Chapter 2

Table 2-1. Earth Science and Space Application Missions (1989–1998)

Launch Date	Mission	Discipline	Remarks
January 1, 1989–February 28, 1989	Airborne Arctic Stratospheric Expedition I (AASE I)	Atmospheric research	NASA-NOAA airborne study
May 14, 1991	NOAA-12	Meteorology	Deployment of NOAA satellite into a morning orbit
September 12, 1991	UARS	Atmospheric research	
October 4, 1991–March 26, 1992	AASE II	Atmospheric research	Airborne study
August 10, 1992	Ocean Topography Experiment (TOPEX)/Poseidon	Ocean surface topography	Joint U.S.-French mission launched from Kourou, French Guiana
October 22, 1992	Laser Geodynamic Satellite II (LAGEOS II)	Earth science	NASA–Italian space agency mission
August 9, 1993	NOAA-13	Meteorology	Deployment of NOAA satellite (contact lost two weeks after launch)
September 12, 1993	Advanced Communications Technology Satellite (ACTS)	Communications	First high-speed, all-digital communications satellite
October 5, 1993	Landsat 6	Earth science	Failed to achieve orbit
1994	Airborne Southern Hemisphere Ozone Experiment (ASHOE)	Atmospheric research	Aircraft flights based in Christchurch, New Zealand
April 13, 1994	Geostationary Operational Environmental Satellite (GOES)-8	Meteorology	Deployment of NOAA satellite (first in a new series of three-axis stabilized satellites)
December 30, 1994	NOAA-14	Meteorology	Deployment of NOAA satellite into an afternoon orbit
April 3, 1995	MicroLab-1 (OrbView-1)	Atmospheric research	Pegasus launch
May 23, 1995	GOES-9	Meteorology	Deployment of NOAA satellite (deactivated on July 28, 1998, because of failing bearings in the momentum wheels)
November 4, 1995	Radar Satellite-1 (RADARSAT-1)	Earth observation and geodesy	Joint Canadian Space Agency (CSA), NASA, and NOAA project

Launch Date	Mission	Discipline	Remarks
July 2, 1996	TOMS Earth Probe (TOMS-EP)	Atmospheric research	Pegasus launch
August 17, 1996	TOMS-Advanced Earth Observing Satellite (TOMS-ADEOS)	Atmospheric research	NASA-provided instrument on Japanese satellite
August 17, 1996	NASA Scatterometer (NSCAT)	Ocean research	NASA-provided instrument on Japanese satellite
April 25, 1997	GOES-10	Meteorology	Deployment of NOAA satellite
August 1, 1997	SeaStar (OrbView-2)	Ocean research	Sea-viewing Wide Field-of-view Sensor (SeaWiFS) payload; Pegasus launch
August 23, 1997	Lewis[1]	Technology demonstration	Failed due to a flawed attitude-control system design and inadequate spacecraft monitoring
November 27, 1997	Tropical Rainfall Measuring Mission (TRMM)	Atmospheric research	Joint project with Japan
May 13, 1998	NOAA-15	Meteorology	Deployment of NOAA satellite into a morning orbit

[1] Details of the Lewis mission can be found in chapter 3 of this volume ("Aeronautics, Technology, and Exploration").

Table 2-2. Attached and Retrieved Missions

Launch Date and Mission Number	Mission	Discipline Area	Remarks
June 5, 1991 STS-40	Spacelab Life Sciences Lab (SLS)-1	Life sciences	Spacelab mission
January 22, 1992 STS-42	International Microgravity Laboratory (IML)-1	Microgravity studies	Spacelab mission
March 24, 1992 STS-45	ATLAS-1	Atmospheric studies	Spacelab mission
June 25, 1992 STS-50	U.S. Microgravity Laboratory (USML)-1	Microgravity studies	Spacelab mission
September 12, 1992 STS-47	Spacelab J	Microgravity and life sciences	Japanese Spacelab mission
October 22, 1992 STS-52	U.S. Microgravity Payload (USMP)-1	Microgravity studies	
April 8, 1993 STS-56	ATLAS-2	Atmospheric studies	Spacelab mission
April 26, 1993 STS-55	Spacelab D2	Microgravity studies	German Spacelab mission
October 18, 1993 STS-58	SLS-2	Life sciences	Spacelab mission
February 3, 1994 STS-60	Wake Shield Facility (WSF)-1	Technology	Attempt to deploy failed
March 4, 1994 STS-62	Shuttle Solar Backscatter Ultraviolet Experiment (SSBUV)	Atmospheric studies	Sixth flight of SSBUV
March 4, 1994 STS-62	USMP-2	Microgravity studies	
April 9, 1994 STS-59	Space Radar Laboratory (SRL)-1	Earth science	
July 8, 1994 STS-65	IML-2	Microgravity studies	Spacelab mission
September 9, 1994 STS-64	Lidar In-Space Technology Experiment (LITE)	Atmospheric research and technology experiment	First use of laser optical radar for atmospheric research
September 30, 1994 STS-68	SRL-2	Earth science	
November 3, 1994 STS-66	Cryogenic Infrared Spectrometers and Telescopes for the Atmosphere-Shuttle Pallet Satellite (CRISTA-SPAS)-1	Earth science	Joint project with Germany
November 3, 1994	ATLAS-3	Atmospheric physics	Spacelab mission

Launch Date and Mission Number	Mission	Discipline Area	Remarks
STS-66			
June 27, 1995 STS-71	Spacelab-*Mir* LM	Life sciences	First Shuttle-*Mir* docking
September 7, 1995 STS-69	WSF-2	Technology	Successful deployment and retrieval
October 20, 1995 STS-73	USML-2	Microgravity studies	
February 22, 1996 STS-75	USMP-3	Microgravity studies	
June 20, 1996 STS-78	Life and Microgravity Spacelab (LMS)	Life and microgravity sciences	
November 19, 1996 STS-80	WSF-3	Technology	Successful deployment and retrieval
April 4, 1997 STS-83	Microgravity Science Laboratory (MSL)-1	Materials sciences	Spacelab mission was cut short
July 1, 1997 STS-94	MSL-1	Materials sciences	Reflight of STS-83 mission
August 7, 1997 STS-85	CRISTA-SPAS-2	Earth science	Joint mission with Germany
November 19, 1997 STS-87	USMP-4	Microgravity studies	
April 17, 1998 STS-90	Neurolab	Neurobiological life sciences	Last Spacelab mission

