiness room. Building 5-1540, Area 39, at Cape Canaveral could be renovated at a minimum cost; food supplies could be obtained from the commissary at Patrick AFB or through local purchase; accounting of moneys spent for food could be made to the hospital food service; and staffing could be handled by two medically trained food-service individuals. Assistance in carrying out this program could be given by the research nutritionist assigned to the Wright Air Development Center.³⁴

As the plan was finally worked out with respect to accounting of moneys spent for food, procedures for procurement on a NASA reimbursable basis were developed by the Office of the Assistant for Bioastronautics without including the hospital food service accounting.³⁵

In another area, the Project Mercury blood program, plans were completed by the spring of 1961. On January 5 the DOD Assistant for Bioastronautics had forwarded the proposed program to STG for review, and on February 16 the Associate Director, Walter C. Williams, approved the program and requested that the Assistant for Bioastronautics proceed with implementation.³⁶

The plan stipulated that blood would be drawn from personnel available locally should a transfusion for the astronauts become necessary. Group and type-specific blood, without cross-matching,

In October and November of that year, Little Joe 1 and Little Joe 2, respectively, were fired from NASA's Wallops Station, Va., to test other aspects of the program. On December 4, 1959, Little Joe 3 was also fired from Wallops Station to check high-altitude performance of the escape system, with rhesus monkey Sam used as a test subject. The next month, on January 21, 1960, Little Joe 4 was fired from Wallops Station to evaluate the escape system under high airloads with another rhesus monkey—Miss Sam—as a test subject. These were followed by a beach abort test on May 9, 1960, and by an unsuccessful shot of the Mercury-Atlas 1 on July 29, 1960. Little Joe 5, also unsuccessful, was fired from Wallops Station on November 8, 1960.

Mercury-Atlas 2 was launched on February 21, 1961 (discussed in detail in the following chapter), and Little Joe 5A on March 18, 1961. On April 25, 1961, Mercury-Atlas 3 was launched in an attempt to orbit a "mechanical" astronaut. Forty seconds after launching, the launch vehicle was destroyed, but the spacecraft was recovered. Little Joe 5B was fired on April 28, 1961, and represented the third attempt to check the escape system under the worst possible conditions. The shot was successful.

Thus, by the spring of 1961, STG was prepared, from the engineering and operations point of view, for the projected Mercury-Redstone 3 flight scheduled for early May. It would carry the first American astronaut on a ballistic flight path. This would be prelude to the first U.S. manned orbital flight.³⁹

Meanwhile, medical support plans for the launching, tracking, and recovery of the astronaut continued. The time and talent contributed by key medical personnel in the services as well as by the day-to-day working-level group is immeasurable. For example—to name only two—Brig. Gen. James W. Humphrys (MC), USAF, commander of the USAF Hospital at Lackland Base, and Brig. Gen. Don C. Wenger, then Deputy Director of Professional Services in the USAF Office of the Surgeon General, were to make themselves available at the shortest notice whenever professional problems arose in connection with planning. Later, as the actual flights were scheduled, they were there at the launch site during the long countdowns, postponements, flights, and recovery. This was part of the pattern carried out not only "in line of duty" but because every element of the military medical profession, no less than the civilian, shared in this most extensive peacetime effort of mobilization.



Extensive testing of Mercury spacecraft and equipment preceded the first manned flight. Above, left, rhesus monkey Sam still sits safely in his biopack on December 4, 1959, after being recovered from a sea landing following a suborbital flight aboard a Little Joe (LJ-3) to test the escape system at high altitude. Miss Sam (above) was recovered after a similar flight (LJ-4) on January 21, 1960. In addition to flight tests, many water tests (left) were also performed, to check on seaworthiness and stability.

NOTES TO CHAPTER VII

¹ Cape Canaveral (later Cape Kennedy) had originally been chosen as a launch site by the DOD for four reasons: (1) The 15,000-acre tract was remote enough to be a safe place for launching test missiles, (2) it provided a vacant area (the Atlantic Ocean) over which the missiles could travel, (3) the climate was suitable for year-round operations, and (4) there was to the southeast a chain of islands on which tracking and telemetry stations could be built. In addition, there was an inactivated Navy base 18 miles south of the cape which would be reactivated (as Patrick AFB) to support AFMTC.

² Thomas S. Gates, Deputy Secretary of Defense, Memo for Secretaries of the Military Depts., the Director of Defense Res. and Engineering, the Chairman, Joint Chiefs of Staff, the Asst. Secretaries of Defense, the General Counsel, the Director, Advanced Res. Projects Agency, and the Assistant to the Secretary of Defense, Subj.: Assignment of Responsibility for DOD Support of Project Mercury, Aug. 10, 1959.

³ See p. 89 for further discussion.

⁴ Gates, *op. cit.* See also Thomas S. Gates, Memo for Maj. Gen. Donald N. Yates, USAF, Subj.: Responsibility for DOD Support of Project Mercury, Aug. 10, 1959.

⁵ The Honorable James H. Douglas, Deputy Secretary of Defense, Memo for Maj. Gen. Leighton I. Davis, USAF, July 9, 1960.

⁶ Maj. Gen. D. N. Yates, DOD Representative, Project Mercury Support Operations, Memo for Col. George M. Knauf, USAF (MC), Subj.: Designation of Assistant for Bioastronautics, Dec. 1, 1959.

⁷ On Jan. 1, 1962, Colonel Knauf was transferred to Hq., NASA, to serve as Deputy Director of Aerospace Medicine, Office of Manned Space Flight (Special Orders AC-809, Hq. AFASC). He was succeeded by Col. Raymond A. Yerg, USAF (MC), who on Oct. 9, 1961, had been designated Deputy Assistant for Bioastronautics [Maj. Gen. L. I. Davis, DOD Representative, Project Mercury Support Operations, Memo for MTD (Col. Raymond A. Yerg), Subj.: Designation of Deputy Assistant for Bioastronautics, Oct. 9, 1961].

⁸ Lt. Col. Stanley C. White, Head, Life Systems Br., Space Task Group, Memo for Project Dir., Subj.: Medical Support for Project Mercury, Oct. 29, 1959.

⁹ Walter C. Williams, Assoc. Dir. of Project Mercury, Ltr to Maj. Gen. Donald N. Yates, DOD Representative, Project Mercury Support, AFMTC, Patrick AFB, Fla., Subj.: Medical Personnel to Support Project Mercury Flight Operations, Nov. 13, 1959.

¹⁰ NASA Space Task Group Briefing, "Medical Monitoring for Project Mercury," Dec. 11, 1959.

¹¹ The three Surgeons General had designated the following officers to serve as their representatives for Project Mercury: Army—Lt. Col. John A. Sheedy, USA (MC); Navy—Capt. Vance E. Senter, USN (MC); Air Force—Col. Karl Houghton, USAF (MC).

¹² As described in ltr from Col. George M. Knauf, USAF (MC), to Hq. USAF, Office of the Surgeon General, Attn.: Col. Karl H. Houghton, USAF

(MC), Subj.: Medical Support of Project Mercury Flight Operations, Dec. 21, 1959.

¹⁵ Robert R. Gilruth, Dir. of Project Mercury, Ltr to Maj. Gen. Donald N. Yates, DOD Representative, Project Mercury Support Operations, Hq. AF Missile Center, Patrick AFB, Dec. 18, 1959. See also ltr, Knauf to Houghton, cited above.

¹⁴ Col. George M. Knauf, USAF (MC), Asst. for Bioastronautics, DOD Representative for Project Mercury Support, Ltr to Maj. Gen. Otis O. Benson, USAF (MC), Commandant, Aerospace Medical Center, Brooks AFB, Tex., Jan. 12, 1961. Further information obtained in interview with Dr. Lamb by the author in Oct. 1963.

¹⁶ Also consultant to STG, Dr. Ellington was at that time Commander of the Gunter Branch of the USAF School of Aerospace Medicine. He later became Commandant of the School of Aerospace Medicine.

¹⁸ Minutes of the meeting, Apr. 13, 1960, prepared by Lt. Col. W. K. Douglas, STG.

¹⁷ Colonel Knauf, Ltr to the Surgeons General, Army, Navy, and Air Force, Apr. 16, 1960; interview with Colonel Knauf by the author, Aug. 21, 1962.

¹⁹ Present as observers were representatives of the Asst. Secretary of Defense, the Lovelace Advisory Group, and the Space Task Group.

²⁰ Interview, Colonel Knauf by the author, Aug. 21, 1962.

²¹ Walter C. Williams, Ltr to Hq., NASA, June 7, 1960.

²² There were professional details that would be equally time consuming and require the painstaking attention of the committee as well. For example, when the members met again at Cape Canaveral on Nov. 29, 1960, details of medical supplies and equipment were discussed.

²³ Walter C. Williams, Assoc. Dir. of Project Mercury, Ltr to Maj. Gen. Leighton I. Davis, USAF, DOD Representative, Project Mercury Recovery Operations, Subj.: Aeromedical Support for Project Mercury Recovery Operations, July 6, 1960.

²⁴ Paul E. Purser, Spec. Asst. to Dir., Project Mercury, Memo for Files, Subj.: Additional Background Material on Project Mercury, May 11, 1960.

²⁵ Ashton Graybiel, "Aerospace Medicine and Project Mercury—Navy Participation," *Aerospace Med.*, vol. 33, no. 10, Oct. 1962, pp. 1193-1198.

²⁶ Informal notes of meeting with Dr. Knauf by Dr. Beischer, U.S. Naval School of Aviation Medicine, July 9, 1960.

²⁷ A. Graybiel, D. E. Beischer, *et al.*, "Project Mercury—Medical Aspects of the Recovery Program," SAM P-14, prepared for NASA at U.S. Naval School of Aviation Medicine, Pensacola, Fla., 1960.

²⁸ Walter C. Williams, Assoc. Dir. of Project Mercury, Ltr to Maj. Gen. Leighton I. Davis, DOD Representative, Project Mercury Support Operations, Attn.: Col. Knauf, July 7, 1960.

²⁹ Col. Raymond A. Yerg, USAF (MC), Deputy for Bioastronautics, Ltr to M. M. Link, Sept. 27, 1963.

³⁰ Animal Recovery Plan, initialed "JPH, 6/30/60," attached as enclosure to ltr from Walter C. Williams, Assoc. Dir. of Project Mercury, to DOD Representative, Project Mercury Support Operations, July 7, 1960.

³¹ Asst. for Bioastronautics, Ltr to CINCUSAFE, ARS, CINCPAC, CINCLANT, and CINCEUR, Mar. 7, 1961.

³² Walter C. Williams, Assoc. Dir. for Project Mercury, Memo for Maj.

Gen. Leighton I. Davis, DOD Representative, Project Mercury Support Operations, Attn.: Col. George M. Knauf, Sept. 20, 1960.

²² Walter C. Williams, Assoc. Dir. for Project Mercury, Ltr to Maj. Gen. Donald N. Yates, DOD Representative for Project Mercury, Feb. 18, 1960.

²³ Beatrice Finkelstein, Chief, Food Technology Section, Life Support Systems Lab., Aerospace Medical Div., Ltr to Col. George Knauf, USAF (MC), Patrick AFB, Subj.: Organizational Plan, Project Mercury, July 2, 1960.

²⁴ Project Mercury, Organizational Plan for Pre-Space Flight Feeding, dated July 21, 1960.

²⁵ Col. Raymond A. Yerg, USAF (MC), Ltr to M. M. Link, Sept. 27, 1963.

²⁶ Walter C. Williams, Assoc. Dir., Project Mercury, Ltr to Commander, AFMTC, Attn.: Col. Knauf, Feb. 16, 1961.

²⁷ This program was based on ltr from Col. Frank M. Townsend, USAF (MC), Director of the Armed Forces Institute of Pathology, to Staff Surgeon (Colonel Knauf), Subj.: Proposed Blood Program for Project Mercury, Dec. 13, 1960.

²⁸ Walter C. Williams, Kenneth S. Kleinknecht, William M. Bland, Jr., and James E. Bost, "Project Review," in *Mercury Project Summary Including Results of the Fourth Manned Orbital Flight, May 15 and 16, 1963*. NASA SP-45, 1963, p. 2.

²⁹ *Manned Space Flight Program of the National Aeronautics and Space Administration: Projects Mercury, Gemini, and Apollo*. Staff Report of the Senate Committee on Aeronautical and Space Sciences, Sept. 4, 1962, pp. 52-53.

CHAPTER VIII

The Season of Crisis: 1961

THE 6-MONTH PERIOD prior to the first manned suborbital flight in May 1961 was fraught with changes at the national level which saw NASA reach its lowest point and catapult again to an even more significant role than it had previously enjoyed. In the early weeks of 1961, the future of the American space flight program beyond Project Mercury hung in precarious balance. It was a momentous period of NASA's history, and its highlights help set the stage for the related Mercury events herein recounted.

Three and one-half years earlier the Nation had rallied enthusiastically to the challenge of the Soviet Sputnik. The National Aeronautics and Space Act of 1958 had been signed into law and created a new agency, NASA. The national objective of the exploration of space for peaceful purposes had crystallized the decision at the Presidential level which led to the establishment of Project Mercury as the pioneering step in manned space flight. Its mission was to launch a man into space, orbit him around the earth, and recover him safely. In national priority, Project Mercury ranked second only to the national defense effort after 1958.

Now, in the message accompanying his Federal Budget for Fiscal Year 1962, President Eisenhower said:

In the program of manned space flight, the reliability of complex booster, capsule, escape, and life support components of the Mercury system is now being tested to assure a safe manned ballistic flight into space, and hopefully a manned orbital flight in calendar year 1961. Further test and experimentation will be necessary to establish if there are any valid scientific reasons for extending manned space flight beyond the Mercury program.

President Eisenhower, mindful of the economic impact of the 1959-60 recession, thus stated in his final budget to Congress that an evaluation was underway to determine whether manned space flight would be continued beyond Project Mercury. This decision, by implication, would be the responsibility of his successor

as well as a product of the success of manned flight in the Mercury program itself.

It is of importance to the history of space medicine that in the weeks just prior to his inauguration, President-elect Kennedy was in the process of reviewing the space program, among other areas of concern. On January 12, 1961, the President-elect released a report prepared by an advisory committee under the chairmanship of Dr. Jerome Wiesner, a member of the President's Scientific Advisory Committee under President Eisenhower, and later President Kennedy's own scientific adviser.¹ The Wiesner report initiated a chain reaction vitally affecting Project Mercury, particularly the medical aspects. It was highly critical of NASA organization and management, and recommended to the President-elect that there be a sweeping reorganization of the national space program, involving effective use of the National Aeronautics and Space Council, single direction within DOD of military space efforts, stronger technical management in NASA, and closer government partnership with industry. The Wiesner report was also critical of the Atlas launch vehicle which was to orbit the Mercury astronaut in space, stating that it was "marginal." Indeed, it was concluded that because the U.S.S.R. possessed larger launch vehicles, the United States would not be the first to orbit a man in space. The report stated:

We have concluded that it is important to reassess thoroughly national objectives in the space effort—particularly in regard to man in space; science and exploration; and the non-military application of space, in order to assure a proper division of effort among these activities. . . .

Mr. Kennedy had, in the weeks prior to his inauguration, turned over to Vice-President-elect Johnson the responsibility of recommending a NASA Administrator. He had found that those who advocated a strong civilian space program were opposed both by influential scientists who wanted to curtail manned space exploration and by spokesmen of the military-industrial complex who favored turning over the major role in the space program to the U.S. Air Force.² James E. Webb, whose name was submitted by Senator Robert S. Kerr of Oklahoma (who had succeeded the Vice-President-elect as chairman of the Senate Aeronautical and Space Sciences Committee), was approached and persuaded to accept the position of Administrator. A businessman and lawyer dedicated to public service, he was to infuse new life almost immediately into the NASA structure.

Mr. Webb endorsed an accelerated space program based on in-

house NASA planning, to include consideration of a landing on the moon by 1969-70 instead of "after 1970," as had been projected by NASA under the previous administration. He asked the Bureau of the Budget for an additional \$308 million to supplement the Eisenhower budget of \$1.1 billion, to be applied mostly to the development of large launch vehicles.

MERCURY BIOMEDICAL CAPABILITY QUESTIONED

During the period of transition from one administration to the other, the Operations Staff of Project Mercury had continued their efforts toward manned space flight. As yet, no known orbital manned flight had been made by any country. A U.S. suborbital animal flight was scheduled for late January 1961, however, and would be followed shortly by a manned suborbital flight.

In the wake of the Wiesner report, the objectives of Project Mercury were critically reviewed by the President's Scientific Advisory Committee. This included a close look at the management of biomedical support for manned space flight.