Table 2-3. Programmed Budget by Major Budget Category (FY 1989–FY 1998) (in thousands of dollars)

Budget Category/Fiscal Year	1989	1990	1991	1992	1993[2]
Earth Sciences and Applications	403,400	434,199	662,300	725,393	—
Materials Processing	75,600	101,887	102,300	120,800	—
Communications	92,200	77,652	50,500	20,000	—
Information Systems	19,900	28,217	35,700	35,000	—
Research Operations Support	—	—	—	83,909	—
MTPE	—	—	—	—	936,316
Total–All Earth sciences and applications/MTPE program areas	*591,100*	*641,955*	*850,800*	*985,102*	*936,316*

Budget Category/Fiscal Year	1994	1995	1996	1997	1998
Earth Sciences and Applications	—	—	—	—	—
Materials Processing	—	—	—	—	—
Communications	—	—	—	—	—
Information Systems	—	—	—	—	—
Research Operations Support	—	—	—	—	—
MTPE	1,112,900	1,344,100	1,360,800	1,361,600	1,417,300
Total–All Earth sciences and applications/MTPE program areas	*1,112,900*	*1,344,100*	*1,360,800*	*1,361,600*	*1,417,300*

[2] A major restructuring of Earth science program areas occurred at this time.

Table 2-4. Earth Science and Applications Funding History (in thousands of dollars)[3]

Year (Fiscal)	Submission	Programmed
1989	450,400/413,700	403,400
1990	434,300/439,299	434,199
1991	661,500/667,900	662,300
1992	775,600/738,500	725,393
1993	868,500/863,848	—[4]
1994	—[5]	—

[3] This budget category was called Environmental Observations in the FY 1989 budget estimate.
[4] There was no programmed amount in budget documents.
[5] This represents a reconfigured budget structure. The category of Earth sciences was included in the MTPE budget and divided among several budget line items.

Table 2-5. Solid Earth Observations Funding History (in thousands of dollars)[6]

Year (Fiscal)	Submission	Programmed
1989	82,100/—[7]	—

[6] Included here are the Payload and Instrument Development, Geodynamics, and Research and Analysis budget categories.
[7] The budget category was eliminated. The Research and Analysis budget was redistributed on a task-by-task basis.

Table 2-6. Land Processes Research and Analysis Funding History (in thousands of dollars)

Year (Fiscal)	Submission	Programmed
1989	22,900[8]/19,900[9]	—
1990	22,500/—[10]	—

[8] This was called Research and Analysis under the Solid Earth Observations Program at the time of the initial FY 1989 budget estimate submission.
[9] Some research activities were deferred to FY 1990 to provide critical funding for near-term planetary missions.
[10] The budget category was discontinued. No revised budget estimate or programmed amounts were shown in budget documents. The Research and Analysis budget was redistributed on a task-by-task basis.

Table 2-7. Payload and Instrument Development (Solid Earth Observations Program) Funding History (in thousands of dollars)

Year (Fiscal)	Submission	Programmed
1989	25,300/24,800[11]	25,300[12]

[11] This was included as a component of the Earth Science Payload Instrument Development budget category.
[12] This was included as a component of the Payload and Instrument Development funding category. See table 2-20.

Table 2-8. Geodynamics Funding History (in thousands of dollars)

Year (Fiscal)	Submission	Programmed
1989	33,900/32,900[13]	—
1990	38,000[14]/—[15]	—

[13] Some research activities were deferred to FY 1990 to provide critical funding for near-term planetary missions.
[14] This be used to fund the U.S. portion of the Laser Geodynamic Satellite (LAGEOS) mission (joint mission with Italy).
[15] The budget category was discontinued. No revised budget estimate or programmed amounts were shown in budget documents.

Table 2-9. Materials Processing in Space Funding History (in thousands of dollars)

Year (Fiscal)	Submission	Programmed
1989	73,400/75,600	75,600
1990	92,700/99,015	101,887[16]
1991	97,300/102,300	102,300
1992	125,800/118,800	120,800
1993	195,300/172,934[17]	—
1994	(89,400)[18]/—	—

[16] The budget category included Research and Analysis, Materials Experiment Operations, Space Station Utilization, and Commercial Microgravity R&D Enhancements.
[17] The budget category included Materials Processing in Space—Research and Analysis, and Materials Processing in Space, Flight Experiments budget categories.
[18] The budget category was transferred to the OLMSA budget category. See chapter 3 of volume VII for details of OLMSA's budget.

Table 2-10. Communications Funding History (in thousands of dollars)

Year (Fiscal)	Submission	Programmed
1989	16,200/92,200[19]	92,200
1990	18,600[20]/77,975[21]	77,652[22]
1991	52,800/52,500	50,500
1992	39,400[23]/12,500	20,000[24]
1993	4,600/4,986	—

[19] The number reflected $74.6 million for the ACTS.
[20] Funding was not included here for continued development of ACTS. It was the Administration's policy that the flight demonstration project was more appropriately and effectively undertaken by the private sector without subsidy or possible competition by the government.
[21] The funding for ACTS was reinstated.
[22] The budget category included funding for ACTS, Advanced Communications Research, Search and Rescue, Radio Science and Support Studies, and Communications Data Analysis.
[23] The reduction reflects a reduced ACTS budget due to progress in the project.
[24] The budget category included ACTS and Search and Rescue funding.

Table 2-11. Advanced Communications Satellite Funding History (in thousands of dollars)

Year (Fiscal)	Submission	Programmed
1989	—[25]	74,600
1990	—/59,975[26]	59,975
1991	34,000/34,000	34,000
1992	11,200[27]/11,200	18,700
1993	3,600[28]/3,968	3,968
1994	3,000/3,000	3,000
1995	2,300/2,300	2,300

[25] This budget category was not established at the time of the budget submission.
[26] The amount reflected congressional reinstatement of ACTS in the NASA budget.
[27] The amount included the budget for the system test of the flight and ground segments and initiation of final preparations for shipment to the launch site, launch, and on-orbit checkout.
[28] This provided for the continuation of mission operations for the ACTS flight and ground systems, which were to continue for two years. The ACTS experiments program was funded and conducted under the Commercial Use of Space program.

Table 2-12. Search-and-Rescue Funding History (in thousands of dollars)

Year (Fiscal)	Submission	Programmed
1989	—[29]/1,350	1,350
1990	1,300/1,280	1,218
1991	1,400/1,400	1,400
1992	1,300/1,300	1,300
1993	1,000/1,018	—
1994	(1,100)[30]/—	—

[29] The budget category was not established at the time of the initial budget submission.
[30] The budget category was transferred to the Commercial Use of Space program.

Table 2-13. Information Systems Funding History (in thousands of dollars)

Year (Fiscal)	Submission	Programmed
1989	22,300/19,900	19,900
1990	34,100/28,200	28,217
1991	36,800/36,700	35,700
1992	42,000/35,000[31]	35,000
1993	40,700/36,193	—
1994	(26,500)[32]/—	—

[31] The funding reduction was due to a congressional reduction of $5.0 million and a $2.0 million transfer to the Global Geospace Science program.
[32] Funding was reallocated between the Space Science and MTPE programs.

Table 2-14. UARS Mission Funding History (in thousands of dollars)

Year (Fiscal)	Submission	Programmed
1989	103,900/94,200[33]	85,200
1990	73,900/64,200[34]	55,200
1991	66,000/64,000[35]	62,000
1992	18,200[36]/—[37]	—

[33] The reduction of $9.7 million reflected the deferral of non-critical activities to FY 1990–1991 in order to provide needed funding for near-term planetary missions.
[34] The reduction of $8.0 million was made to provide funds for the TOPEX mission, which required additional funding to overcome technical and schedule problems experienced by its mission contractor. The remaining $1.7 million decrease resulted from the general congressional reduction and the FY 1990 sequestration.
[35] The reduction was made to provide funds for the TOPEX mission.
[36] The reduced budget was needed to support spacecraft launch site activities and the launch of UARS, as well as to complete integration and testing of the ground data handling facility, including hardware and software verification activities before launch.
[37] The amount of $18.2 million for UARS development was eliminated in accordance with congressional direction. The satellite launched in September 1991.

Table 2-15. TOPEX Funding History (in thousands of dollars)

Year (Fiscal)	Submission	Programmed
1989	97,800/83,000[38]	83,000
1990	72,800/80,000[39]	84,800
1991	68,000/76,000[40]	80,400
1992	51,900/59,000[41]	65,000
1993	—[42]	—

[38] The reduction was the result of congressional direction ($10.0 million) and a $4.8 million reallocation of funding to the Scatterometer program to preserve the Japanese ADEOS launch opportunity.
[39] An additional $8.0 million was added to the TOPEX program from the UARS program to maintain schedules leading to a launch then scheduled for June 1992.
[40] An additional $8.0 million was added, including $3.0 million by congressional direction to maintain schedules leading to a launch then scheduled for June 1992.
[41] The amount of $8.0 million was added to maintain critical schedules leading to a launch then planned for July 1992.
[42] The instrument was launched and moved to the Mission Operations budget category.

Table 2-16. Earth Probes Funding History (in thousands of dollars)

Year (Fiscal)	Submission	Programmed
1990	—[43]	13,600[44]
1991	25,000[45]/54,700[46]	51,700
1992	68,200[47]/92,800[48]	77,800
1993	88,900/99,413	99,413
1994	97,300/96,426[49]	96,426
1995	82,000[50]/81,600	81,600
1996	36,900/46,000	80,100[51]
1997	47,100/57,200	61,800
1998	40,700/48,600	34,900

[43] The budget category was not established at the time of the budget submission. In FY 1990, $10.0 million appropriated by Congress to begin developing the TOMS instruments was carried under the Earth Sciences Payload and Instrument Development budget category.

[44] This included the Scatterometer and the start of development of the TOMS free-flyer spacecraft and definition studies for TRMM.

[45] The Scatterometer ($3.7 million) was not included here, but in a separate budget category.

[46] The budget category was augmented by $31.0 million per congressional direction: $15.0 million to the TRMM, $11.0 million to TOMS, and $5.0 million to the Ocean Color mission (SeaWiFS). Funding for SeaWiFS was included under Earth Science mission operations and data analysis to reflect the proposed data purchase plan.

[47] This included NSCAT.

[48] Increases here reflected $15.0 million for Climesat and $5.0 million for TRMM, less $0.3 million contractor conversion adjustment, as directed by Congress. Funding for the Scatterometer was increased by $4.0 million to support ongoing hardware and software development. TOMS was increased by $1.0 million (less $0.1 million contractor conversion adjustment) to maintain the launch schedule for a 1993 launch.

[49] The reduction reflected a decrease in the amount allocated for support contractors.

[50] The decrease reflected the planned completion of current approved Earth probes.

[51] Included here were NSCAT, TOMS, TRMM, Earth system science pathfinders, Lewis and Clark, "LightSAR," and experiments of opportunity. The Lewis and Clark missions were funded primarily by the Advanced Smallsat Technology program in the Office of Advanced Concepts and Technology (OACT) and the Office of Space Access and Technology (OSAT).

Table 2-17. Scatterometer Funding History (in thousands of dollars)

Year (Fiscal)	Submission	Programmed
1989	103,900/94,200[52]	10,600
1990	13,800/13,600	13,600
1991	17,800[53]/17,800	20,700
1992	24,000/28,000	28,000
1993	20,200/20,200	20,200
1994	18,700/18,700	17,095
1995	15,400/15,400	15,400
1996	3,900[54]/7,700	3,200

[52] The reduction of $10.0 million resulted from congressional action offset by a reallocation of $4.8 million from the TOPEX program. The FY 1989 Scatterometer budget maintained instrument development activities so that a possible launch aboard the Japanese ADEOS mission could be preserved.

[53] The Scatterometer budget was broken down differently in the original FY 1991 budget estimate, which showed $3.7 million for NSCAT flight hardware development. In the FY 1992 budget estimate for Earth probes, which included NSCAT and TOMS, the initial amount for NSCAT was shown as $17.8 million. The total Earth probe amount for FY 1991, as shown in the initial budget submission, and for initial FY 1991, as shown in the FY 1992 budget submission, was $28.7 million but was broken down differently.

[54] This decrease reflected a planned February 1996 launch.