Since the fall of 1958, when Project Mercury was announced as the first U.S. manned space-flight program, this moment of crisis had been slowly building in the life-sciences community both inside and out of government circles, although it took the impact of the Wiesner report released on January 12, 1961, to bring it to the point of explosion. A key medical spokesman for Project Mercury later summed it up in these words:

A universal debate concerning whether man could survive in the hostile environment of space was carried on by all of the scientific disciplines as late as 1958 . . . numerous problems were identified which might jeopardize man and thereby make his chance of survival tenuous if at all possible. The fact that the problems concerning survivability originated from the varied scientific disciplines gave emphasis to their plausibility.³

The conflict was mainly between the laboratory scientist, who wished to take a conservative course and carry out extensive animal experimentation prior to exposing a human being—perhaps tragically—to manned space flight, and the operations engineer. The latter relied to a great extent upon the extension and application of existing biotechnology and biomedical experience that had supported the X-15 and other comparable programs. It was believed that the hazards of manned space flight were no greater than those experienced by the X-15 test pilot.

The assessment of the Mercury biomedical program which was to take place in March 1961 would be formalized in a report sub-

mitted to the President in April. By that time significant progress had been made in Project Mercury, including the first successful suborbital flight by chimpanzee Ham.

THE LESSONS OF ANIMAL EXPERIMENTATION

Already the Russians had demonstrated that animals could survive in space. Between 1949 and 1952 they had carried out six experiments with dogs, reaching a maximum altitude of 55 nautical miles. By 1956 another nine flights, to a maximum altitude of 115 nautical miles, had been achieved.

Following Sputnik I, the Soviets had orbited a small dog, Laika, in Sputnik II (which weighed over 1,100 pounds). Laika had been equipped with a comprehensive array of telemetry sensors which gave continuous physiological information to tracking stations. The cabin conditioning system maintained sea-level atmospheric pressure within the cabin, and Laika survived 6 days before depletion of the oxygen stores caused asphyxiation. The Laika flight demonstrated that space flight was tolerable to animals. It indicated, too, that Soviet interests extended to the use of manned satellites. According to Fryer, who has summed up the situation very well indeed:

The really major problem which remained was that of reentry and the Russian intention of exploring this was made clear in August 1958 by their sending of two dogs on a ballistic flight to an altitude of 280 miles with the successful recovery by ejection of the dog container during the descent.⁴

Through the next 3 years, the Russians had pursued a systematic and progressive research and development program that would ultimately lead to the first manned orbital space flight in history.

In the United States, meanwhile, on January 31, 1961, Mercury-Redstone 2 was fired carrying Ham, a 37-pound chimpanzee. He had received 219 hours of training in behavioral task performance over a 15-month period. Prior to flight, he had been subjected to Redstone launch profiles on the centrifuge at the U.S. Air Force Medical Laboratory, Dayton, Ohio.⁵ The spacecraft reached an altitude of 155 statute miles, landed 420 statute miles downrange, and was recovered. By the time it was recovered it was nearly filled with water because some small holes had been punctured in the lower pressure bulkhead at landing. Ham was rescued before the spacecraft had taken on too much water.⁶ From the engineering and operations point of view, the flight was a success except for the leaking spacecraft. The flight had demonstrated the validity of the Mercury spacecraft.

Life scientists, however, raised immediate questions about the advisability of proceeding with the first suborbital manned flight because of the biological information telemetered back to tracking stations during the flight. As previously noted, both inside and outside NASA there had been those who, from the very beginning, had questioned the advisability of early manned space flight prior to extensive animal experimentation. As early as January 1959, when the Joint AF-NRC Committee on Bioastronautics had visited the Space Task Group at Langley, there had been a lively discussion about the need for such experimentation, not merely to test the life-support system of the spacecraft, but to determine the effects of combined stresses upon man. According to the résumé of the briefing given by STG:

The formal part of this briefing was well received and was followed by a rather lively discussion period. The main subject of the discussion was the need for animal flights preceding any manned flights in the proposed program. Many members of the group were strong in their opinion that any new mission involving a man could not be justified unless the mission had been previously validated by successful recovery of animals.⁷

The basic reasoning behind this idea was the fact that little was known about the effects of combinations of high stresses such as would occur in the Project Mercury missions.

At this briefing, representatives of the Space Task Group had pointed out that animal flights were involved in the program, but that the flights were "oriented directly at the Mercury objectives," that is, testing the system itself. The visiting AF-NRC Committee, it was reported, "felt that this approach was satisfactory," but "emphasized that our animal program should be pursued aggressively in that large lead times are involved." The résumé of the briefing concluded: "A rather definite impression was obtained that this group felt we should be utilizing animal validations to a greater extent than the briefing indicated."⁸

During the following months planning had proceeded as outlined by the Space Task Group to provide a limited number of animal flights prior to each progression in manned flight leading from suborbital to orbital flight. Prior to the establishment of the formal Mercury animal program, however, NASA was to make available a limited amount of space for the Air Force to carry out bio-pack testing in the Little Joe series. This may have resulted from the previous urging of the AF-NRC Committee on Bioastronautics. In any event, the animal program for Project Mercury was to consist of two phases: Flights of small primates in



The principal suborbital animal flight in connection with Project Mercury was that of the chimpanzee Ham on January 31, 1961. The flight was successful, and Ham reached happily for his first food after 4 hours in the spacecraft (above). The bio-medical data telemetered back during the flight did not completely satisfy the various schools of concern about the medical feasibility of manned space flight.

the Little Joe spacecraft, and flights of medium-size primates in Mercury spacecraft launched by Redstone and Atlas vehicles.⁹

These have already been discussed in connection with the sequence of testing carried out by NASA prior to manned flight. In the first phase, space had been made available to the USAF School of Aviation Medicine, Brooks AFB, Tex., for bio-packs containing American-born rhesus monkeys weighing 6 to 7 pounds. Although not an essential part of the Mercury program, these tests were to provide important data. Specifically, there was a biomedical evaluation of the accelerations expected during the abort of a Mercury flight at liftoff and shortly after liftoff. This test phase was successfully completed with the Little Joe flights on December 4, 1959, and in January 1960.

Following the initiation of the Little Joe bio-pack program,

representatives of NASA and the McDonnell Aircraft Corp., together with Navy, Army, and Air Force biomedical specialists, planned a further series of flight tests with animals to provide (1) animal verification of the feasibility of a manned flight, (2) data on the level of mental and physical activity that could be expected during a flight, and (3) a dynamic test of countdown procedures and training of support personnel in handling the biological aspects of manned flight. Briefly, it was agreed that existing Mercury spacecraft life-support, environmental-control, and instrumentation systems should be used without modification.

Responsibility for training the animals, preparing them for flight, and handling them after recovery was assigned to the 6571st Aeromedical Research Laboratory at Holloman Air Force Base. A NASA representative would serve as coordinator to integrate the animal flights into the total flight program. Two Air Force physicians were to be closely identified with the program. Lt. Col. James P. Henry, who served as NASA representative, had long enjoyed an international reputation in aviation medical research. His work had included high-altitude research in the late 1940's and the 1950's, including research to support the Air Force BOSS concept. Now, in 1959, he was a member of Dr. White's aeromedical team at STG. Dr. Hessberg, the second Air Force physician, directed the animal program at the 6571st Aeromedical Research Laboratory at Holloman AFB.

The decision to use chimpanzees rather than other primates for the Mercury animal program was aimed at providing the highest level of performance short of human. As described later by Henry and Mosely,¹⁰ restraint would be minimal so as to make possible the performance of psychomotor tests. The electrocardiograms, body temperature, and respiratory movement would be recorded by the techniques planned for use with human astronauts. If possible, arterial pressure would be recorded. Urine would be saved for a study of steroid output and there would be photography of the subject.¹¹

Although the Aeromedical Research Laboratory at Holloman possessed animals, veterinarians, and space physiologists, it lacked facilities to obtain behavioral measurements of the animals. Accordingly, arrangements were made to train several chimpanzees under contract with the Wenner-Gren Aeronautical Research Laboratory, University of Kentucky. Subsequently, Air Force personnel were transferred from the Unusual Environments Section of the Aerospace Medical Laboratory, Aerospace Systems Divi-

sion, Wright-Patterson AFB. Also, arrangements were made with the Walter Reed Army Institute of Research to aid in the establishment of a comparative psychology branch at AMRL. Training of eight chimpanzees began with the use of standard operator conditioning equipment and special restraint chairs.

As training progressed, the Veterinary Services Branch of AMRL was collecting normal baseline data on an entire colony of immature chimpanzees.¹² Study was also begun by specialists in ecology to determine the temperature and humidity tolerances of the chimpanzees. Concurrently AMRL personnel were designing and fabricating methods of restraint. A series of simulated flights was made on the centrifuge at the laboratory to determine the effects of acceleration and vibration on the chimpanzee, and also to evaluate the complete chimpanzee couch system. Medical recovery plans—described in the previous chapter—were being formulated by the Manned Spacecraft Center (formerly STG) at Langley, the Office of the Staff Surgeon, Patrick Air Force Base, and the Aeromedical Research Laboratory. A total of 35 veterinary technicians and 10 veterinary officers were trained. Lt. Col. Walter E. Brewer, USAF (VC), as previously noted, headed the program at Cape Canaveral.

This, then, had been prelude to the MR-2 flight on January 31, 1961. Now, in the weeks following the animal suborbital flight which had tested the spacecraft system, STG prepared for the first manned suborbital flight.

TOWARD COUNTDOWN

Events were to move swiftly toward the climax—the actual flight of the first U.S. man in space. All bore an interrelationship not only with science and technology, but also with the reassessment of U.S. goals in space exploration.

In the weeks following the suborbital flight of chimpanzee Ham on January 31, 1961, the life-sciences community began with renewed vigor to assess the biomedical program and to weigh the implications of early manned space flight without further animal experimentation. Secondhand sources, for example, have indicated to the author that highly placed officials suggested facetiously that centrifuges be transported to Africa where chimpanzees would be readily available for further testing prior to actual manned flight. Be that apocryphal or not, it would seem to indicate the trepidation felt by certain members of the life-sciences

group who felt that, at best, the Atlas launch vehicle was marginal and that perhaps manned space flight should proceed at a slower and more conservative pace rather than take what seemed an unwarranted risk with human life.¹³

In contrast to the scientists who desired further extensive animal testing prior to manned flight, the operations staff of STG had moved forward with confidence toward the first U.S. suborbital flight. Since 1958 their total effort had been to bend the potential of technology to overcome the hazards of space travel. The STG aeromedical team, having witnessed the application of technology to the problems of human survival in flight, was now satisfied that extension of the principles and practice of aviation medicine would suffice to sustain the astronaut for a short mission in space. Extended space flight would pose biological problems not yet understood; but the short-range Mercury flights must be undertaken as a logical step in the orderly progression of steps necessary to solve these problems.*

So intent was the Space Task Group upon the forthcoming Shepard flight—and the realization of a 3-year dream—that they may have given little thought to other developments. At NASA Headquarters, for example, the long-range life-sciences program was getting underway, having been established the previous March in accordance with the recommendations of the Kety committee. At the national level, a new administration had just come into office, and Dr. Glennan, the NASA Administrator, had been succeeded by James E. Webb. But at the STG level, there had been no concomitant change in the mission-oriented staff. Dr. Gilruth remained Director of Project Mercury; W. C. Williams was Operations Director; and the aeromedical team remained relatively unchanged. Dr. White continued to direct Medical Operations, and Dr. Douglas continued to be personal physician to the astronauts.

Apparently one point of continuing concern to life scientists outside NASA had been the lack of a program to measure blood pressure. Indeed, as early as the period of the Stever committee, the Lovelace ad hoc committee had recommended that this measurement be taken. Now, in April 1961, the Director of Life Sci-

*There was no document available to the author by which to gage the reaction of the President but, in the light of historical fact, it appears that he took no step to postpone the MR-3 flight, thereby indicating his own confidence in the mission. This part of the Mercury history remains yet to be written.



Provision for safe recovery of the astronauts at every point in the flight profile was an overriding concern in Project Mercury. In addition to the tracking stations, ships, and aircraft to be positioned downrange, the launch area featured for on-pad emergencies the "cherry picker" (above) to go in and remove the astronaut from his spacecraft;

for off-the-pad aborts the amphibious lark stood offshore to hoist the spacecraft out of the water and run in onto the beach near the forward medical center.

ences, NASA Headquarters, was to contract with Webb Associates, Yellow Springs, Ohio, to survey current capabilities in blood pressure measurement, state of the art, and suitability for use in space vehicles.

More than a dozen laboratories in Government and industry across the country were visited during May 1961 by Webb Associates. Four different instruments were found from which a choice could be made by NASA. This information, together with the results of an extensive literature search, was made available to Dr. Henry at the Space Task Group.¹⁴ In addition, a preliminary review of previous related experiences in laboratory stress situations was undertaken. This included such stresses as acceleration, heat and cold, hypoxia and hyperoxia, hypocapnia and hypercapnia, vestibular stimulation, and vibration.

The results of this study were to have impact in later flights, but not in April 1961 as the Space Task Group (STG) concentrated upon the immediate problem at hand—the MR-3 flight.

By April the crescendo of activities had begun to mount at an unprecedented pace as the days drew near for countdown and launch.

All plans for the Shepard flight had been made.

The eyes of the world were focused on one geographical spot—Cape Canaveral. Terms such as “gantry” and “cherry picker” were becoming part of the world language.

Soon there would be countdown. . . .

The author can remember in vivid detail the tension and great sense of dedication reflected by every team member at the Cape, each grateful for his own small part in this unprecedented event. On April 12, she was one of the group from the Office of the Surgeon General, USAF, which was visiting Cape Canaveral for a Mercury briefing and a staff visit to Grand Bahama Island, where the prefabricated surgical hospital and debriefing unit had been recently built. This briefing had been arranged by Col. George M. Knauf, the DOD Assistant for Bioastronautics, Project Mercury.

Each person living then would remember his own reaction to that historic day, April 12, 1961, and tell his children and his children's children; but that visiting group would remember it with particular intensity.

There had been the ride by military bus from Patrick Air Force Base to the Cape Canaveral complex, and the strict security guard at the gate.

Then the ride along the stark flat land with the gantries in the distance rising orange-red into the sky. And finally, the briefing room.

It was during the briefing by General Flickinger, Assistant for Bioastronautics to General Schriever, Commander of the Air Force Systems Command, that he was handed a note. He read it, then quietly announced to the group: “They've got a man in orbit.” “They” meant the Soviet Union.

Disappointment, yes, that the United States had not been first—that was the immediate reaction. Following close, then, the sense of pride in what man, with his scientific knowledge, had been able to accomplish. And then, the new girding of will and dedication to the U.S. effort . . . this was the emotional pattern that day. Or so it seemed to the writer.

On this day, April 12, 1961, the Russians had successfully orbited the first man in space.

Six weeks later, on May 25, 1961, President Kennedy would

announce as a national objective an accelerated space program to accomplish a landing on the moon in the 1969-70 period instead of sometime after 1970 as projected by the previous administration.

Success obviously breeds success, and now that technology had validated the fact that man could be provided with the necessary life-support systems for short-term space flight, there would be the orderly progression to overcome the biological hazards of extended space flight. As a first step, the United States would carry out the Shepard suborbital flight as planned. For, although Gagarin had demonstrated that man could survive space travel, the United States had yet to test its own spacecraft and life-support system.

During the 3 weeks after the Gagarin flight the pace of activities at Cape Canaveral, the command post, intensified. Waiting—checking the last-minute details—tense to the point of explosion—the aeromedical team had gathered together from the corners of the earth to focus upon one lone man who, atop a rocket, would shortly plunge into the unknown.

There was the waiting period for the astronaut as he went into retreat, accompanied only by his fellow astronauts and by the aeromedical team.

Finally, in the very early hours of the morning he would arise, partake of a hearty low-residue breakfast, be dressed in his pressure suit, enter the waiting van with Dr. Douglas, his personal physician, and start through the morning darkness toward the gantry and the unknown.

Astronaut Shepard was ready.

NOTES TO CHAPTER VIII

¹“Report to the President-elect of the Ad Hoc Committee on Space,” for release to the press, radio, and television on Jan. 12, 1961. Other members of the Ad Hoc Committee were Kenneth B. Belieu, Staff Director, Senate Committee on Aeronautical and Space Sciences; Trevor Gardner, President, Hycon Manufacturing Co. (and former Asst. Secretary of the Air Force); Donald F. Hornig, Chairman, Dept. of Chemistry, Princeton Univ.; Edwin H. Land, President, Polaroid Corp.; Max Lehrer, Asst. Staff Director, Senate Committee on Aeronautical and Space Sciences; Edward M. Purcell, Prof. of Physics, Harvard Univ.; Bruno B. Rossi, Prof. of Physics, MIT; and Harry J. Watters, Assistant to the President, Polaroid Corp. Released report was an unclassified version of a more detailed classified document.