Table 2-18. TOMS Funding History (in thousands of dollars)

Year (Fiscal)	Submission	Programmed
1991	10,900/21,900[55]	16,000
1992	29,900/30,800	30,800
1993	18,700/27,685[56]	27,685
1994	9,800[57]/11,000	13,805
1995	16,500/14,900	14,900
1996	8,500/8,500	3,000
1997	2,600/1,000	3,900
1998	5,700/8,200	6,000

[55] Congress allocated an additional $15.0 million.
[56] The increase included $8.7 million that was reallocated from the Payload and Instrument Development budget to fund cost growth in TOMS instrument and spacecraft contracts.
[57] This reflected funds required for the system integration of the TOMS 1994 flight, including satellite system environmental tests, preparations for satellite launch, and associated on-site activities. The ADEOS-TOMS instrument would be fabricated, tested, and shipped to Japan for spacecraft integration and testing.

Table 2-19. TRMM Funding History (in thousands of dollars)

Year (Fiscal)	Submission	Programmed
1991	—/15,000[58]	15,000
1992	14,300/19,000	19,000
1993	50,000/51,528	51,528
1994	68,800/66,726	65,526
1995	50,100/51,300	51,300
1996	24,500/24,200	25,500
1997	20,900/17,700	17,300
1998	—[59]/900	900

[58] Congress allocated $15.0 million to TRMM.
[59] This was launched in November 1997. Data gathering was funded from Mission Operations and Data Analysis and EOSDIS budgets.

Table 2-20. Payload and Instrument Development (Earth Science and Applications Program) Funding History (in thousands of dollars)

Year (Fiscal)	Submission	Programmed
1989	45,000/46,400[60]	46,400
1990	66,500/76,100[61]	76,100
1991	49,700/49,700	49,100
1992	48,600/39,600[62]	37,900
1993	49,400/35,461[63]	35,461
1994	22,900/22,900	25,900
1995	19,500/19,500	19,500
1996	4,900[64]/—	—[65]

[60] This included Payload and Instrument Development from the Solid Earth Observations Program. The net increase of $1.4 million resulted from an increase of $2.0 million to continue the development of the TOMS instrument and a reduction of $0.6 million from the transfer of the Imaging Spectrometric Observatory—a space physics Spacelab instrument—to Physics and Astronomy Payload and Instrument Development consistent with the 1988 OSSA reorganization. TOMS funding was reallocated from the Upper Atmosphere Research and Analysis budget.
[61] This included $10.0 million to begin developing the TOMS instruments, partially offset by a decrease resulting from the general congressional reduction.
[62] The reduction of $8.0 million was made to provide funds for TOPEX. In addition, the Atmospheric Payloads program was reduced by $1.0 million to support TOMS-EP development tasks. Reductions were to be accommodated by deferring advanced development activities.
[63] The reduction reflected a $9.2 million reallocation from the payloads program to provide $8.7 million to TOMS for instrument and spacecraft cost growth and $0.5 million to TRMM to support development of the TRMM microwave imager instrument. These reductions were accommodated through significant reductions in reserves and deferring advanced technology development activities. To provide for mission management and integration of ATLAS-3 and Shuttle Radar Laboratory (SRL) missions, $5.1 million was transferred to the Physics and Astronomy Shuttle/Spacelab Payload Mission Management and Integration budget. These adjustments were partially offset by a $0.3 million increase due to redistributing Research Operations Support (ROS) funding. (ROS funds provided support to the civil service workforce and to the physical plant at NASA centers and at NASA Headquarters.)
[64] This reflected the reduced rate of Spacebound Imaging Radar (SIR)-C data processing and reduction and remaining closeout activities of the ATLAS-3 mission.
[65] No amount was indicated in budget documents.

Table 2-21. Mission Operations and Data Analysis Funding History (in thousands of dollars)

Year (Fiscal)	Submission	Programmed
1989	18,500/17,600[66]	17,600
1990	24,800/23,900[67]	23,800
1991	30,400/39,400[68]	39,400
1992	56,300/83,800[69]	100,646
1993	142,100[70]/147,553[71]	93,983
1994	198,800/97,444[72]	—[73]
1995	97,500/—[74]	—

[66] The reduction resulted from deferring some research activities to FY 1990 to provide funding for high-priority planetary missions.
[67] The reduction was due to the general congressional reduction and the impact of the FY 1990 sequestration. Some data analysis activities were deferred as a result.
[68] The increase reflected $8.0 million in additional funds provided for the Center (Consortium) for International Earth Science Information Network (CIESIN) activities, as well as $5.0 million for the Ocean Color Mission per congressional direction. As part of the general reduction, $4.0 million was reduced from programs unrelated to the congressional augmentations.
[69] The increase was due to congressional direction requiring increased mission operations and data analysis programs by $25.0 million for the CIESIN program, in addition to $2.5 million for Landsat activities.
[70] These funds supported UARS satellite operations, TOPEX experiment operations, Ocean Color Mission data purchase, CIESIN, Landsat, and other Earth sciences mission operations and data analysis.
[71] The increase of $5.5 million reflected a congressionally directed general reduction of $15 million, offset by additional funding for the CIESIN program and a $0.5 million increase due to redistributing ROS funding.
[72] The reduction reflected the removal of Landsat and CIESIN from the Mission Operations and Data Analysis budget category.
[73] No amount was indicated in budget documents.
[74] The budget category included Applied Research and Data Analysis. See table 2-51.

Table 2-22. Interdisciplinary Research Funding History (in thousands of dollars)

Year (Fiscal)	Submission	Programmed
1989	1,200/2,200[75]	2,200
1990	2,300/8,600[76]	8,600
1991	2,400/12,400[77]	12,400
1992	2,500/2,500	2,340
1993	2,600/4,453	4,453
1994	5,000/5,000	—[78]
1995	4,600/—	—

[75] The amount of $1.0 million was added as directed by Congress for global climate change research activities.
[76] The increase reflected an additional $9.0 million as directed by Congress for climate studies and university consortia research. This was offset by the general congressional reduction and the impact of sequestration.
[77] The increase reflected direction from Congress to add $10.0 million for climate studies and individual research grants. Climate funding would augment NASA's current climate modeling program and associated global field campaigns. The program would enhance access to and use of Earth science and related information by the scientific and policy-making community in pursuit of global change issues.
[78] No programmed amount was shown in budget documents.

Table 2-23. Upper Atmosphere Research and Analysis Funding History (in thousands of dollars)

Year (Fiscal)	Submission	Programmed
1989	34,000/31,100[79]	—[80]
1990	38,100/—	—

[79] The reduction was a result of the transfer of $2.0 million to Earth Science Payloads and Instrument Development in order to prepare the TOMS instrument for a 1991 flight. The balance represented a deferral of research activities to FY 1990 to provide funding for near-term planetary missions.
[80] No programmed amount was shown in budget documents. The Research and Analysis budget was redistributed on a task-by-task basis.

Table 2-24. Ocean Processes Research and Analysis Funding History (in thousands of dollars)

Year (Fiscal)	Submission	Programmed
1989	21,600/20,800[81]	—[82]
1990	24,500/—	—

[81] Some research activities were deferred to FY 1990 to provide funding for near-term planetary missions.
[82] No programmed amount was shown in budget documents. The Research and Analysis budget was redistributed on a task-by-task basis.

Table 2-25. Atmospheric Dynamics/Radiation Research and Analysis Funding History (in thousands of dollars)

Year (Fiscal)	Submission	Programmed
1989	31,400/32,800[83]	—[84]
1990	37,400/—	—

[83] Some research activities were deferred to FY 1990 to provide funding for near-term planetary missions.
[84] No programmed amount was shown in budget documents. The Research and Analysis budget was redistributed on a task-by-task basis.

Table 2-26. Research Facilities Funding History (in thousands of dollars)[85]

Year (Fiscal)	Submission	Programmed
1989	—[86]	30,600
1990	27,900/27,399	27,399
1991	28,900/28,900	—[87]
1992	29,600/—	—

[85] This included Laser Research Facilities and Airborne Science and Applications.
[86] The budget category was not established at the time of the budget submission.
[87] No amount was shown in budget documents.

Table 2-27. Laser Research Facilities Funding History (in thousands of dollars)

Year (Fiscal)	Submission	Programmed
1989	—[88]	7,600
1990	8,200/8,000	8,000
1991	8,700/8,700	—[89]
1992	9,000/—	—

[88] The budget category was not established at the time of the budget submission.
[89] No amount was shown in budget documents.

Table 2-28. Airborne Science and Applications Funding History (in thousands of dollars)

Year (Fiscal)	Submission	Programmed
1989	23,000[90]/23,000	23,000
1990	19,700/19,399	19,399
1991	20,200/20,200	20,200
1992	20,600/20,300[91]	20,300
1993	22,900/20,707[92]	20,707
1994	25,200/25,200	—
1995	26,000/—[93]	—

[90] This allocation allowed for the operation of the DC-8, two ER-2s, and the C-130 aircraft for projects such as collecting and analyzing stratospheric air samples, testing newly developed instrumentation, demonstrating new sensor concepts, investigating the ozone hole phenomena, and participating in other field experiments. This also provided for NASA's final payment to the U.S. Air Force, completing the purchase of the second ER-2 aircraft.
[91] The decrease applied to laser research (process studies) activities.
[92] The reduction of $3.1 million was consistent with congressional direction. As a result, all environmental research conducted aboard the C-130 aircraft was deferred until FY 1994. These adjustments were offset by a $0.9 million increase due to redistributing ROS funding.
[93] No budget estimate or programmed amount was shown in budget documents.

Table 2-29. EOS Funding History (in thousands of dollars)

Year (Fiscal)	Submission	Programmed
1990	—	—[94]
1991	199,000[95]/155,000[96]	150,600[97]
1992	253,400/184,400[98]	176,400
1993	308,400[99]/263,784[100]	263,747
1994	322,700/318,776[101]	392,876
1995	455,100[102]/591,100	574,100
1996	591,100/535,300	554,200
1997	585,700/586,700	582,200
1998	679,700/704,600	754,500

[94] Prior to FY 1991, funding for the Polar Platform (EOS observatory) was included in the Space Station Freedom budget (FY 1991 Funding Requirements, p. RD 6-7).
[95] This amount reflected $36.0 million that was deducted from the original estimate of $235.0 million for EOSDIS, which became a separate budget category. Also represented here was a transfer from the Space Station *Freedom* program to OSSA. Beginning in FY 1991, OSSA had budget and management responsibility for the Polar Platform, while project management resided with the EOS program (FY 1991 Funding Requirements, pp. 6-7–6-8).
[96] The reduction reflected congressional direction, which reduced EOS observatories (platforms) by $72.0 million and allocated an additional $28.0 million to instruments.
[97] Reflected here was the restructuring of the EOS program to conform to congressional guidance, as well as the results of the External Engineering Review.
[98] The reduction reflected congressional direction to reduce the amount by $65.0 million and reallocate $4.0 million to NSCAT in order to maintain the delivery schedule in support of the launch.
[99] The budget was restructured to conform to the new EOS program.
[100] The reduction reflected realignment within the total EOS program. See changes to individual EOS budget categories.
[101] Funding was reduced by $1.9 million due to a reduction to support contractors and an additional $2.0 million congressionally directed reduction. This was accommodated by reducing program flexibility.
[102] The increase from FY 1994 to FY 1995 accommodated the planned increase in EOS work leading to first launch in 1998, offset by reductions to support contractors and the transfer of the Small Business Innovative Research (SBIR) program to Advanced Concepts and Technology.

Table 2-30. Instruments–EOS Funding History (in thousands of dollars)

Year (Fiscal)	Submission	Programmed
1991	45,000[103]/79,000[104]	79,000
1992	159,000/123,000	114,000
1993	—[105]	—

[103] The budget category included the design of EOS-A flight instruments that were to be selected in FY 1991. Instruments planned for the EOS-B series were to continue conceptual definition in preparation for later flight selection.
[104] This increase reflected the reallocation of funds from the observatories budget category as part of the increased emphasis on advanced sensors development and the importance of instrument readiness to the overall EOS schedule.
[105] The budget category was eliminated in the realignment of the program to conform to the new EOS program.

Table 2-31. EOS Development–EOS Funding History (in thousands of dollars)

Year (Fiscal)	Submission	Programmed
1991	103,000[106]/—[107]	—[108]

[106] This included EOSDIS.
[107] There is no comparable budget category in the FY 1992 budget estimate. Budget categories were realigned to reflect major EOS components, and EOSDIS was identified as a separate budget element.
[108] The budget category was eliminated as part of the restructuring of the EOS program.