²Jay Holmes, *American on the Moon* (Philadelphia: J. B. Lippincott Co., 1962), p. 189. Mr. Holmes is currently in the Office of Manned Space Flight, NASA. This brief summary is based on his readable and interesting account. Much of the documentation for this important period is being col-

lected and collated for the John F. Kennedy Library by the NASA historical staff.

² Stanley C. White, "Biomedical Data Collection for Space Program," presented to First International Manned Space Flight Symposium, Unesco House, Paris, Oct. 3, 1962.

⁴ D. I. Fryer, "The Medical Sciences and Space Flight," *R.A.E. News*, Feb. 1964. See also Y. I. Gazdovsky, "Biological Experiments on Rockets and Artificial Earth Satellites," a paper presented at the Rocket and Satellite Symposium during the Fifth Revision of the Comité Spéciale, Année Géophysique Internationale, Moscow, July 30–August 9, 1958; Washington, D.C., National Academy of Sciences-National Research Council. See also A. G. Kousnetzov, "Some Results of Biological Experiments in Rockets and Sputnik II," *J. Aviation Med.*, vol. 29, no. 11, Nov. 1958, pp. 781–784. See also N. M. Sisakyan, ed., *Problems of Space Biology, Vol. 1*, NASA TT F-174, 1963.

⁵ Frederick H. Rohles, Jr., Marvin E. Grunzke, and Richard E. Belleville. "Performance Aspects of the MR-2 Flight," ch. 5 in *Results of the Project Mercury Ballistic and Orbital Chimpanzee Flights*, NASA SP-39, 1963. Mercury-Redstone 1, the first unmanned Redstone booster flight, had been fired Nov. 21, 1960. A premature engine cutoff activated the emergency escape system, but the spacecraft was recovered for reuse. The shot was repeated successfully on Dec. 19, 1960.

⁶ Walter C. Williams, Kenneth S. Kleinknecht, William M. Bland, Jr., and James E. Bost, "Project Review," in *Mercury Project Summary Including Results of the Fourth Manned Orbital Flight, May 15 and 16, 1963*, NASA SP-45, 1963.

⁷ Charles W. Mathews, Aeronautical Res. Engineer, Memo for Director of Project Mercury, Feb. 10, 1959.

⁸ *Ibid.*

⁹ Information is based on (1) Paul E. Purser, Spec. Asst. to Director, Project Mercury, Memo for File, Subj.: Additional Background Material on Project Mercury, Mar. 23, 1959; (2) James P. Henry, "Project Mercury—Status of the Animal Test Program," NASA Project Mercury Working Paper No. 158, Oct. 20, 1960.

¹⁰ James P. Henry and John D. Mosely, "Antecedents and Planning Aspects of the MR-2 Flight," ch. 2 in *Results of the Project Mercury Ballistic and Orbital Chimpanzee Flights*, NASA SP-39, 1963.

¹¹ It was also decided that various types of performance would be required of the subjects to simulate the tasks of the human operator. These, Henry and Mosely reported further, involved simple movements of the arms and hands, discrimination of visual signals, and acts requiring judgment. In the longer orbital flights the difficulty of the task would be raised to a level "that would approximate the man's task as closely as possible within the animals' capability."

¹² This program, carried out for the Air Force at the Univ. of Texas, represented one of the truly unique scientific resources of the nation. NASA was to continue its dependence on this resource as the space program progressed.

¹³ It was not possible to document this statement from official sources,

but the author has discussed the problem with officials closely associated with the Mercury program.

¹⁴ "A Survey and Evaluation of Methods of Measuring Blood Pressure for Immediate Space Flight Programs," prepared under contract NASr-51 for the Office of Life Science Programs, NASA, by Webb Associates, June 30, 1961. Also, personal conversations by the author with Dr. Paul Webb, Principal Investigator, Webb Associates, in the spring of 1964. This problem is discussed in detail in *The Measurement of Blood Pressure in the Human Body*, NASA SP-5006, 1964, pp. 17 ff.

CHAPTER IX

Space Medicine in 1961-62

THE SUBORBITAL FLIGHT OF ALAN SHEPARD on May 5, 1961, was, in one sense of the word, anticlimactic. Gagarin had already orbited the earth on April 12. In another sense, however, the Shepard flight was even more dramatic than the Gagarin flight. For here, the entire world witnessed and shared the delays, the tension, and the success of the first U.S. astronaut to travel in space. His ballistic flight path reached a peak of 116 statute miles for a downrange distance of 302 statute miles.¹

The details of this event, as well as those of the later manned space flights of Project Mercury, have been recorded in the annals of history. The present account will therefore concentrate upon the medical implications, both in terms of operations and lessons learned and in terms of long-range high-level planning for medical support of manned space flight, rather than upon recounting of each individual mission.

On July 21, 1961, the second suborbital flight was made with Astronaut Virgil Grissom aboard. He traveled to an altitude of 118 statute miles, and 303 miles downrange.² With this flight and the subsequent orbital flight of the chimpanzee Enos, the Space Task Group could look forward to placing a man in orbit. As the summer of 1961 drew to a close, the rate of progress was unprecedented.

CHIMPANZEE ENOS AND THE NEAR-CRISIS

On November 29, 1961, the Mercury-Atlas 5 launch at Cape Canaveral carried chimpanzee Enos into orbit for a scheduled three-orbit mission. Because the attitude-control system malfunctioned, retrorockets were fired on the second orbit. The Mercury spacecraft was recovered 1 hour 25 minutes after the water landing, and Enos was recovered in seemingly excellent condition except that the extreme heat had obviously plagued him.³



Of the two manned suborbital flights in Project Mercury, the first was flown on May 5, 1961, by Astronaut Alan B. Shepard. These photos show Shepard being assisted into Freedom 7 by fellow astronaut and back-up pilot John Glenn (above, left) and his ascent into the Marine recovery helicopter (above, right), with his spacecraft in tow on another cable. Astronaut Gus Grissom, shown (left, below) talking to the astronauts' flight surgeon, Dr. William K. Douglas, made the second flight July 21, 1961, during which his fellow astronauts (left to right, Glenn, Schirra, and Shepard) were part of the Mercury Control team keeping intensive check on the minute by minute details of the launch, flight, reentry, and recovery.



During the postflight medical examination of Enos, there was to be considerable concern over the variations in cardiac rhythm which had been recorded by the instruments developed for this flight. The critical question posed was whether plans should proceed for the first manned orbital flight. Yet on the date of Enos' flight, President Kennedy had announced that Lt. Col. John Glenn would be the prime astronaut for the first manned orbital mission to take place shortly, with Lt. M. Scott Carpenter as backup. Capt. Donald Slayton would be the prime astronaut for the second manned orbital mission with Lt. Comdr. Walter Shirra as backup.⁴

During the following days, however, it appeared that this announcement might have been premature in the light of medical findings of the Enos flight. The tension of those days has been described unofficially to the author. It must have been a period of uncertainty as to the proper course of action to take, for the first manned orbital flight was scheduled for December 1961.

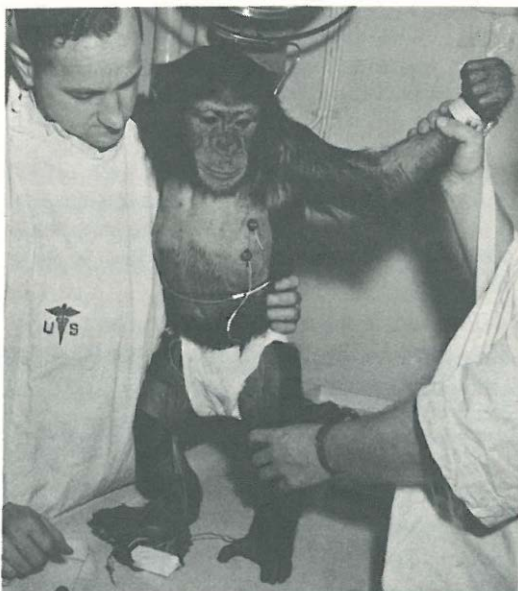
Fortunately this potential medical crisis did not become full blown. Eminent cardiologists were asked to review the records and biological data obtained during the orbital flight of Enos, to determine the reason for the arrhythmia, if possible, and to separate it from the influences exerted by weightlessness in space flight. It was found that the difficulty lay with the instrumentation, and that the data were therefore invalid. Accordingly, it was recommended that the manned orbital flight proceed as scheduled.⁵

MEDICAL IMPLICATIONS OF THE CHIMPANZEE FLIGHTS

The two chimpanzee flights in Project Mercury were to reveal significant medical data. The suborbital flight of Ham was without complications, but it was considerably less complex than Enos' orbital flight.

In the Mercury-Atlas 5 (MA-5) orbital flight, Enos performed a complex multiple operant task as he twice orbited the earth. The 42-pound subject, whose age was estimated to be 63 months, had been exposed to simulated launch accelerations on the centrifuge at the University of California. He had also served as a subject for a laboratory model of a 14-day flight. Over a 16-month period he had received a total of approximately 1,263 hours of training, of which 343 hours were accomplished under restraint conditions in a model of the actual couch used in flight.⁶

The success of the two manned suborbital flights still left much unknown about physiological responses to orbital flights with their extended periods of weightlessness. To find some answers prior to manned orbital flight, the chimpanzee Enos—shown at right with biosensors attached to his body—was sent aloft November 29, 1961, for two orbits. His flight confirmed normal bodily functions and motor abilities in weightlessness.



According to Henry, the results of the two animal flights (Ham and Enos) showed that :

(1) Pulse and respiration rates, during both the ballistic (MR-2) and the orbital (MA-5) flights, remained within normal limits throughout the weightless state. Effectiveness of heart action, as evaluated from the electrocardiograms and pressure records, was also unaffected by the flights.

(2) Blood pressures, in both the systemic arterial tree and the low-pressure system, were not significantly changed from preflight values during 3 hours of the weightless state.

(3) Performance of a series of tasks involving continuous and discrete avoidance, fixed ratio responses for food reward, delayed response for a fluid reward, and solution of a simple oddity problem, was unaffected by the weightless state.

(4) Animals trained in the laboratory to perform during the simulated acceleration, noise, and vibration of launch and reentry were able to maintain performance throughout an actual flight.

On the basis of the flight, Henry and his group drew the following conclusions :

(1) The numerous objectives of the Mercury animal test program were met. The MR-2 and MA-5 tests preceded the first ballistic and orbital manned flights, respectively, and provided valuable training in countdown procedures and range monitoring and recovery techniques. The bioinstrumentation was effectively tested and the adequacy of the environmental control system was demonstrated.

(2) A 7-minute (MR-2) and a 3-hour (MA-5) exposure to the weightless state were experienced by the subjects in the context of an experimental design which left visual and tactile references unimpaired. There was no significant change in the animal's physiological state or performance as measured during a series of tasks of graded motivation and difficulty.

(3) The results met program objectives by answering questions concerning the physical and mental demands that the astronauts would encounter during space flight and by showing that these demands would not be excessive.

(4) An incidental gain from the program was the demonstration that the young chimpanzee can be trained to be a highly reliable subject for space-flight studies.⁷

The experience gained from the two animal flights (MR-2 and MA-5) was, however, not the only source of information available on space flight.

MEDICAL IMPLICATIONS OF THE COSMONAUT FLIGHTS

On April 26, 1961, 2 weeks after the orbital flight of Gagarin, the Embassy of the Union of Soviet Socialist Republics in Washington, D.C., issued certain medical data about the mission.⁸ The release read in part:

The time has come for the practical creation of extraterrrestrial scientific stations They will be followed by manned flights to the moon and other planets of the solar system, the creation of manned interplanetary stations and the gradual conditioning of men to space flight.⁹

According to the release, Gagarin felt "perfectly well" throughout the orbiting phase and also during the period of weightlessness. It was noted that measures had been taken to protect the spacecraft from the hazards of space radiation.

To provide answers to the medicobiological problems posed by space flight, it was reported, Soviet scientists since 1951 had carried out experiments with flights of animals in rockets to altitudes up to 450 kilometers (approximately 280 miles). Later, artificial earth satellites were used for making biological experiments—for example, it was considered important to study with maximum accuracy the biological effects of cosmic radiation. As a result of experimentation, orbital flight below the radiation belts was found to be safe for organized representatives of the animal world. It was therefore concluded that manned flight could be undertaken without harm to the cosmonaut's health.

The cosmonauts' training had included, among other subjects, orientation in space medicine. Also included were special training and tests in aircraft flights under conditions of weightlessness, training in a simulated spacecraft cabin and on a special training

machine, prolonged stay in a specially equipped soundproof chamber, centrifuge tests, and parachute jumps from aircraft. Cosmonauts had to be able to stand the state of weightlessness for as long as 40 seconds and to partake normally of liquid, semiliquid, and solid food during that time. They also had to be able to discharge such functions as writing, radio communication, and reading, and to maintain visual orientation in space. Physiological studies and special psychophysiological methods "permitted the selection of people best fitted to discharge the missions accurately and who had the most stable nerves—emotional health," according to the Soviet report of April 26, 1961. The future cosmonauts "systematically did physical exercises to raise the organisms' resistance to acceleration forces as well as other factors of the new medium," it was reported. From the group of cosmonauts thus trained, Gagarin had been chosen to make the first orbital flight.

From the foregoing description, it is apparent that the U.S.S.R. and the U.S.A. had approached the problem of selection and training of the astronauts in much the same manner, following the traditional methods of selection and training of pilots. The main difference in the biological-medical procedures had been that the U.S.S.R. had carried out more extensive animal experimentation than had the United States.

A major difference in the approach, however, had been in the development of the life-support systems of the spacecraft. For Gagarin's flight the air-conditioning system maintained normal pressure and normal oxygen concentration in the pilot's cabin. The concentration of carbon dioxide did not exceed 1 percent. The temperature ranged from 15° to 22° C and the relative humidity from 30 to 70 percent. The air was regenerated chemically, and the heat in the pilot's cabin was absorbed by a liquid cooling agent. Gagarin wore a protective space suit.

The journal *Meditsinskiy Rabotnik* (Medical Worker) reported that Gagarin ate solid, pastelike, and liquid food during the flight. His menu was designed to avoid both overcharging the digestive system and accumulating excessive cellular tissue. He had no difficulty eating in the condition of weightlessness. Prior to flight he had tested foods prepared for consumption in flight and had chosen his favorites. "It is important," wrote G. F. Arutyunov (Master of Science in Medicine), "to have all the constituents of the food ration assimilated by the organism to the utmost."¹⁰

The major problem with which the Russians had wrestled prior to manned orbital flight was that of reentry. In August 1958

they had sent two dogs on a ballistic flight to an altitude of 280 miles with successful recovery by ejection of the dog containers during the descent. Subsequent development and testing led to the system used by Gagarin, which included a descent phase lasting approximately 30 minutes. In case the braking engine failed, the ship was designed to take advantage of atmospheric drag. The cosmonaut would make a landing on dry land, as contrasted with the Mercury landings on water.¹¹

On August 6, 1961, after Grissom's suborbital flight in July, the U.S.S.R. launched Cosmonaut Gherman S. Titov into orbit in a spacecraft (Vostok II) weighing 13 pounds more than Vostok I, launched the previous April. (On the same date the report of the Space Science Board of the National Academy of Sciences was released; it recommended exploration of the moon and planets as the official goal of the U.S. space program.) The following day, August 7, it was reported from Moscow that Major Titov had successfully landed in Vostok II after 17 orbits in 25 hours 18 minutes. This was the first manned flight of more than one orbit, and the first test of man's reaction to prolonged weightlessness.¹²

Other medical information would be forthcoming shortly.

TOWARD GEMINI AND APOLLO

Concurrent plans and objectives for space exploration brought the life sciences into an increasingly important role as the Mercury Space Task Group prepared for the next operational step. The long-range obligations of space exploration enunciated by the President meant that not only must Mercury be successfully completed but Gemini and Apollo now must be planned for.

All was not well, however, in the minds of the Nation's life scientists, despite the obvious success of the two U.S. suborbital flights and the U.S.S.R. orbital flight. The international scientific community had become increasingly concerned about reports—unverified at first, and then confirmed—that Titov had suffered motion sickness while in orbit. Did this mean that there were hazards of weightlessness or of combined stresses that should be investigated before further plans were made to orbit a U.S. man in space? The matter was of grave concern to the U.S. life scientists, aware that their first projected orbital flight was but a few months away.