Table 2-32. Observatories–EOS Funding History (in thousands of dollars)[109]

Year (Fiscal)	Submission	Programmed
1990	—	—[110]
1991	132,000/60,000[111]	55,600
1992	58,500/30,200	31,000
1993	—[112]	—

[109] The budget category called "Polar Platform Development" was in the FY 1991 budget estimate.
[110] Development funding for the EOS platforms (observatories) before 1991 was included in the Space Station *Freedom* budget (FY 1991 Funding Requirements, p. RD 6-7).
[111] The reduction of $72.0 million included a $44.0 million reduction as a result of congressional direction and a $28.0 million allocation to the instruments.
[112] The budget category was eliminated as part of the realignment of the program to conform to the new EOS program.

Table 2-33. Science–EOS Funding History (in thousands of dollars)

Year (Fiscal)	Submission	Programmed
1991	22,000/16,000	16,000
1992	35,000/31,200	31,400
1993	18,000[113]/44,996[114]	44,477
1994	47,100/46,792	—[115]
1995	76,800/—	—

[113] This represents funding for interdisciplinary science only.
[114] The revised FY 1993 estimate included all EOS science, not only interdisciplinary science.
[115] No amount was shown in budget documents. Amounts for science were included with EOS-AM, -PM, and -Chemistry series budgets.

Table 2-34. AM Series–EOS Funding History (in thousands of dollars)

Year (Fiscal)	Submission	Programmed
1993	241,500[116]/181,388	180,782
1994	200,100/196,659	198,759
1995	243,800/260,800	259,800
1996	202,200/170,000	178,700
1997	84,700[117]/82,800	82,800
1998	49,100/44,900	71,200[118]

[116] The AM series budgets included development costs for components unique to the series, such as instruments, spacecraft, science computing facilities, science product capability development, and mission science. Development costs were to cover the period of development through launch plus 30 days' inflight checkout. Mission operations and data analysis were to include all costs associated with the flight after development. Interdisciplinary science was to include funding and science computing facilities for the selected interdisciplinary science investigators and the EOS fellowship program.

[117] Reduction in funding reflected the shifted emphasis in the AM-1 development program to fabrication and assembly of subsystem engineering models and the buildup of subsystem flight models following the Critical Design Review and External Independent Readiness Review in January 1995.

[118] Increase reflected failure of the externally provided ground system leading to an unspecified delay in launch and reorganization of the EOS program. (Launch delay extended 18 months.) Failure of a Delta 3 launch vehicle resulted in further launch uncertainty due to the commonality of the RL-10 rocket engine used on both the Delta 3 and the Atlas IIAS to be used for EOS AM. Closure of Lockheed Martin's Valley Forge facility (where EOS AM—renamed Terra—was located) led to NASA's moving operations to the launch site at Vandenberg Air Force Base in California. Finally, NASA Headquarters "overfunded" Terra by using unfunded carryover (unobligated funds) from FY 1998 and prior years with the expectation that funds could be carried over into FY 1999 (e-mail to author from Christopher Scolese, former EOS-Goddard Project Manager and NASA Chief Engineer, 23 January 2007).

Table 2-35. PM Series–EOS Funding History (in thousands of dollars)

Year (Fiscal)	Submission	Programmed
1993	30,900[119]/24,100	24,631
1994	58,200/55,700[120]	50,100
1995	78,500/88,800	88,800
1996	127,300/101,800	103,700
1997	171,200/149,700	147,500
1998	218,000/175,900	175,900

[119] The PM series budgets included development costs for components unique to the series, such as instruments, spacecraft, science computing facilities, science product capability development, and mission science. Development costs were to cover the period of development through launch plus 30 days' inflight checkout. Mission operations and data analysis were to include all costs associated with the flight after development. Interdisciplinary science was to include funding and science computing facilities for the selected interdisciplinary science investigators and the EOS fellowship program.

[120] This reflected extended the detailed definition phase for EOS-PM and related spacecraft bus to permit further consideration of spacecraft configurations compatible with a medium-class ELV. Current program schedule and funding plans assumed a larger spacecraft platform and commensurately sized launch vehicle.

Table 2-36. Chemistry–EOS Funding History (in thousands of dollars)

Year (Fiscal)	Submission	Programmed
1993	6,800[121]/1,100	1,251
1994	1,500/2,200	2,200
1995	5,900/10,300	10,300
1996	27,700/27,300	27,300
1997	77,400[122]/63,300	46,600
1998	100,600/100,600	110,400

[121] The Chemistry series budgets included development costs for components unique to the series, such as instruments, spacecraft, science computing facilities, science product capability development, and mission science. Development costs were to cover the period of development through launch plus 30 days' inflight checkout. Mission operations and data analysis were to include all costs associated with the flight after development. Interdisciplinary science was to include funding and science computing facilities for the selected interdisciplinary science investigators and the EOS fellowship program.
[122] Increase in budget reflected major procurement activities.

Table 2-37. Special Spacecraft–EOS Funding History (in thousands of dollars)[123]

Year (Fiscal)	Submission	Programmed
1993	11,200/12,200	12,606
1994	15,800/17,425	20,925
1995	50,100/85,500	81,700
1996	69,700/71,700	60,500
1997	66,700/83,100	65,500
1998	91,700/101,200	96,700

[123] The Special Spacecraft budget category referred to spacecraft designed to study atmospheric aerosols, ocean circulation, ice-sheet mass balance, cloud physics, atmospheric radiation properties, and solar irradiance. It included a SAGE-III planned to fly on a Russian spacecraft in 1998 and another SAGE III planned to fly aboard the Space Station. The budget category also included the SeaWinds instrument to fly on the Japanese ADEOS-II, the Altimetry Radar mission as a joint mission with France, and a number of flights of opportunity, including Active Cavity Radiometer Irradiance Monitor (ACRIM), Solar Stellar Irradiance Comparison Experiment (SOLSTICE), and Clouds and Earth’s Radiant Energy System (CERES). This category was called “Small Spacecraft” in the FY 1993 budget estimate.

Table 2-38. Landsat 7–EOS Funding History (in thousands of dollars)

Year (Fiscal)	Submission	Programmed
1992		7,500
1993[124]	25,000/25,000	25,000
1994	59,100/54,100[125]	74,100
1995	62,400/87,400	77,400
1996	78,800/78,800	85,200
1997	73,900/76,200	78,800
1998	52,100/52,600	74,300

[124] This was an element of the Mission Operations and Data Analysis budget category through FY 1993.
[125] This became part of the EOS program. The reduction of $5.0 million was directed by Congress.

Table 2-39. QuikSCAT–EOS Funding History (in thousands of dollars)

Year (Fiscal)	Submission	Programmed
1997	—[126]	35,000
1998	—/34,500	37,900

[126] This budget category was not established at the time of the budget submission.

Table 2-40. Algorithm Development–EOS Funding History (in thousands of dollars)[127]

Year (Fiscal)	Submission	Programmed
1994	—[128]	46,792
1995	—/58,300	55,100
1996	85,400/75,700	73,300
1997	101,800/84,900	75,900
1998	102,700/96,300	92,300

[127] The budget category was related to the development of science software necessary to produce standard data products for each mission and to support the mission launch.
[128] The budget category was not established at the time of the budget submission.

Table 2-41. Technology Infusion–EOS Funding History (in thousands of dollars)

Year (Fiscal)	Submission	Programmed
1996	—[129]	25,500
1997	—/46,700	50,100
1998	65,500/93,100	91,900

[129] The budget category was not established at the time of the budget submission.

Table 2-42. EOS Follow-on–EOS Funding History (in thousands of dollars)

Year (Fiscal)	Submission	Programmed
1996	—[130]/5,500	—[131]
1997	—	—
1998	—	3,900

[130] The budget category was not established at the time of the initial budget submission.
[131] No amounts were shown in budget documents.

Table 2-43. EOS Data and Information System Funding History (in thousands of dollars)

Year (Fiscal)	**Submission**	**Programmed**
1991	36,000[132]/36,000	36,000
1992	82,600/82,600	77,670
1993	82,600/130,651[133]	130,688
1994	182,700/188,158[134]	188,158
1995	284,900/230,600	220,600
1996	289,800/241,200	247,200
1997	261,100/254,600	234,600
1998	244,700/209,900	210,100

[132] The EOSDIS budget was separately identified from the EOS program budget per congressional direction.
[133] The increased budget estimate resulted from the realignment within the total EOS program. Funding for science computing facilities and science data product capability development was reallocated to EOSDIS from the individual EOS missions and included redistribution of ROS funding.
[134] An increase of $5.5 million was the net effect of a reduction of $1.5 million for support contractors, and an increase of $7.0 million was consistent with congressional direction to augment program reserves for developing the EOSDIS Core System.

Table 2-44. Modeling and Data Analysis Funding History (in thousands of dollars)

Year (Fiscal)	Submission	Programmed
1989	—[135]	34,100
1990	44,800/38,500[136]	38,500
1991	41,300/44,300[137]	44,300
1992	45,000/49,000[138]	45,798
1993	45,000/42,571[139]	42,571
1994	45,000/44,245	—[140]
1995	41,200/—	—

[135] The budget category was not established at the time of the budget submission.
[136] The decrease resulted from the general congressional reduction and the impact of the FY 1990 sequestration. Research and analysis activities were to be correspondingly decreased, although climate studies were congressionally augmented under the Interdisciplinary Research and Analysis Budget category, thereby mitigating the full impact.
[137] This reflected a $5.0 million congressional augmentation that consisted of $2.0 million for biogeochemistry and geophysics and $3.0 million for physical climate and hydrologic systems. A reduction of $1.0 million from each program was necessary to provide funds for the schedule-critical TOPEX mission.
[138] The increase reflected increased climate modeling studies in accordance with congressional direction.
[139] The reduction of $3.6 million was needed to fully fund the FY 1993 request for Landsat. This reduction was offset by a $1.5 million increase due to a redistribution of ROS funding and a $0.3 million internal adjustment.
[140] No amount was indicated in budget documents.

Table 2-45. Process Studies Funding History (in thousands of dollars)

Year (Fiscal)	Submission	Programmed
1989	—[141]	93,700
1990	107,500/106,200[142]	106,200
1991	111,100/107,500[143]	116,200
1992	123,300/123,600[144]	121,539
1993	126,600/119,255[145]	119,255
1994	131,500/129,667	—[146]
1995	119,400/—	—

[141] The budget category was not established at the time of the budget submission.
[142] This decrease was a result of general congressional reduction and the FY 1990 sequestration.
[143] A reduction of $1.0 million was made to provide additional funds for the TOPEX mission, and $2.6 million was transferred to planetary mission operations and data analysis to provide necessary support for Galileo mission operations.
[144] This increase was applied to Laser Research Facilities from Airborne Science and Applications.
[145] The reduction of $11.4 million was needed to fully fund FY 1993 requirements for Landsat. Funding for biochemical processes was increased by $1.6 million through the transfer of the Biospheric program from Life Sciences. These adjustments were increased by $2.5 million due to a redistribution of ROS funding.
[146] No amount was indicated in budget documents.

Table 2-46. MTPE Funding History (in thousands of dollars)

Year (Fiscal)	Submission	Programmed
1992	—[147]	985,102[148]
1993	1,207,100/1,148,022	936,316[149]
1994	1,112,900/1,068,400[150]	1,068,000
1995	1,221,100/1,340,100	1,344,100
1996	1,341,100/1,289,400	1,360,800
1997[151]	1,402,100/1,361,600	1,361,600
1998	1,417,300/1,367,300	1,417,300

[147] The budget category was not established at the time of the budget submission.
[148] The programmed amount was transferred from the former Earth Science budget category to MTPE.
[149] This included $52.3 million to SAT for construction of facilities.
[150] This reduction reflected a decrease of $36.1 million as the result of specific congressional direction, an additional reduction of $8.0 million as part of the total Agency reduction for support contractor labor, and a transfer of $0.4 million to Physics and Astronomy/Information Systems.
[151] The budget category was renamed Earth Science.

Table 2-47. MTPE Information Systems Funding History (in thousands of dollars)

Year (Fiscal)	Submission	Programmed
1993	—[152]	11,200[153]
1994	11,800/11,184	—
1995	9,800/—[154]	—

[152] This budget category was not established at the time of the budget submission.
[153] Reflected here is the MTPE portion of the Information Systems budget.
[154] This was included with funding for Applied Research and Data Analysis. See table 2-51.