Also still unresolved was the total complex of problems that had bothered the life scientists since 1958 when Project Mercury

was established. As Dr. White had reported, early work had been undertaken to extend man's tolerance to the biomedical rigors calculated to be inherent in the early flights.¹³ Although technology would sustain life-support systems, there still remained serious problems about man's ability to meet the individual stresses which could not be reproduced on the ground (weightlessness and radiation) and the effect of the stresses on the body systems. The latter was complicated by the lack of knowledge of the impact of increasing time exposure. According to White:

. . . proposed as a serious area for study was the composite effect of: the psychological effects of flight; the accelerations and vibrations of powered flight; the abrupt shift to the weightless environment with its inherent requirement for the adjustment of the physiological systems to the new baseline, later a reversal of these orbital patterns back to an entry program of acceleration, vibration, oscillation, and heating; and the landing impacts. This composite effect was a highly suspect one which would challenge man's survivability in space flight.¹⁴

Now, on the eve of the first U.S. manned orbital flight, these questions of man's survivability in the light of these combined stresses were still unanswered.

NOTES TO CHAPTER IX

¹ *Proceedings of a Conference on Results of the First U.S. Manned Sub-orbital Space Flight*, NASA, June 6, 1961.

² For complete details, see *Results of the Second U.S. Manned Suborbital Space Flight, July 21, 1961*, Manned Spacecraft Center, NASA.

³ L. E. Stringly, "Countdown and Procedures for Project Mercury. Atlas-5 Flight (Chimpanzee Subject); Final Technical Documentary Report." Aeromedical Res. Lab. Tech. Documentary Rep. 62-17, Holloman AFB, 1962.

⁴ *Aeronautical and Astronautical Events of 1961*, Report of the National Aeronautics and Space Administration to the Committee on Science and Astronautics, U.S. House of Representatives, 87th Congress, 2d sess., June 7, 1962, p. 68.

⁵ Based on classified documents and off-the-record discussions by the author.

⁶ Frederick H. Rohles, Jr., Marvin E. Grunzke, and Herbert H. Reynolds, "Performance Aspects of the MA-5 Flight," ch. 9 in *Results of the Project Mercury Ballistic and Orbital Chimpanzee Flights*, NASA SP-39, 1963.

⁷ James P. Henry, "Synopsis of the Results of the MR-2 and MA-5 Flights," ch. 1 in *Results of the Project Mercury Ballistic and Orbital Chimpanzee Flights*, NASA SP-39, 1963.

⁸ Press Release No. 109, Embassy of the Union of Soviet Socialist Republics, Apr. 26, 1961.

⁹ *Ibid.*

¹⁰ As cited, *ibid.*

¹¹ *Ibid.* See also D. I. Fryer, "The Medical Sciences and Space Flight," *R.A.E. News*, Feb. 1964.

¹² *Aeronautical and Astronautical Events of 1961*, *op. cit.*, p. 38.

¹³ See ch. VIII, note 3.

¹⁴ *Ibid.*

CHAPTER X

Mercury Medical Operations

AS HAS BEEN NOTED, on November 29, 1961, while Enos orbited the earth, Project Mercury officials had announced that John H. Glenn would be the prime astronaut for the first manned orbital mission with M. Scott Carpenter as backup, and that Donald Slayton would be the prime astronaut for the second manned orbital mission with Walter Schirra as backup.¹

Through the next weeks the tension once more built up at Cape Canaveral as the pattern of the Shepard and Grissom flights was repeated on an even more intense scale. Perhaps no part of history has been better documented than the U.S. orbital flights. To recount again the emotional drama that accompanied them—particularly the first U.S. orbital flight—would be anticlimactic. Yet each, in its own fashion, led man progressively further toward his goal of space exploration.

At Cape Canaveral, countdown for Marine officer Glenn began again and again, only to be postponed for first one reason and then another. Disciplined patience now became the supreme virtue as the astronaut's will was tested no less than that of the Nation. The fruits of technology were not perfect and there were to be malfunctions; the weather yielded itself to no man's convenience. Astronaut Glenn waited . . .

On February 20, 1962, after eight postponements, he was finally launched and successfully completed three orbits of the earth in his spacecraft *Friendship 7*. This flight was followed on May 24, 1962, by the MA-7 flight, M. Scott Carpenter's three-orbit flight in the *Aurora 7* spacecraft. Originally it had been planned that this flight would be made by "Deke" Slayton, whose grounding for medical reasons in March 1962 is discussed in the next section. Walter M. Schirra made a six-orbit flight in the *Sigma 7* spacecraft (designated the MA-8 flight) on October 3, 1962. On May 15, 1963, Gordon M. Cooper flew the final Mercury orbital mission

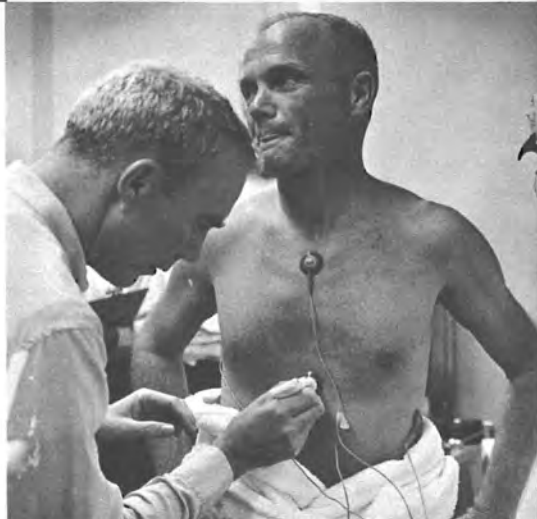


FIRST U.S. MANNED ORBITAL FLIGHT February 20, 1962

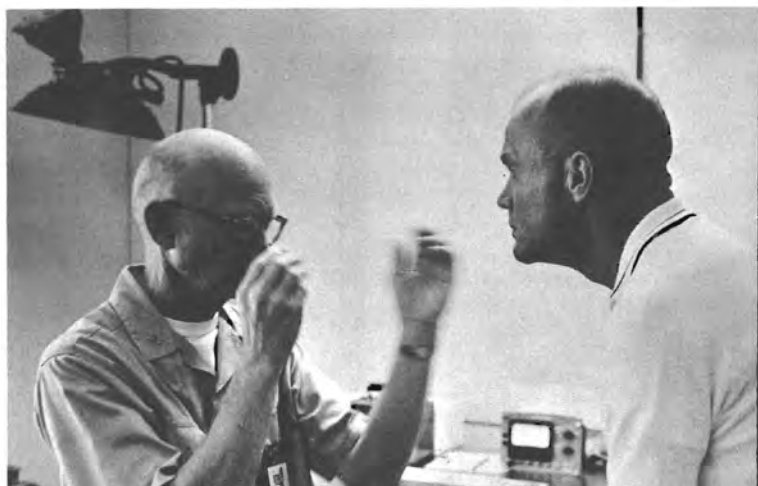
*Glenn (Feb. 20, 1962) has
low-residue breakfast.*



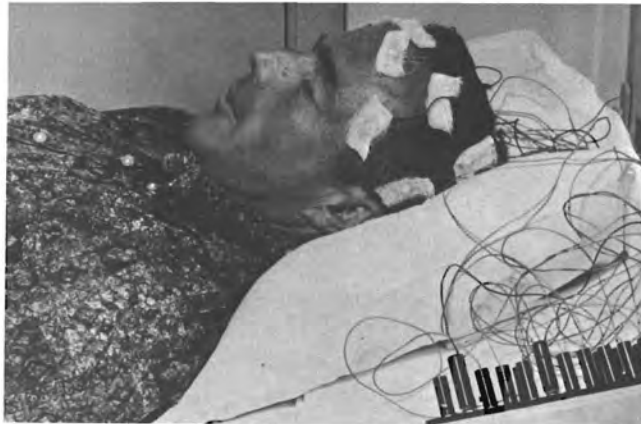
Leaving Hangar S.



*Preflight medical examination by Dr. Douglas
(above). Dr. Douglas, as countdown approaches
zero (below, left). After the successful flight,
medical debriefing by Dr. Graybiel (below, right).*



**AND
THREE
MORE**



*Carpenter (May 24, 1962)
has encephalogram before
three-orbit flight.*



*Schirra (Oct. 3, 1962) gets caloric test
after six-orbit flight.*

*Cooper (May 15-16, 1963) has 5-hour
physical prior to 22-orbit flight.*



in the *Faith 7* (MA-9 flight), bringing to a close the first phase of the United States' manned space flight effort.²

ASTRONAUT SLAYTON GROUNDED

Although it had been announced on November 29, 1961, that Donald Slayton would be the prime astronaut for the second U.S. manned orbital mission, on March 16, 1962, NASA announced that he would be replaced by M. Scott Carpenter, alternate pilot in the Glenn mission. This decision, made at NASA Headquarters, was prompted by a minor heart defect, on record since 1959. The physical disability which caused Astronaut Slayton's disqualification was described as "recurring arterial fibrillation without heart disease." Little positive information was available concerning either the etiology or prognosis of this condition. Since the medical profession did not establish a firm prognosis in this case, the decision whether Slayton would fly the mission was one that had to be made by management.

This decision by NASA was to be discussed extensively by the press following a news conference held by NASA at noon that day, with Dr. Hugh Dryden, Deputy Director, NASA; Dr. Roadman, Director, Aerospace Medicine; Astronaut Donald K. Slayton; and John H. (Shorty) Powers, Public Affairs Officer, participating.³ For example, in an interpretive report, William Hines of the *Washington Sunday Star* wrote:

The conference brought out the fact that, based on some medical second-guessing, a hasty change had been made in what supposedly had been well-laid plans for the second manned orbital flight. Lt. Col. William Douglas, the astronauts' personal physician, did not participate in the medical review of Major Slayton, which is said to have been unanimous. Dr. Douglas had made no secret of the fact that he believes Major Slayton is fit to fly and should fly.⁴

The decision to ground the astronaut had been made by NASA Headquarters, and not by Dr. Robert R. Gilruth, Director of the Manned Spacecraft Center (formerly the Space Task Group), who had said:

My own feeling is that Deke is an extremely competent engineering test-pilot and entirely capable of this mission. In no case has the abnormality interfered with Deke's performance.

Nevertheless—bowing to medical advice—the management echelon at NASA Headquarters decided that Astronaut Slayton would not undertake the MA-7 mission. Whether he would be given a clean bill of health to fly in future missions remained to be de-

terminated. Dr. Dryden had stated in the March 16 press conference that Slayton would remain in the Mercury program and might possibly yet make a flight.

Following extensive observation and examination by eminent specialists, including Dr. Paul Dudley White (who had attended former President Eisenhower), it was recommended by the Director of Space Medicine, Office of Manned Space Flight, that Astronaut Slayton be removed from consideration "for any Mercury flights."⁵ On July 11, NASA reported:

The principal conclusion of the examinations is that the hazards from the arrhythmia of Slayton's heart, under the particularly stressful circumstances of current manned space flight operations, are too great to recommend that he should make a one-manned solo space flight. The examinations of Slayton's heart condition included those by members of the Manned Spacecraft Center Medical Staff under a variety of circumstances, two groups of heart specialists convened by the Air Force and a detailed examination by Dr. Paul Dudley White, eminent cardiologist of Boston, Massachusetts. The conclusions represent the consensus of all the medical specialists involved.⁶

Astronaut Slayton would, however, remain with the manned Spacecraft Center, assuming new engineering and operational planning duties on all manned space flight programs, including Projects Mercury, Gemini, and Apollo.

THE MERCURY FLIGHTS: 1962-63

Except for this one incident, the six orbital flights of Project Mercury were to proceed as planned. Modifications in life-support systems were continuous as increasing experience was gained. Also, as the missions progressed, the initial elaborate medical procedures for tracking and recovery operations were modified. Increasingly, NASA turned to its own growing medical in-house capability and became less dependent upon the Services for medical support.

The author remembers vividly the contrast between the first suborbital flight, viewed on television from the conference room of the USAF Surgeon General in Washington, D.C., on May 5, 1961, and the 22-orbit flight of Astronaut Cooper, last of the Mercury flights, which was viewed from the blockhouse at Cape Canaveral on May 15, 1963.

In 1961, the U.S. capability was untried. Now, in 1963, there was confidence born of experience. The author recalls the predawn trip from Patrick Air Force Base to the Cape on May 14, 1963, and the long wait atop the blockhouse as events on the gantry

seemed slowly to take shape. Through binoculars the orange-red gantry could be viewed at close range; and with the naked eye it could be seen in the distance as the sun rose. Nearby, the noisy helicopters waited and the scuba divers in their black leotards and fin shoes lounged in readiness. The sounds of the loudspeaker system battled with those of transistor radios carried by various individuals.

That morning there appeared to be trouble with the gantry, and as the visitors stared at the spacecraft poised on the launch vehicle that spewed a continuous white steam from the area near the ground, there was intermittent conversation . . .

"Do you remember," one medical officer asked another, "how one of the astronauts found it imperative to void in his pressure suit prior to countdown?"

"And do you remember," asked someone else, "the ham sandwich that was smuggled aboard a previous flight?"

Apocryphal or not, these were reminders that it was man—a normal, functioning man, constrained in his activities by biological considerations that science and technology could not change—who was being launched into orbit.

Suddenly, then, the word "Scrub!" The flight was postponed.

Next day the observers waited as they had waited the previous day; the countdown finally ticked away; the big Atlas slowly rose off the pad, gaining speed, turned in the direction of the blockhouse, and soared out of sight. Through the long day, the author, like the world, waited and watched by television the progress of Astronaut Cooper. At one point, General Roadman took her, along with other NASA Headquarters Space Medicine observers, to the Mercury Control Room. Sitting silently, watching, were Dr. Gilruth and D. Brainerd Holmes. Behind them were the group of new astronauts, chosen to supplement the original seven. In the center of the room sat Lt. Col. Charles Berry, USAF (MC) (who had succeeded Dr. Stanley White), at one of the control positions. At this point in the mission it might be a medical decision as to whether, at any time, the flight would be cut short.⁷

This flight, successfully concluded after 22 orbits, brought Project Mercury to a close.

MEDICAL CARE

The Mercury staff in October 1963 briefed the scientific community on its evaluation of the Mercury program.⁸ Aeromedical

considerations were discussed in detail by the staff of the Manned Spacecraft Center, and will be only briefly summarized here. Medical Operations involved medical maintenance and preflight preparation, medical monitoring, analysis, physiological responses to space flight, and recovery operations.

Medical maintenance for the astronauts had included routine medical care, together with annual and special physical examinations. Preflight physical examinations were given for two purposes: To allow the flight surgeon to state that the astronaut was qualified and ready for flight; and to provide a baseline for any changes resulting from exposure to the space-flight environment. Early in the program, 10 days before the scheduled mission, the flight astronaut and his backup were given a thorough evaluation. This was performed by a Department of Defense team of medical specialists providing the specialties of internal medicine, ophthalmology, neurology, psychiatry, and laboratory medicine. These specialties continued to be represented in later flights, although certain modifications were made as experience demonstrated the lack of serious effects of flight on the astronaut. Three days prior to the flight a detailed physical examination was completed by the various medical specialists with necessary laboratory work.

On the morning of the flight, a brief medical examination was made to determine the readiness of the astronaut. On the last two missions, MA-8 and MA-9, participation was reduced to that of the flight crew surgeon only.

The postflight medical examinations were made initially by Department of Defense recovery physicians stationed aboard the recovery vessel, but as the flights were lengthened and experience accumulated, the pattern here too was modified. On the early missions, the astronaut was flown to Grand Turk Island where he was joined by the team of medical specialists who had made the preflight examination and by the flight crew surgeon. In the later, longer flights, when the recovery was made in the Pacific Ocean, NASA flight surgeons were predeployed aboard the recovery carrier to perform the initial postflight examination and debriefing.

Several valuable lessons were learned both with respect to the pattern of medical care provided and to policies relating to the astronaut. In the first instance, it was learned early that there was need for many practice runs. A medical countdown was developed with specific timing of events. Also it was learned that



The automatic medical injectors shown above were carried by Astronaut L. Gordon Cooper on his 22-orbit flight. Two drugs were provided—Tigan, for motion sickness, and Demerol, for pain. The tubes encased in the blocks were stowed in the astronaut's survival kit; the single injection tubes were placed in a pocket of his space suit for availability in case of possible emergency during the flight.

backup personnel were needed, just as backups were needed for the various pieces of equipment, although the number must be kept at a minimum.

With reference to the individual astronaut, the medical profession learned many lessons from the flights. For example, initially consideration had been given to isolating the flight crew so as to prevent development of a communicable disease immediately prior to flight. This soon proved impractical, however, because the astronaut had too many last-minute activities. Because of the relatively short period of the Mercury flight, no difficulty was experienced with a very modified isolation plan, although it was recognized that longer periods of flight in future missions might call for an evaluation of this problem.

Initially the basic concept regarding drugs had been that they would be made available for emergency use only. Injectors made it possible for the astronaut to self-administer drugs through the pressure suit. For the first four missions these drugs included an

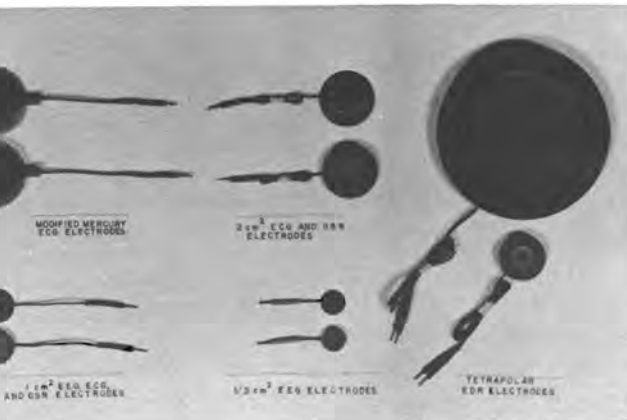


Food carried on the last Mercury manned space flight, Astronaut Cooper's 22-orbit 34-hour flight, included the previously used bite-size ready-to-eat food (top right) and experimental dehydrated foods being tested for possible use in the Gemini manned space-flight program. The dehydrated foods in the plastic bags (shown here are shrimp, apple juice, and potato salad) are combined with water and mixed for 5 minutes before eating.

anodyne, an anti-motion-sickness drug, a stimulant, and a vasoconstrictor for treatment of shock. In later missions these were reduced to the anti-motion-sickness drug and an anodyne (available both in the suit and in the survival kit). For the last Mercury flight (MA-9), it was decided to make tablets of dextro-amphetamine sulfate available, both in the suit and in the survival kit, and medication was used for the first time during flight when the dextro-amphetamine sulfate was taken prior to the initiation of retrosequence.

Experience showed that care must be taken to prevent astronaut fatigue during the final preflight preparations as well as during postflight activities. Minimum time for postflight rest and relaxation following a 34-hour mission was between 48 and 72 hours.

Dietary control was in force for approximately 1 week prior to each mission. To prevent defecation during the mission, a low-residue diet was programmed for 3 days prior to launch, with the time extended if the launch was delayed.



These photographs show representative types of the biosensors attached to the astronauts to telemeter back to earth readings of their physical condition.



In flight, food consisted of bite-size and semiliquid tube food on early missions, although on the MA-9 mission freeze-dehydrated food was added. The bite-size food caused problems by crumbling and some difficulty was encountered in hydrating the freeze-dehydrated food.

In the early missions urine was collected in a single container within the suit, but this device became unworkable as the mission time increased. Modifications of the suit made it possible to collect five separate and complete samples, although the system would require modification for future missions.

No blood samples were obtained during flight, and every attempt was made to combine the various blood requirements so as to minimize the number of venipunctures, both preflight and post-flight.

MEDICAL MONITORING

When the Mercury program began, continuous monitoring of physiological data while a pilot performed his flight mission was a new concept. Consequently, there were no off-the-shelf items for continuous and reliable monitoring. When it was decided to attempt to monitor body temperature, chest movement, and heart action (ECG), equipment standards were established: The sensors and equipment must be comfortable, reliable, and compatible with other spacecraft systems, and must not interfere with the pilot's primary mission. Biomedical sensors were used primarily to assist the flight surgeon in determining whether the astronaut was physiologically capable of continuing the mission.

Considerable experience was gained through the use of range simulations as well as actual flight. It was soon apparent that the medical flight controller was an extremely important member of the flight control team. The development of mission rules to aid in flight control was necessary in the medical area as well as in the many engineering areas. As experience was gained, the evaluation and judgment of the medical flight controller were the prime determinants in making a decision. According to Dr. Berry, the "condition of the astronaut as determined by voice and interrogation rather than physical parameters alone became a key factor in the aeromedical advice to continue or terminate the mission."⁹

The physiological parameters monitored were modified as experience was gained. Body temperature was monitored with a rectal thermistor in all missions. The thermistor would be modified for oral use in future missions of longer duration. Respiration was measured initially by an indirect method through the use of a linear potentiometer and carbon-impregnated rubber. Soon this method was replaced by a thermistor kept at 200° F and placed on the microphone pedestal of the helmet. Since neither gave reliable respiration traces, a change was made to the impedance pneumograph for the MA-8 and MA-9 flights. This device provided accurate respiration information during most of the flight.

Electrocardiographic electrodes of a low impedance to match the spacecraft amplifier were required to record during body movements and to stay effective during flight durations of over 30 hours. These electrodes, Dr. Berry notes, functioned well and provided excellent information on cardiac rate and rhythm.

Not until the MA-6 mission of Astronaut Glenn had blood pres-

sure readings been taken, because until that time no satisfactory system had been developed. As early as the MR-3 flight, however, definitive work had begun with an automatic system using a unidirectional microphone and cuff. The system without the automatic feature was used on the MA-6 mission. During MA-7, all the inflight blood pressure readings obtained were elevated. An extensive postflight evaluation determined that instrument error had probably caused this result. Suggested remedies included considerable preflight calibration and matching of the settings to the individual astronaut along with the cuff and microphone. Excellent blood pressure tracings were obtained in both the MA-8 and MA-9 flights.

Voice transmissions were a valuable source, and the normal flight reports and answers to queries were used for evaluation of the pilot. (To insure that the medical monitors were familiar with the astronaut's voice, tapes of mission simulations were dispatched to all range stations.)

Inflight photography and television proved of little value in medical monitoring because of the poor positioning of the cameras and the varying lighting conditions that resulted from the operational situation.

PHYSIOLOGICAL RESPONSES TO SPACE FLIGHT

One of the basic objectives of Project Mercury was to evaluate man's responses to the space-flight environment. The stresses of this environment which would elicit physiological responses included, according to Dr. Berry,¹⁰ the wearing of the full-pressure suit although not pressurized in flight, confinement and restraint in the Mercury spacecraft with the legs at 90° elevated position, the 100-percent oxygen atmosphere at 5 psi pressure, the changing cabin pressure through powered flight and reentry, variation in cabin and suit temperature, the acceleration forces of launch and reentry, varying periods of weightless flight, vibration, dehydration, the performance required by the flight plan, the need for sleep and for alertness, changes in illumination inside the spacecraft, and diminished food intake.

Data showed that the peak physiological responses were closely related to critical inflight events. The six astronauts who flew a mission showed themselves capable of normal physiological function and performance during the accelerations of launch and reentry; they tolerated the vibration of launch and reentry well;

there was no evidence of motion sickness. The heat loads imposed caused discomfort upon occasion but did not become a limiting factor in the missions.

Since the Mercury missions were planned for altitudes that would not involve contact with the Van Allen radiation belt, radiation was not considered to be a problem until the manmade radiation belt was noted prior to the MA-8 mission. At that time, personal dosimeters were added within the astronaut's suit and inside the spacecraft. The MA-8 and MA-9 flights revealed that the astronauts received no greater radiation dose than would have been received on earth, and even less than that received during a chest X-ray.

Weightlessness caused no problems, according to the astronauts. They were able to conduct complex visual-motor coordination tasks proficiently in the weightless state. No evidence of body system dysfunction was discovered during the flights. Urination occurred normally in time and amount, and there was no evidence of difficulty in intestinal absorption in the weightless state.

Signs of orthostatic hypotension were noted after the last two missions; they persisted for between 7 and 19 hours after landing.

MEDICAL DATA

The foregoing conclusions are based on the extensive data that were collected, reduced, and analyzed in connection with Project Mercury. Many of the scientific papers on various phases of the program are cited throughout this monograph. There is sufficient agreement among reputable investigators to validate the general conclusions drawn. It will not, therefore, be the purpose here to set forth statistical and mathematical treatments of the data, but rather to present representative types of medical data acquired. This is done without analytic comment to provide a historical record and to serve as a possible reference source for scientific investigators.

Two representative types of medical data will be presented: (1) Those medical data acquired in-flight during the six manned space missions of Project Mercury, and (2) the medical data primarily acquired immediately before and after each of the six missions.

In-Flight Data

In-flight data were acquired and analyzed primarily to determine the well-being of the astronaut while in flight and to make

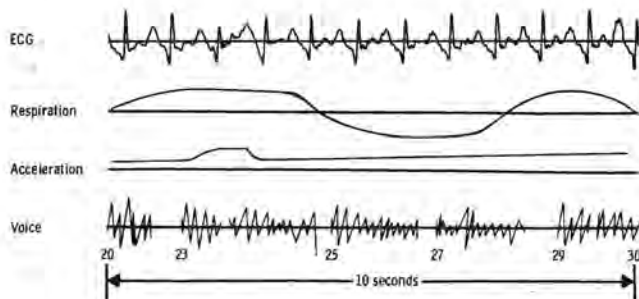
postflight detailed analyses of medical aspects of each mission for analytic, comparative, and predictive purposes.¹¹ The physicians monitoring the well-being of each astronaut while in flight used data which were telemetered to the ground stations for immediate assessments, whereas the postflight analyses were conducted after the completion of the missions, essentially from records which had been made on board the spacecraft during flight.

Several kinds of data were acquired, including physiological, environmental, and operational performance data. The physiological data included electrocardiogram (ECG), respiration, blood pressure, and body temperature. Spacecraft environmental data consisted of acceleration, space-suit inlet temperature, suit outlet temperature, carbon dioxide partial pressure, and cabin pressure. The operational performance type of data included a continuous record of what each astronaut was doing (performing) and what he was saying throughout each mission.

The postflight analysis of in-flight medical data focused attention upon time-line analysis information. That is, the data were prepared in such a manner that the physician could analyze and assess, within the limits of the measurements taken, the composite of what was occurring to the astronaut at any given time interval, and for consecutive time intervals. For example, all relevant information for a given time interval was recorded on one data sheet. This included available information of importance to the physician concerning the physiological, environmental, and operational performance measurements for a specific time interval of short duration. Next, additional data sheets were constructed for consecutive time intervals. If the first data sheet covered the 10-second interval immediately after liftoff, the succeeding data sheet would cover the interval from 10 seconds to 20 seconds, and the next sheet, 20 seconds to 30 seconds, and so on.

The requirements for the duration of time intervals were different for various portions of a mission. This was because the physician is interested not only in change, per se, but also in the rate of change, and the rate-of-rate of change, of physiological reactions and environmental conditions. These types of changes generally take place more rapidly during exit and reentry than during routine portions of a mission such as during weightlessness. A data sheet covering the short interval of 10 seconds during exit and reentry was therefore considered necessary, whereas a data sheet covering the longer interval of 1 minute during weightlessness was considered to be acceptable. Also, the 1-minute inter-

HEART RATE		RESPIRATION		ACCELERATION		SUIT INLET TEMPERATURE	SUIT OUTLET TEMPERATURE	CARBON DIOXIDE PARTIAL PRESS.	CABIN PRESS.
Beats/min	Standard score	Breaths/min	Standard score	Z-axis	Standard score				
115.60	38.20	16.90	36.40	1.77	50.30	65.22	84.52	.0000	15.24
112.14	36.79	15.78	35.39	1.90	50.96	65.24	84.58	.0000	15.21
112.14	36.79	22.72	41.63	1.77	50.30	65.22	84.50	.0000	15.19
...	...	...	...	...	...	Mean = 65.22	Mean = 84.53	Mean = .0000	15.22
Mean = 117.07	...	Mean = 18.46	...	Mean = 1.82	...				Mean = 15.215
Sigma = 3.96	...	Sigma = 3.73	...	Sigma = .26	...				
Variance = 15.69	...	Variance = 13.88	...	Variance = .07	...				



ACTIVITY

1. Planned: Start back-up clock
2. Actual: Start back-up clock

COMMUNICATION

- 20 sec: Ground: "Mark"
 23 sec: Pilot: "Roger, and the back-up clock is running"
 25 sec: Ground: "Roger, you look good here Gordo"
 27 sec: Pilot: "Roger, feel good, buddy"
 29 sec: Ground: "Good sport"

Figure 1.—Sample time-line data sheet. MA-9 mission; time period 20 sec to 30 sec after T-zero.

val proved to be satisfactory in most cases for data sheets covering the preflight and postflight periods. An example of the information that was included on a data sheet is shown in figure 1.

Although the example shown is for a 10-second interval for a given mission, the data sheet for a 1-minute interval would be similar. The graphs represent the wave trains for ECG, respiration, acceleration, and voice. With reference to the ECG wave train, should there be, for example, 19 heartbeats indicated for the 10-second period, there would be 19 entries in the heart rate column. If the heart rate was not uniform, this would be evident in the entries in the heart rate column. For the data entered under each heading across the top of the data sheet, the mean and the variance for the 10-second interval were computed. Also, for the data under the headings "Heart rate," "Respiration," and "Acceleration," the standard scores were computed for each entry, converting to a mean of 50 and a standard deviation of 10 to avoid the use of negative numbers. The fact that rate is seldom identical for any given 10-second or 1-minute time interval was a major consideration here, and the resultant means, variances, and standard scores shown on each data sheet provided one important basis for interpreting the physiological and environmental changes that took place.

Considering the data sheet as a whole and its purpose, it is easy to discern why the various headings and data were selected for inclusion. It was necessary, for example, to know what activity was planned for any given time and what task the astronaut was actually performing, so that an assessment could be made of the difficulty of the tasks being performed. Was the astronaut ahead of or behind schedule? What was the relationship between activity and physiological measurements? It was necessary to know what the astronaut was saying, how he was saying it, and how quickly he responded to questions, because certain types of analyses can be made from this aspect to assess the state of tension existing in the astronaut and possible ramifications. This information, in turn, would provide data for analysis from the standpoint of speech processes, audiology, and information processing for the crew.¹²

The wave train graphs served two purposes. First, they were used to check the validity of the digital entries on each data sheet to determine whether these entries were correct. This was necessary because, when converting analog data to digital form, it is likely that some errors will be made. Such erroneous data are not

	15 MINUTE PERIOD @ 1 MIN SAMPLES AT A COMMON TIME BETWEEN 1- 80 MIN AND 1-7 MIN	1-2 MIN TO LIFTOFF @ 10 SEC SAMPLES	LIFTOFF TO ZERO g @ 10 SEC SAMPLES	ZERO g TO + 15 MIN @ 1 MIN SAMPLES	ZERO g + 30 MIN TO ZERO g + 45 MIN	PERIOD OF ASTRONAUT ACTIVITY	SLEEP	RETRO SEQUENCE -90 MIN TO -75 MIN BASED ON MA-6 & MA-7	RETRO SEQUENCE -70 MIN TO -75 MIN BASED ON MA-8	RETRO SEQUENCE -90 MIN TO -75 MIN BASED ON MA-9	RE-ENTRY SEQUENCE -15 MIN TO -05 BASED ON MA-6 & MA-7	RE-ENTRY SEQUENCE -15 MIN TO -05 g BASED ON MA-8	RE-ENTRY SEQUENCE -15 MIN TO -05 g BASED ON MA-9	LANDING + 5 MIN @ 1 MIN SAMPLE 5 TABS 15 PLOTS	POST-LANDING
MR - 3	15 MIN DATA CONTINUOUS 15 TABS 45 PLOTS	2 MIN DATA 12 TABS 12 PLOTS	2 MIN 40 SEC DATA 16 TABS 16 PLOTS	ONLY 5 MIN OF DATA 5 TABS 15 PLOTS	/	/	/	/	/	/	/	/	00:07:50 TO 00:15:37 47 TABS 47 PLOTS	LANDING + 5 MIN @ 1 MIN SAMPLE 5 TABS 15 PLOTS	
MR - 4	"	"	"	ONLY 5 MIN OF DATA 5 TABS 15 PLOTS	/	/	/	/	/	/	/	/	00:07:50 TO 00:15:37 47 TABS 47 PLOTS	"	
MA - 6	"	"	5 MIN DATA 30 TABS 30 PLOTS	15 MIN DATA 15 TABS 45 PLOTS	15 MIN DATA 15 TABS 45 PLOTS	00:25:00 TO 00:30:00 5 TABS 15 PLOTS	3:09:08 TO 3:24:08 15 TABS 45 PLOTS	/	/	4:29:03 TO 4:44:03 15 TABS 45 PLOTS	/	/	4:44:03 TO 4:55:23 68 TABS 68 PLOTS	"	
MA - 7	"	"	"	"	"	3:52:00 TO 4:07:00 15 TABS 45 PLOTS	/	"	/	"	/	/	4:44:03 TO 4:55:57 72 TABS 72 PLOTS	"	
MA - 8	"	"	"	"	"	/	"	7:22:00 TO 7:37:00 15 TABS 45 PLOTS	/	"	8:46:40 TO 9:01:40 15 TABS 45 PLOTS	/	9:01:40 TO 9:13:11 70 TABS 70 PLOTS	"	
MA - 9	"	"	"	"	"	2:19:00 TO 2:34:00 15 TABS 45 PLOTS	13:59:00 TO 15:03:00 27 TABS 81 PLOTS	"	"	32:29:30 TO 32:44:30 15 TABS 45 PLOTS	"	"	33:53:36 TO 34:08:36 15 TABS 45 PLOTS	34:08:36 TO 34:19:49 68 TABS 68 PLOTS	"
MA - 9	"	"	"	"	"	/	/	25:00:00 TO 25:15:00 15 TABS 45 PLOTS	/	/	/	/	/	/	/
TOTAL	90 TABS 270 PLOTS	72 TABS 72 PLOTS	152 TABS 152 PLOTS	70 TABS 210 PLOTS	60 TABS 180 PLOTS	35 TABS 105 PLOTS	27 TABS 81 PLOTS	60 TABS 180 PLOTS	45 TABS 135 PLOTS	15 TABS 45 PLOTS	60 TABS 180 PLOTS	30 TABS 90 PLOTS	15 TABS 45 PLOTS	372 TABS 372 PLOTS	30 TABS 90 PLOTS

Figure 2.—Mercury biomedical data requirements. Total, 1,133 tables and 2,207 plots.

used in the analyses. With respect to the second purpose, the wave form graphs were required for making pattern and wave form analyses, employing such techniques as cross-spectral analysis, autocorrelation, and Fourier analysis. Additionally, certain of the astronauts attempted to enhance their ability to withstand acceleration forces by controlling their breathing. Consequently, an analysis of the respiration wave forms could have applications to the training program, by deriving information as to the best method of breathing.

The Mercury biomedical data requirements in figure 2 indicate how consecutive data sheets of the type described were selected. The vertical column at the left represents the two suborbital Mercury missions of Alan B. Shepard, Jr., and Virgil I. Grissom (MR-3 and MR-4) and the four orbital missions of John H. Glenn, Jr., M. Scott Carpenter, Walter M. Schirra, Jr., and L. Gordon Cooper, Jr. (MA-6, 7, 8, and 9). As indicated by the row of headings across the top, there was selected first a 15-minute period of 1-minute data sheets for a common time between T minus 60 and T minus 45; that is, there was a data sheet for T minus 60 to T minus 59, for T minus 59 to T minus 58, and progressively to T minus 46 to T minus 45.

Since physiological changes generally take place more rapidly immediately before liftoff, a sample of data sheets of 10-second duration each was selected for the period T minus 2 minutes to liftoff. Accordingly, there were 12 data sheets of this kind, since there are 120 seconds during this period, with one data sheet for

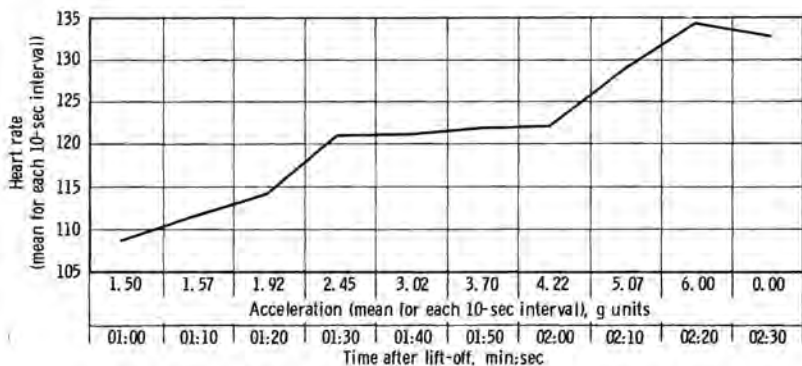


Figure 3.—Mercury time-line data: heart rate and acceleration for one astronaut.

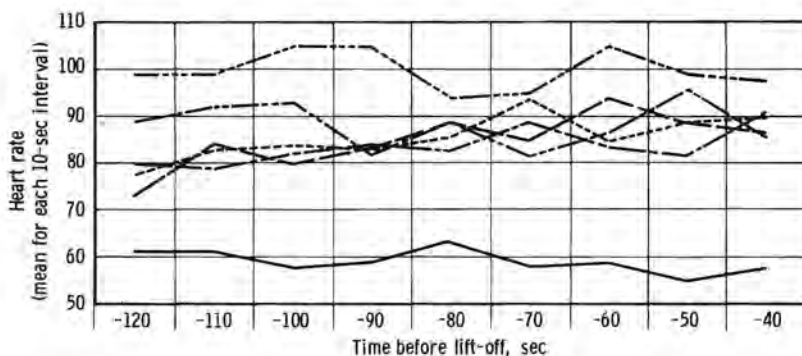


Figure 4.—Mercury time-line data: heart rate only for six astronauts.

each 10-second interval. The next sample selected (as shown in fig. 2) covered the period from liftoff to zero-g at 10-second intervals. This was followed by a 15-minute sample for the period from zero-g to 15 minutes past zero-g; next from zero-g plus 30 minutes to zero-g plus 45 minutes; and so on to the last entry, which covers the period from landing or "splash" to 5 minutes after landing.

By preparing the in-flight medical data in the time-line format described, it was possible to subject these data to many types of mathematical, statistical, and graphical treatment. These included subjecting the data to computers using techniques such as chi-square, correlation, analysis of variance, and factor analysis, and utilizing the data in the construction of graphs such as figures 3 and 4.

Preflight and Postflight Data

A considerable amount of the medical data which were systematically acquired before and soon after each Mercury flight was consolidated as exemplified in tables I to XII. These tables were taken from the series of six NASA publications summarizing the results of the Mercury mission.¹³ Since these publications contain more detailed information than the present discussion, they provide an excellent source of research information concerning preflight and postflight medical data. The examinations were designed to meet what would be considered requirements by a physician for the evaluation of a patient under normal clinical medical conditions.

At least one table has been selected from each of the six cited publications to provide an overview of the types of data which were acquired. The tables selected are described briefly below:

MR-3, First Manned Suborbital Flight.—Table I provides a summary of vital-signs data, including such measurements as preflight and postflight body weight, temperature, pulse rate, and blood pressure. In table II a serum and plasma enzymes summary is presented, comparing analyses accomplished during the centrifuge program with preflight and postflight analyses. Determinations included transaminases, esterase, peptidase, aldolase, isomerase, and dehydrogenases.

MR-4, Second Manned Suborbital Flight.—A comparison of physical examination findings during simulated and actual flight is shown in table III. Blood chemistry findings, comparing data acquired during the centrifuge program with preflight and postflight data, are given in table IV. The blood chemistry determinations include sodium (serum), potassium (serum), chloride, protein, albumin, globulin, glucose, epinephrine, and norepinephrine.

MA-6, First Manned Orbital Flight.—The tables selected here pertain to clinical evaluation conducted immediately before and soon after the MA-6 mission.¹⁴ Evaluations were made of such factors as general status, weight, temperature, respiration, pulse rate, blood pressure, heart, lungs, and skin (table V). Fluid intake and output are shown in table VI.

MA-7, Second Manned Orbital Flight.—A preflight and postflight peripheral blood value summary was selected for illustrative purposes pertaining to this mission. This involved determinations of preflight and postflight hemoglobin, hematocrit, white blood cells, red blood cells, and differential blood count (table VII).

MA-8, Third Manned Orbital Flight.—A summary of heart rate and respiration data from physiological monitoring is presented in table VIII and a summary of blood pressure data is presented in table IX. In addition to preflight and postflight data, some in-flight determinations are given.

MA-9, Fourth Manned Orbital Flight.—The tables selected for presentation here include one concerning pilot preflight activities (table X) and one showing a comparison of typical preflight and postflight urine values (table XI).¹⁵ In addition, the data collected during tilt table studies are summarized in table XII.

TABLE I.—Vital Signs (MR-3 Flight)

	Preflight		Postflight	
	- 8 hr		Shipboard	+ 3 hr
Body weight nude (post voiding).	169 lb 4 oz . . .		167 lb 4 oz . . .	166 lb 4 oz
Temperature, °F	99.0 (rectal) . . .		100.2 (rectal) . . .	98 (oral)
Pulse per min	68		100	76
Respiration per min	16			20
Blood pressure, mm Hg:				
Standing				102/74
Sitting	120/78		130/84	
Supine				100/76
Pulse per min:				
Before exercise	68			76
After exercise	100			112
	(2¾ min)*			(3 min)*

* Time for return to normal.

TABLE II.—Serum and Plasma Enzymes Summary (MR-3 Flight)

	Normal range, units	Centrifuge			MR-3 flight		
		Prerun	Postrun		Preflight	Postflight	
			+30 min	+2 hr	-4 days	+3 hr	+45 hr
Transaminases:							
SGOT	0-35	19	17	10	23	22	16
SGPT	0-20	4	4	9	0	6	8
Esterase acetylcholine	^a 130-260	235	230	210	195	210	220
Peptidase leucylamino	100-310	240	220	310	360	415	400
Aldolase	50-150	25	28	19	28	38	41
Isomerase phosphohexose	^b 10-20	12	11	11	5	15	7
Dehydrogenases:							
Lactic	150-250	200	190	235	185	170	190
Malic	150-250	190	155	220	225	190	220
Succinic	Neg.	Neg.	Neg.	Neg.	Neg.	Neg.	Neg.
Inosine	Neg.	Neg.	Neg.	Neg.	Neg.	Neg.	Neg.
Alpha ketoglutaric	Neg.	Neg.	Neg.	Neg.	Neg.	Neg.	Neg.

^a ΔpH units.^b Bodansky units.

TABLE III.—Comparison of Physical Examination Findings During Simulated and Actual Flight (MR-4 Flight)

	Simulated Redstone I	Simulated Redstone II	MR-4 flight
Temperature, °F:			
Before.....	97.9.....	97.4.....	97.8
After.....	99.0.....	98.0.....	98.4
Change.....	1.1.....	0.6.....	0.6
Weight, lb:			
Before.....	150.31.....	148.25.....	150.5
After.....	147.10.....	146.36.....	147.5
Loss.....	3.21.....	1.89.....	3.0
Pulse rate per min:			
Before.....	68.....	69.....	68
After.....	82.....	84.....	160 to 104
Blood pressure (LA), mm Hg:			
Before.....	110/68.....	100/70.....	128/75
After.....	100/70.....	128/80.....	120/84
Vital capacity, liters:			
Before.....	5.9.....	.....	5.0
After.....	5.4.....	.....	4.5
Postflight physical findings.....	Chest clear to P and A; slightly increased DTR's; no change in ECG; no petechia; appears warm and tired.	Chest clear; DTR's 2+; no petechia.	Chest clear; no petechia; appeared fatigued.

TABLE IV.—Blood Chemistry Findings (MR-4 Flight)

	Centrifuge			MR-4 flight			
	Prerun	Postrun		Preflight	Postflight		
		+30 min	+2 hr		-4 days	+1 hr	+5 hr	+49 hr
Sodium (serum), meq/l.....	147	141	143	142	140	144	141
Potassium (serum), meq/l....	5.4	5.9	4.6	4.1	3.5	4.4	4.8
Chloride, meq/l.....	89	94	90	97	95	101	99
Protein, total.....	7.5	8.0	7.6	7.4	7.3	7.1	7.9
Albumin, g/100 ml.....	4.1	4.3	4.0	3.25	4.2	5.0	4.2
Globulin, g/100 ml.....	3.4	3.7	3.6	4.15	3.1	2.1	4.7
Glucose, mg/100 ml.....	78	118	95	94	136	105	---
Epinephrine, ^a µg/l.....	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	---
Norepinephrine, ^b µg/l.....	2.3	7.2	1.5	5.1	16.5	7.2	---

^a Normal values: 0.0 to 0.4 µg/l.

^b Normal values: 4.0 to 8.0 µg/l.

TABLE V.—Clinical Evaluation (MA-6 Flight)

[All times are eastern standard]

	Preflight (launch morning)		Postflight	
General status.....	Eager for flight.....		Alert, but not talkative; sweating profusely; appeared fatigued; not hungry.	
Weight, lb.....	171 $\frac{1}{16}$ at 3:15 a.m.....		166 $\frac{1}{16}$ at 6:50 p.m. (5 $\frac{1}{16}$ lb loss). ^a	
Temperature, ° F.....	98.2 (oral).....		99.2 (rectal at 4:00 p.m.); 98.0 (oral at 12:00 p.m.).	
Respiration, breaths/min.....	14.....		14.	
Pulse, beats/min.....	68.....		76 on shipboard, 72 at Grand Turk.	
Blood pressure, (left arm), mm Hg.....	118/80 (sitting).....		105/60 (standing); 120/60 (supine) at 3:45 p.m.; 128/78 (sitting) at 9:30 p.m.	
Heart and lungs.....	Normal.....		Normal—no change.	
Skin.....	No erythema or abrasions.		Erythema of biosensor sites; superficial abrasions second and third fingers of right hand.	
Extremity measurements:	Left	Right	Left	Right
Wrist, in.....	6 $\frac{7}{8}$	7	6 $\frac{3}{4}$	7
Calc (maximum), in.....	16 $\frac{7}{8}$	16 $\frac{1}{2}$	16 $\frac{5}{8}$	16 $\frac{1}{2}$
Ankle (minimum), in.....	9 $\frac{3}{8}$	9 $\frac{1}{8}$	9	9 $\frac{1}{4}$

^a Not true inflight weight loss, since the scales were neither the same nor compared and postflight weight was 4 hours 8 minutes after landing.

TABLE VI.—Fluid Intake and Output (MA-6 Flight)

	Urine output (cc)	e.s.t.	Fluid intake	e.s.t.
Countdown.....	0		0 cc	
Inflight.....	* 800	2:00 p.m.	^b 94 cc	11:48 a.m.
			265 cc iced tea	3:45 p.m.
Postflight, ship.....	0		240 cc water	6:30 p.m.
			125 cc coffee	6:50 p.m.
Total.....	800		724 cc	

* Specific gravity, 1.016.

^b 119.5 grams of applesauce puree (78.7 percent water).

Conclusion

The general conclusions previously drawn about the physiological effects of space flight on man during the Mercury flights appear to be valid, as supported by analyses of a considerable amount

TABLE VII.—Astronaut Peripheral Blood Values (MA-7 Flight)

Determination	Preflight		Postflight	
	-7 days	-2 days	May 25, 1962 12:15 a.m.	May 26, 1962 12:00 m
Hemoglobin (cyanmethemoglobin method), grams/100 ml.....	15.0	13.8	16.0	14.8
Hematocrit, percent.....	47	42	50	46
White blood cells/mm ³	12,700	11,600	12,500	11,900
Red blood cells, millions/mm ³	5.2	-----	5.6	5.2
Differential blood count:				
Lymphocytes, percent.....	25	19	27	37
Neutrophils, percent.....	71	79	65	58
Monocytes, percent.....	2	1	3	2
Eosinophiles, percent.....	2	1	4	2
Basophiles, percent.....	0	0	1	1

of preflight, in-flight, and postflight medical data. Not all of these data have been analyzed with respect to each possibility that may present itself in the future. The data are available, however, for utilization in connection with additional statistical or experimental studies which may become necessary as man pursues his missions in outer space.

RECOVERY

Two basic requirements for the medical support of Project Mercury recovery operations were the provision of prompt, optimum medical care for the astronaut if necessary upon his retrieval from the spacecraft and the early medical evaluation of the astronaut's postflight condition. Experience led to a change in emphasis from taking the medical care to the astronaut, as practiced in the early missions, to returning the astronaut to a point where he could receive this care, as provided in later missions.

In the launch-site area, medical support included a general surgeon, an anesthesiologist, a surgical technician and nurses, a thoracic surgeon, an orthopedic surgeon, a neurosurgeon, an internist, a pathologist, a urologist, a plastic surgeon, and supporting technicians. In early missions they were deployed to Cape Canaveral. On the last two missions it became necessary, because of the distances involved, to develop a team at Tripler Army Hospital, Hawaii, for the Pacific area in addition to the team at Cape Canaveral which covered the Atlantic area. Because such large numbers of highly trained physicians were thus deployed without

TABLE VIII.—Summary of Heart Rate and Respiration Data From Physiological Monitoring (MA-8 Flight)

Date	Procedure	Duration of observation, hr: min	Heart rate, beats/min				Respiration rate, breaths/min			
			Number of determinations	Standard deviations, 2 σ	Range	Mean	Number of determinations	Standard deviations, 2 σ	Range	Mean
Preflight										
March 1959.....	Lovlace Clinic dynamic tests.....	Variable	39	(*)	68 to 160	96		None recorded		
Sept. 22, 1961.....	Mercury-Atlas centrifuge dynamic simulation.	1:07.5	75	50 to 78	48 to 78	64	25	9 to 15	7 to 18	12
May 4, 1962.....	MA-7 launch pad simulated flight.	1:09	24	53 to 91	58 to 88	72	19	10 to 22	10 to 24	16
Apr. 17 and Aug. 14, 1962.....	Hangar simulated flights.....	9:47	87	52 to 78	51 to 76	65	19	14 to 26	14 to 24	20
Sept. 10, 1962.....	Launch pad simulated flight 1A.....	3:09	69	45 to 65	43 to 72	55	68	14 to 26	10 to 28	20
Sept. 14, 1962.....	Launch pad simulated flight 2A.....	2:35	68	54 to 82	52 to 86	68	68	14 to 30	12 to 28	22
Sept. 28, 1962.....	Launch pad simulated launch.....	3:07	72	49 to 73	46 to 74	61	71	12 to 28	9 to 26	20
Oct. 3, 1962.....	Launch countdown.....	2:33	61	64 to 80	58 to 88	72	61	17 to 23	16 to 26	20
Infight										
Oct. 3, 1962.....	Infight.....	9:13	220	50 to 102	56 to 121	76	220	11 to 27	10 to 43	19
Postflight, clinical										
Oct. 3 and 4, 1962.....	Debriefing onboard recovery ship.	Variable	22	52 to 112	56 to 104	82		None recorded		

* These data are included for completeness, but the conditions were very different from the other procedures.

TABLE IX.—Summary of Blood-Pressure Data (MA-8 Flight)

Date	Procedure	Mean blood pressure, mm Hg	Systole				Diastole				Mean pulse pressure, mm Hg
			Number of determinations	Standard deviation, 2σ	Range, mm Hg	Mean, mm Hg	Number of determinations	Standard deviation, 2σ	Range, mm Hg	Mean, mm Hg	
Preflight, clinical											
Mar. 1959.....	Lovlace Clinic dynamic tests.	119/67	39	(*)	90 to 164	119	39	(*)	52 to 84	67	52
July 25, 1962.....	Special BPMS test.....	104/75	27	92 to 116	94 to 116	104	27	62 to 88	64 to 94	75	29
1960 to Oct. 3, 1962.	Random clinical determinations.	115/76	13	103 to 127	100 to 122	115	13	62 to 90	64 to 84	76	39
Preflight, BPMS											
Sept. 22, 1961.....	Mercury-Atlas dynamic simulation on centrifuge.	133/96	11	111 to 155	115 to 150	133	11	68 to 124	76 to 120	96	37
July 25, 1962.....	Special BPMS test.....	108/67	28	(*)	94 to 126	108	28	(*)	54 to 100	67	41
May to Oct. 1962....	Hangar and launch complex tests.	107/70	31	92 to 122	94 to 123	107	29	58 to 82	58 to 80	70	37
Oct. 3, 1962.....	Prelaunch (hangar, transfer van, and block-house).	117/80	14	103 to 121	110 to 143	117	14	66 to 94	71 to 94	80	37
Infight, BPMS											
Oct. 3, 1962.....	Infight.....	126/69	20	116 to 136	111 to 158	126	16	64 to 74	59 to 75	69	57
Postflight, clinical											
Oct. 3 and 4, 1962..	Debriefing onboard carrier.	112/78	12	92 to 132	94 to 120	112	12	70 to 86	70 to 84	78	37

* These data are included for completeness but the conditions were very different from the other procedures.

TABLE X.—Pilot Preflight Activities (MA-9 Flight)
 [Selected activities for which medical study or support was performed]

Date (1963)	Activity	Medical study or support
Jan. 5.....	Altitude-chamber spacecraft checkout.	Physical examination before and after; background data (biosensors)
Mar. 22-23.....	Hangar flight simulation.....	Physical examination before and after; background data (biosensors); low residue diet (3 days) and flight food (2 days)
Apr. 23.....	Flight simulation no. 1.....	Physical examination; background data (biosensors); timed urine collection
May 4.....	T-10 day physical examination.....	Physical examination, 45 minutes
May 7.....	Mission simulation (procedures trainer).	Physical examination before and after; background data (biosensors); timed urine collection
May 8.....	Launch simulation.....	Physical examination before and after; background data (biosensors); timed urine collection; begin controlled diet; blood specimen, 50 cc
May 10.....	Flight simulation no. 3.....	Physical examination before and after; timed urine collection; background data (biosensors)
May 11.....	.....	Begin low residue diet
May 12.....	T-2 day physical examination.....	Comprehensive medical examination, 2½ hours; blood (30 cc) and urine specimen
May 14.....	Countdown (flight canceled).....	Physical examination before and after; timed urine collection; blood specimen, 30 cc
May 15.....	Flight countdown.....	Physical examination; aeromedical countdown; awaken 2:51 a.m. e.s.t.; launch 8:40 a.m. e.s.t.

TABLE XI.—Urine Analysis (MA-9 Flight)

Date (1963)	Time	Total volume, cc	Specific gravity	Na, meq/l	K, meq/l	Ca, meq/l	Cl, meq/l	PO ₄ , mg%	Creati- nine, mg%	Comments	
Mar. 20.....	7:30 a.m. to 9:26 a.m.....	184	1.012	141	55	4.15	161	26.7	85	Low residue diet.	
Mar. 20.....	9:26 a.m. to 12:59 p.m.....	260	1.013	180	49	16.3	207	42.2	110		
Mar. 20.....	12:59 p.m. to 4:45 p.m.....	420	1.014	129	40	10.1	159	56.6	86		
Mar. 20.....	4:45 p.m. to 9:10 p.m.....	330	1.015	125	38	8.7	111	73	111		
Mar. 21.....	9:10 p.m. to 1:00 a.m.....	340	1.012	137	17	7.5	100	58.3	102		
Mar. 21.....	1:00 a.m. to 7:52 a.m.....	830	1.005	79	14	5.0	79	31.4	62		
Mar. 21.....	7:52 a.m. to 12:46 p.m.....	470	1.011	143	42	10.3	174	26.6	94		
Mar. 21.....	12:46 p.m. to 5:28 p.m.....	286	1.017	179	54	16.85	210	74.3	125		
Mar. 21.....	5:28 p.m. to 11:35 p.m.....	600	1.015	189	41	7.6	178	48	105		
Mar. 22.....	11:35 p.m. to 3:26 a.m.....	210	1.015	239	31	10.6	163	54	-----		
Mar. 22.....	3:26 a.m. to 5:36 a.m.....	110	1.018	216	34	25.5	165	55	-----		
Mar. 22.....	5:36 a.m. to 10:47 a.m.....	255	1.018	154	38	21.3	142	54	134		
Mar. 22.....	10:47 a.m. to 6:35 p.m.....	300	1.020	116	47	20.85	86	135	152		
Mar. 23.....	6:35 p.m. to 1:20 a.m.....	360	1.023	131	51	18.9	119	75.4	142		Before hangar simulated flight.
Apr. 23.....	6:00 a.m. to 6:50 a.m.....	32	-----	196	58	7.75	158	146	144		During hangar simulated flight.
Apr. 23.....	6:50 a.m. to 12:35 p.m.....	394	1.020	226	85	3.04	220	70.8	106		Simulated flight no. 1 (before).
Apr. 23.....	12:35 p.m. to 5:08 p.m.....	122	1.022	195	51	5.95	187	68.6	98		Simulated flight no. 1 (during).
Apr. 25.....	Unknown to 11:35 a.m.....	170	1.020	192	83	6.3	212	18.7	107		Simulated flight no. 1 (after).
Apr. 25.....	11:35 a.m. to 4:28 p.m.....	134	1.024	242	40	5.75	226	35.4	104		Simulated flight no. 2 (before).
Apr. 25.....	4:28 p.m. to 5:55 p.m.....	308	1.018	250	44	3.40	234	46.1	107		Simulated flight no. 2 (during).
										Simulated flight no. 2 (after).	

May 7.....	6:30 a.m. to 8:30 a.m.....	64	1.020	115	56	13.9	198	103	152	Procedures trainer (before).
May 7.....	8:30 a.m. to 2:00 p.m.....	480	1.014	124	60	5.65	146	63.6	88	Procedures trainer (during).
May 8.....	9:15 a.m. to 1:40 p.m.....	540	1.012	137	79	7.4	166	41.6	74	Launch simulation (during).
May 8.....	1:40 p.m. to 6:00 p.m.....	360	1.012	137	53	3.2	125	43	104	Launch simulation (after).
May 10.....	7:30 a.m. to 11:45 a.m.....	180	1.023	148	85	17.8	176	45.7	130	Simulated flight no. 3 (before).
May 10.....	11:45 a.m. to 2:00 p.m.....	170	1.025	198	72	20.7	219	76	114	Simulated flight no. 3 (before).
May 10.....	2:00 p.m. to 6:30 p.m.....	320	1.023	181	83	13.4	201	97	115	Simulated flight no. 3 (during).
May 10.....	6:30 p.m. to 10:05 p.m.....	80	1.026	200	71	6.9	165	148	139	Simulated flight no. 3 (after).
May 13.....	6:30 p.m. to 9:00 p.m.....	440	1.025	177	54	19.95	165	128	137	Before canceled flight.
May 14.....	9:00 p.m. to 2:50 a.m.....	225	1.024	165	32	10.0	107	161	152	Before canceled flight.
May 14.....	2:50 a.m. to 7:30 a.m.....	680	1.012	120	49	5.6	128	12.6	56	Collection device—canceled flight.
May 14.....	7:30 a.m. to 12:30 p.m.....	315	1.015	98	50	5.85	1109	34	104	After canceled flight.
May 15.....	10:00 p.m. to 2:52 a.m.....	178	1.028	112	34	23.4	73	214	162	Preflight.
May 15.....	2:52 a.m. to 3:55 a.m.....	25	1.025	98	48	12.4	89	185	165	Preflight.
May 15.....	3:55 a.m. to 7:56 a.m.....	177	-----	184	68	8.25	212	33.8	125	Preflight (pad) bag no. 1.
May 15.....	7:56 a.m. to 12:29 p.m.....	195	-----	213	69	14.1	236	28.4	131	Inflight bag no. 2.
May 15.....	12:29 p.m. to 10:09 p.m.....	314	-----	197	56	12.6	188	130	154	Inflight bag no. 3.
May 16.....	10:09 p.m. to 7:15 a.m.....	333	-----	120	38	17.7	128	125	169	Inflight bag no. 4.
May 16.....	7:15 a.m. to 1:14 p.m.....	107	1.026	137	41	15.6	150	136	170.8	Collection device.
May 16.....	1:14 p.m. to 9:30 p.m.....	70	1.031	107	96	16.4	126	240	177	1st voided sample.
May 17.....	9:30 p.m. to 1:05 p.m.....	475	1.026	41	62	20.95	29	149	148	2d voided sample.
May 17.....	1:05 p.m. to 9:12 p.m.....	315	1.020	29	54	24.3	59	68.5	148	3d voided sample.
May 18.....	9:12 p.m. to 12:00 p.m.....	605	1.023	29	70	17.4	41	114	139	4th voided sample.
May 20.....	8:00 a.m. to 10:15 a.m.....	-----	1.019	125	92	15.2	150	68	110	4 days after recovery (physical exam Patrick AFB).

TABLE XII.—Summary of Tilt Studies (MA-9 Flight)

Subject	No. of determinations	Pretilt					Tilt					Posttilt				
		Heart rate, beats/min		Blood pressure, mm Hg			Heart rate, beats/min		Blood pressure, mm Hg			Heart rate, beats/min		Blood pressure, mm Hg		
		Mean	Range	Mean	Range		Mean	Range	Mean	Range		Mean	Range	Mean	Range	
					Systolic	Diastolic				Systolic	Diastolic				Systolic	Diastolic
Preflight																
Cooper preprocedure . . .	5	66	53 to 76	100/73	91 to 112	60 to 87	82	60 to 105	100/86	88 to 144	60 to 94	66	60 to 90	102/75	89 to 114	60 to 88
Cooper postprocedure . . .	6	64	51 to 85	99/74	92 to 128	66 to 82	85	72 to 108	105/87	92 to 134	60 to 97	62	52 to 76	102/75	90 to 114	64 to 94
Cooper and Shepard (all preflight tilts) . . .	15	67	55 to 85	100/71	90 to 112	60 to 82	86	60 to 117	107/86	88 to 145	64 to 98	64	52 to 80	103/72	90 to 114	60 to 94
Postflight																
Cooper ^a	3	83	76 to 81	89/64	86 to 90	52 to 82	123	96 to 144	90/73	80 to 110	68 to 84	76	64 to 88	98/60	90 to 106	58 to 80
Cooper ^b	1	58	56 to 60	98/61	96 to 100	60 to 62	80	76 to 88	94/68	86 to 100	64 to 78	60	56 to 64	102/56	96 to 108	54 to 58

^a Tilts between 1 and 7 hours after landing.^b Tilt 18 hours after landing.

the likelihood that their services would be required, it was concluded, after careful evaluation, that the specialty team could be maintained on a standby basis at a stateside hospital and flown to Cape Canaveral or a recovery site if their services were needed. Surgical resuscitation teams would be available at these sites, and other launch-site support would be provided by a point team composed of a flight surgeon and scuba-equipped para-rescue personnel airborne in a helicopter. Medical technicians who could render first aid were also available in small vehicles on the Banana River at Cape Canaveral. A surgeon and an anesthesiologist, together with supporting personnel, were stationed in the blockhouse at Cape Canaveral to serve as the first echelon of resuscitative medical care in the event of an emergency. This was in accordance with basic planning discussed earlier in this study.

For the early missions each vessel was assigned a surgeon, an anesthesiologist, and a medical technician team with the supporting equipment necessary for evaluation and medical care. Later, this distribution was modified to include the assignment of a single physician (either a surgeon or an anesthesiologist) to the destroyer. The general concept was that he would provide resuscitative care only, and then evacuate the astronaut to the carrier in his particular area.

SPACE MEDICINE LOOKS TO THE FUTURE

Project Mercury had demonstrated forcibly that man could survive and function ably as a pilot-engineer-experimenter in the space environment without undesirable reactions or detriment to normal body functions for periods of as long as 34 hours. Other medical knowledge gained included the fact that there had been no evidence of abnormal sensory, psychiatric, or psychological response to an orbital space flight of up to 1½ days. Sleep in flight was proved to be possible and subjectively normal. The radiation dose received by the astronauts was considered medically insignificant.

Following missions of 9 and 34 hours' duration, there was an orthostatic rise in heart rate and fall in blood pressure, which persisted for between 7 and 19 hours after landing. The changes following the 34-hour flight were of greater magnitude than those following the 9-hour flight, but all changes disappeared in a similar time interval in both cases. The implications of this hemodynamic response obviously would require serious study prior to



Much was learned about space medicine in Project Mercury; much of it is still being assimilated and then must be taught to others. Dr. W. Randolph Lovelace II, NASA Director of Space Medicine, is shown here lecturing to Service doctors on space medicine.

longer space missions. No other clearly significant changes were found in the comprehensive preflight and postflight physiological examination.

Certain basic problems in space medicine remained unresolved, although investigators were now in a much better position to utilize improved biomedical instrumentation and to establish experimental designs having greater potential for solving these problems. What would be the effects of prolonged weightlessness and combined stresses upon the astronaut? What would be the effects of space radiation? Would toxic hazards within the spacecraft endanger the safety of the astronaut? Some basic biological questions had to be answered. How would man survive for extended periods of time in a closed ecological system? Could his food and wastes be recycled and regenerated? Problems of biotechnology, too, were still unsolved.

All these fundamental problem areas had been defined in the late 1940's by Strughold and his group at the School of Aviation Medicine, Texas, on the basis of the German aeromedical experience at Peenemunde, and logically on man's historical ability to observe. In this sense, space medicine may indeed have been said to antedate aviation medicine.

Be that as it may, the problems had been defined long since. Project Mercury had provided the first step in answering them.

Simulation and testing on centrifuges could provide a partial answer, but only through actual experience in orbiting space laboratories could the larger answers be provided. As Project Mercury drew to a close, the scientific community looked forward with confidence to meeting that challenge.

NOTES TO CHAPTER X

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⁴ William Hines, "Slayton's Grounding Raises Questions on Space Program," *The Sunday Star* (Washington), Mar. 18, 1962. See also NASA Press Release No. 62-67, Mar. 17, 1962.

⁵ Brig. Gen. Charles H. Roadman, Director, Aerospace Medicine, Office of Manned Space Flight, Memo for D. Brainerd Holmes, Director of Manned Space Flight, July 10, 1962.

⁶ NASA Release No. 62-161, July 11, 1962. Subsequently, Major Slayton resigned from the Air Force and assumed important duties with MSC in a civilian capacity.

⁷ Personal notes of the author.

⁸ *Mercury Project Summary Including Results of the Fourth Manned Orbital Flight, May 15 and 16, 1963*, NASA SP-45, 1963. This 444-page document provides the basis of the following summary which, in many instances, is a synoptic version of the original document. See particularly Charles A. Berry, ch. 11, "Aeromedical Preparations," pp. 199-209.

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Graybiel, and Willard R. Hawkins, "Aeromedical Preparation and Results of Postflight Medical Examinations," ch. 8 in *Results of the First United States Manned Orbital Space Flight, February 20, 1962*, Manned Spacecraft Center, NASA.

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CHAPTER XI

The End of the Beginning

AT CAPE CANAVERAL during the first Cooper orbit, the author had stood on the site from which the MA-9 launch had been made, an empty, desolate place with burned-out scraps of debris from the launching scattered around. The press had not yet arrived, and only a few orange-helmeted workmen moved quietly about. The impact was one of finality, the end of an era. . . .

At the northern part of the Cape, bounded on one side by the Banana River and on the other by the Atlantic, the new Saturn launch complex with its towering gantries from which the Gemini and Apollo launches would be made already dwarfed the Mercury-Atlas complex.

Truly this was a moment of transition.

As early as January 1963, NASA Administrator Webb had indicated that the Cooper flight, MA-9, would conclude the Mercury series unless unforeseen problems arose, but in the first few days following the flight there was speculation as to whether another shot would be made. Unless there were further flights, there was facing the Nation a long, dry period between the Mercury and Gemini flights. There would be pressing day-to-day work that would tax the resources of the Nation, but little in the way of demonstrated progress in manned space flight.

Administrator Webb's viewpoint was based on many factors, obviously including the NASA image before Congress, the overall economy of money and manpower, and the psychological need to focus on the future of Projects Gemini and Apollo rather than extend the past as represented by Project Mercury. On the other hand, the operations staff of Project Mercury could point with equally compelling logic to resources ready for use, including a launch vehicle and spacecraft, and trained astronauts. The launch, tracking, and recovery organization was in existence and would profit from being used. To the operations staff it could therefore logically have seemed a relatively economical opportunity to ex-

tend the learning curve. This part of the Mercury story remains to be written. Suffice it for purposes of this study to state merely that on June 12, 1963, NASA Headquarters announced the termination of Project Mercury.

The manned space-flight program had come to a period of transition in yet another way, as two key individuals left NASA. On that date, June 12, 1963, D. Brainerd Holmes, Director of the Office of Manned Space Flight, resigned to return to private industry. Brig. Gen. Charles Roadman, Director of Space Medicine under Holmes, returned to duty with the Air Force on July 1, 1963.

Thus the mission-oriented Project Mercury was officially at an end by the early summer of 1963; and while basic concepts regarding man's ability to survive and function on short-range space flights had been verified, the biological implications of extended manned space flight remained largely for future resolution. Mercury had been, as some described it, merely "the end of the beginning" in the U.S. manned exploration program.

Already the Russians had accumulated a greater number of manned space-flight hours than had the United States. Now the international scientific community awaited the assessment and exchange of biological data that would indicate whether, from the physiological viewpoint, man could survive extended space travel. The principles and practice of space medicine in all its ramifications would be brought to bear upon this, the next potential milestone in man's quest for the stars.

APPENDIX A

*Members of Committees Listed
on Chart 1*

NATIONAL AERONAUTICS AND SPACE COUNCIL

THE PRESIDENT OF THE UNITED STATES

BRONK, DR. DETLEV W.
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National Academy of Sciences

BURDEN, WILLIAM A. M.
New York

DOOLITTLE, GEN. JAMES H.
Chairman of Board
Space Technology Laboratories, Inc.
Thompson Ramo-Wooldridge Corporation

DULLES, THE HON. JOHN FOSTER
Secretary of State

MC ELROY, THE HON. NEIL H.
Secretary of Defense

GLENNAN, DR. T. KEITH
Administrator
National Aeronautics and Space
Administration

MCCONE, JOHN A.
Chairman
U.S. Atomic Energy Commission

WATERMAN, DR. ALAN T.
Director
National Science Foundation

NASA SPECIAL COMMITTEE ON LIFE SCIENCES

LOVELACE, DR. W. RANDOLPH II, *Chairman*
 Lovelace Foundation for Medical
 Education and Research

BARR, CAPT. NORMAN LEE, USN (MC) Director, Astronautical Division Bureau of Medicine and Surgery Navy Department	LANGHAM, DR. WRIGHT HASKELL Los Alamos Scientific Laboratory University of California
EBERSOLE, LT. COMDR. JOHN M., USN (MC) National Medical Center	LIVINGSTON, DR. ROBERT B. Director of Basic Research NIMH-NINDB National Institutes of Health
FLICKINGER, BRIG. GEN. DONALD D., USAF (MC) Surgeon and Asst. Deputy Com- mander for Research Air Research and Development Com- mand	REYNOLDS, DR. ORR Director, Office of Science OASD (R&E)
HOLMES, LT. COL. ROBERT H., USA (MC) Chief, Biophysics & Astronautics Branch U.S. Army Medical Research and Development Command	MYERS, BOYD C. II (Secretary) National Aeronautics and Space Administration

CIVILIAN-MILITARY LIAISON COMMITTEE

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Office, Secretary of Defense

National Aeronautics and Space Administration Members

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Deputy Administrator

SILVERSTEIN, ABE
Director of Space Flight Development

STEWART, DR. HOMER J.
Director of Program Planning

ABBOTT, IRA H.
Assistant Director of Aerodynamics
and Flight Mechanics Research

WYATT, DEMARQUIS (*alternate*)
Technical Assistant to Director of
Space Flight Development

HYATT, ABRAHAM (*alternate*)
Assistant Director for Propulsion
Development

*Department of Defense Members**Office of Secretary of Defense*

JOHNSON, ROY W.
Director, Advanced Research Projects Agency

MACAULEY, JOHN B. (*alternate*)
Deputy Assistant Secretary of
Defense (R&E)

Army

DICK, MAJ. GEN. W. W., JR.
Director of Special Weapons
Office, Chief of Research and
Development

SMOLLER, COL. J. F. (*alternate*)
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Office, Chief of Research and
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Navy

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Deputy Chief of Naval Operations
(Air)

HAYWARD, REAR ADM. J. T.
(*alternate*)
Assistant Chief, Naval Operations
(R&D)

Air

SWOFFORD, MAJ. GEN. R. P., JR.
Assistant Deputy Chief of Staff,
Development

DEMLER, MAJ. GEN. M. C. (*alternate*)
Director of R&D
Assistant Deputy Chief of Staff

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 School of Medicine

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 Advanced Research Projects Agency

LA MER, DR. VICTOR K.
 Department of Chemistry
 Columbia University

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 Brookhaven National Laboratories

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 Department of Biophysics
 Johns Hopkins University

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 Department of Physics
 University of Minnesota

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 Rockefeller Institute

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 University of California (Berkeley)

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 Department of Biology
 Brookhaven National Laboratories

FITTS, DR. PAUL M.
 Department of Psychology
 University of Michigan

FLICKINGER, BRIG. GEN. DON D.,
 USAF (MC)
 Assistant Deputy Commander for
 Research
 Air Research and Development
 Command
 Andrews Air Force Base

FRENCH, DR. JOHN D.
 Department of Anatomy
 University of California Medical
 Center

GELL, CAPT. CHARLES F., USN (MC)
 Special Assistant for Medical &
 Allied Sciences
 Office of Naval Research
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 Johnsville, Pa.

HOLMES, LT. COL. ROBERT H., USA
 (MC)
 Chief, Biophysics & Astronautics
 Branch
 U.S. Army Medical Research & De-
 velopment Command

Ex-Officio Members

CANNAN, DR. R. KEITH
 Chairman, Division of Medical
 Sciences
 National Academy of Sciences—
 National Research Council

CUTLER, MAJ. KAY, USAF (MC)
 Chief, Radiobiology Branch
 Air Research & Development Com-
 mand
 Andrews Air Force Base

SEELEY, DR. SAM F. (*Acting Executive Secretary*)
 National Academy of Sciences—National Research Council

APPENDIX B

Aeromedical Monitoring Personnel

SUMMARY OF MONITOR PLAN

1. The following assumptions are made :
 - (a) Department of Defense physicians will be used.
 - (b) Personnel to be trained and assigned on a TDY basis.
 - (c) When possible, station assignment will be close to duty station.
 - (d) Provision will be made to train additional DOD personnel to provide a pool of trained monitors for later operations and to provide a reserve for Mercury operations.
 - (e) Advanced residents in aviation medicine would be a good source of extra personnel.
 - (f) STG-NASA reserves right to review and interview qualifications of personnel to be assigned in direct support of Mercury.
 - (g) STG-NASA will be responsible for monitor training.
 - (h) Where possible Mercury personnel will be used to accomplish other national objectives as a by-product.
 - (i) Approximate total time for monitor training—4-6 weeks over a period of about 10 months.
2. For certain key monitor positions in Project Mercury, Space Task Group medical personnel will be used. Included in this list should be :

USAF (MC)

Lt. Col. Stanley C. White—STG

Lt. Col. William K. Douglas—STG

Lt. Col. James P. Henry—STG

Lt. Col. Rufus R. Hessberg—Holloman AFB, N. Mex.—project officer for STG animal research program

Col. George M. Knauf—AFMTC—whose close work in support of Mercury will have given him the detailed knowledge of the project necessary for a key monitor

USA (MC)

Capt. William S. Angerson—STG
3. Suggested monitors are as follows on the chart :

Station		Location	
Phoenix Island.	Thomas R. A. Davis, M.D.	Civilian scientist, Ft. Knox.	M.D.—specialty research in environmental physiology, experienced in public health, formerly at USAF Arctic Aero Med Laboratory, surgical training.
	Capt. Charles Wilson, USAF, or USN or USPHS as alternate.	Harvard.	Flight surgeon, aviation medicine resident WADC stress research, Man High monitor.
Hawaii	Maj. Harry Bratt, USAF.	BMD-Edwards	Flight surgeon, board certificate in aviation medicine, WADC research.
	Capt. Wm. Blanchard.	Aero-Med Lab., WADC.	Flight surgeon, board certificate in aviation medicine.
West Coast U.S.	Pacific Missile Range Staff (Capt. Pruett, USN).	Point Mugu, Calif.	Navy flight surgeon, R&D experience.
	HMD-Edwards Staff.	Edwards AFB, Calif.	X-15 flight surgeon, pilot, R&D monitor experience.
Baja California.	USAF School of Aviation Medicine, Lt. Col. David Simons, USAF.	Brooks AFB, Tex.	Flight surgeon, boards in aviation medicine, Man High pilot and project officer.
Corpus Christi.	USAF School of Aviation Medicine Staff, Capt. Hawkins, USAF.	Brooks AFB, Tex.	Flight surgeon, boards in aviation medicine, researcher in physiology, space flight.
	Brooke Army Hospital.	San Antonio, Tex.	Specialist in internal medicine, Surgical Research Unit.
Grand Bahama Island.	Not decided		One or another of these may be considered a critical station. Would be important during reentry. Will consider feasibility of manning from Cape.
Grand Turk Island.			
Mid-Atlantic Ship.	2 USN personnel, Comdr. Frank Anstlin, USN.	Pensacola NAS	Navy flight surgeon with R&D experience, naval aviator with suit test experience, knows several astronauts personally, test pilot.
Canary Islands.	Maj. Julian Ward, USAF.	USAF, Europe	Flight surgeon, boards in aviation medicine, discoverer and School of Aviation Medicine research.
Nigeria	Col. Vance Marchbanks, USAF.	SAC-Loring AFB, Limestone, Maine.	Senior flight surgeon, expert in flight stresses, on B-52 around the world and over the pole flights. Background would assist U.S. prestige in Nigeria.
Tanganyika	Maj. John Lawson, USA.	Ft. Rucker, Ala.	Flight surgeon, specialist in internal medicine, training in physiology research, M. Public Health, Tropical Medicine. Background would be useful in station and local recovery.

Station	Name	Location	Background & Comments
Indian Ocean Ship.	2 USN.....	Pensacola Staff....	
Perth, Australia.	1. Maj. Gerald Champlin, USA. 2. United Kingdom associate.	At Navy School of Aviation Medicine.	Aviation medicine training, specialist in surgery.
Woomera, Australia.	1. Australian..... 2. Lt. Col. Richard Taylor, USA.	SGO—Washington.	Board certificate in internal medicine, cardiology, pulmonary diseases; research in physiology; participated—Able-Baker; Chief, Biophysics, Bioastronautics, Army Medical R&D Command.

4. Additional consultants and monitors regarded as desirable:

Station	Name	Location	Background & Comments
Corpus Christi.	Dr. Larry Lamb.....	-----	Cardiologist, USAF-SAM.
Baja California.	Maj. Per Lanjoen.....	-----	Cardiologist, Wm. Beaumont Army Hospital.
Hawaii.....	Col. Sandifer.....	-----	Chief of Cardiology, Tripler Army Hospital.
Canary Islands.	Maj. Clyde Kratochvil, USAF.	-----	ARDC Liaison Office Europe, Ph.D. in physiology, SAM researcher, flight surgeon.
Bermuda (or elsewhere).	Maj. Charles Berry, USAF—SGO.	-----	Flight surgeon, space medicine researcher, boards in aviation medicine.
	Lt. Col. William Turner, USAF.	-----	Flight surgeon, boards in aviation medicine, WADC researcher.

AEROMEDICAL MONITORS ORIGINALLY APPOINTED

1. Capt. Carl E. Pruett, USN (MC)
2. Col. Vance H. Marchbanks, USAF (MC)
3. Capt. Edward L. Beckman, USN (MC)
4. Lt. Col. Edwin L. Overholt, USA (MC)
5. Lt. Col. Charles A. Berry, USAF (MC)
6. Lt. Col. William R. Turner, USAF (MC)
7. Lt. Col. Jacques L. Sherman, USA (MC)
8. Thomas R. Davis, M.D.
9. Lt. Comdr. Frank H. Austin, USN (MC)
10. Maj. John C. Lawson, USA (MC)
11. Lt. Comdr. John J. Gordon, USN (MC)
12. Maj. William H. Hall, USA (MC)

13. Maj. Harry R. Bratt, USAF (MC)
14. Maj. Fritz M. G. Holstrom, USAF (MC)
15. Lt. Comdr. Glenn S. Kelly, USN (MC)
16. Maj. George B. Smith, USAF (MC)
17. Maj. Robert H. Moser, USA (MC)
18. Maj. Robert R. Burwell, USAF (MC)
19. Maj. Willard R. Hawkins, USAF (MC)
20. Maj. Julian E. Ward, USAF (MC)
21. Maj. C. H. Kratochvil, USAF (MC)
22. Lt. Edmund P. Jacobs, USN (MC)

AEROMEDICAL CONSULTANTS ORIGINALLY APPOINTED

1. Col. Harold Ellingson, USAF (MC)
2. Lawrence E. Lamb, M. D.
3. Col. Samuel M. Sandifer, USA (MC)
4. Maj. James C. Syner, USA (MC)

BIBLIOGRAPHIC NOTE

The source materials used in the present monograph are housed in a variety of places. Major listings are offered to guide the reader who wishes to pursue background reading further.

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7. *Scientific and Technical Aerospace Reports (STAR)* published semimonthly by the NASA Scientific and Technical Information Division.

II. *Manuscript Materials*—The following major sources were utilized:

1. Hq. NASA Historical Archives; Office of Manned Space Flight records; and historical records of the NASA Centers, particularly the Manned Spacecraft Center, Houston, Tex.

2. Hq. USAF Historical Archives, particularly those of the Office of the Surgeon General; and historical records of the Air Force Systems Command, particularly those of the Aerospace Medical Laboratory at Wright-Patterson AFB, the Holloman Laboratory in New Mexico, and the Aerospace Medical Division at Brooks AFB.

3. U.S. Navy historical documents, particularly at the School of Aviation Medicine, Pensacola, Fla.

4. National Academy of Sciences National Research Council.

5. President's Scientific Advisory Committee Records. (A limited number of reports were studied as background, but were not quoted directly.)

III. *Congressional Hearings and Staff Reports.*

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