Table 2-48. Research Operations Support Funding History (in thousands of dollars)[155]

Year (Fiscal)	Submission	Programmed
1992	—[156]/82,300[157]	83,909
1993	98,000/70,061[158]	—
1994	67,000/—[159]	—

[155] Although ROS was included in the budget submissions for FY 1992–FY 1994, amounts were actually programmed only in FY 1992.
[156] This budget category was not established at the time of the initial budget submission.
[157] Establishment of ROS was accomplished by transferring funds contained in the Operation of Installation account in the Research and Program Management (R&PM) appropriation to the R&D and Space Flight, Control and Data Communications (SFC&DC) appropriations.
[158] Funding for activities dedicated to a single program was transferred to the benefiting program. The decrease in ROS funding reflected the transfer of $22.1 million that was consistent with the restructuring activity and offset by a reduction of $5.8 million consistent with congressional direction to reduce ROS funding.
[159] The budget category was not shown in the revised budget estimate or in programmed amounts in budget documents.

Table 2-49. Ocean Color Mission Data Purchase Funding History (in thousands of dollars)[160]

Year (Fiscal)	Submission	Programmed
1993	—[161]	15,570
1994	—/3,400	—
1995	600/—[162]	—

[160] This indicates the funds for the purchase of ocean color data for research use from the SeaWiFS instrument scheduled for launch on the SeaStar spacecraft in 1994.
[161] The budget category was not established at the time of the budget submission.
[162] This amount was included with the funding for Applied Research and Data Analysis. See table 2-51.

Table 2-50. Center/Consortium for International Earth Science Information Network (CIESIN) Funding History (in thousands of dollars)

Year (Fiscal)	Submission	Programmed
1993	—[163]	18,000
1994	18,000/5,000	—
1995	6,000/—[164]	—

[163] The budget category was not established at the time of the budget submission.
[164] This amount was included with the funding for Applied Research and Data Analysis, as well as Mission Operations and Data Analysis. See tables 2-21 and 2-51.

Table 2-51. Applied Research and Data Analysis Funding History (in thousands of dollars)

Year (Fiscal)	Submission	Programmed
1993	—[165]	339,500
1994	417,300/375,200[166]	317,140
1995	—/344,300[167]	361,800
1996	308,400/337,800	350,100
1997	379,100/373,400	393,300
1998	325,300/364,400	373,400

[165] The budget category was not established at the time of the budget submission.
[166] The reduction of $42.1 million included $3.7 million for support contractors, $38.0 million consistent with congressional direction, and the transfer of $0.4 million to Physics and Astronomy/Information Systems. Also included are a reduction of $13.0 million for CIESIN, a reduction of $5.0 million for Landsat, and the deletion of the Science Data Purchase program, which resulted in a reduction of $20.0 million.
[167] A new budget category included funding for MTPE science and operations, data retrieval, and storage. Operations, data retrieval, and storage included funds for the following budget categories: Mission Operations and Data Analysis ($96.7 million), Information Systems ($12.7 million), CIESIN ($6.0 million), and Ocean Color Data Purchase ($1.1 million).

Table 2-52. Global Observations to Benefit the Environment Funding History (in thousands of dollars)

Year (Fiscal)	Submission	Programmed
1994	—[168]	(300)
1995	—/5,000	5,000
1996	5,000/5,000	5,100
1997	5,000/5,000	5,000
1998	5,000/5,000	5,000

[168] The budget category was not established at the time of the budget submission.

Table 2-53. Launch Services Funding History (in thousands of dollars)[169]

Year (Fiscal)	Submission	Programmed
1994	—[170]	18,000
1995	—/17,000	62,200
1996	17,000/107,100	107,100
1997	124,100/84,700	84,700
1998	121,900/34,800[171]	39,400

[169] Funding for mission-unique launch services was included under the budget for the benefiting program. While funding for ELVs was found within the MTPE budget, program management for the ELVs rested with NASA's Launch Vehicles Office.
[170] The budget category was not established at the time of the budget submission.
[171] The reduction reflected delays in planned launches.

Table 2-54. Construction of Facilities Funding History (in thousands of dollars)

Year (Fiscal)	Submission	Programmed
1993	—[172]	52,300
1994	—/20,000	—[173]
1995	17,000/	17,000
1996	—/17,000	17,000

[172] The budget category was not established at the time of the budget submission.
[173] No programmed amount was shown in budget documents.

Table 2-55. MTPE Measurement Areas

Environmental Area	Measurement Area
Atmosphere	Cloud properties
	Radiative energy fluxes
	Precipitation
	Tropospheric chemistry
	Stratospheric chemistry
	Aerosol properties
	Atmospheric temperature
	Atmospheric humidity
	Lightning
Land	Land cover and land use change
	Vegetation dynamics
	Surface temperature
	Fire occurrence
	Volcanic effects
	Surface wetness
Ocean	Surface temperature
	Phytoplankton and dissolved organic matter
	Surface wind fields
	Ocean surface topography
Cryosphere	Ice sheet topography and ice volume change
	Sea ice
	Snow cover
Solar radiation	Total solar irradiance
	Ultraviolet spectral irradiance

Source: "Mission to Planet Earth Strategic Enterprise Plan, 1996–2002," National Aeronautics and Space Administration, Mission to Planet Earth, March 1996, p. 10.

Table 2-56. Terra Key Measurements

Discipline	Measurement	Terra (EOS AM-1) Instrument
Atmosphere	Cloud properties	MODIS, MISR, ASTER
	Radiative energy fluxes	CERES, MODIS, MISR
	Tropospheric chemistry	MOPITT
	Aerosol properties	MISR, MODIS
	Atmospheric temperature	MODIS
	Atmospheric humidity	MODIS
Land	Land cover and land use change	MODIS, MISR, ASTER
	Vegetation dynamics	MODIS, MISR, ASTER
	Surface temperature	MODIS, ASTER
	Fire occurrence	MODIS, ASTER
	Volcanic effects	MODIS, MISR, ASTER
Ocean	Surface temperature	MODIS
	Phytoplankton and dissolved organic matter	MODIS, MISR
Cryosphere	Land ice change	ASTER
	Sea ice	MODIS, ASTER
	Snow cover	MODIS, ASTER

Source: “EOS AM-1: The First EOS Satellite, NASA’s Earth Observing System,” NASA Publication NP-1998-03-018-GSFC, p. 7.

Table 2-57. Terra (EOS AM-1) Characteristics

Launch date/launch site	December 18, 1999/Vandenberg Air Force Base
Launch vehicle	Atlas IIAS
NASA role	Mission management; provided spacecraft and the MODIS, CERES, and MISR instruments
Responsible (lead) Center	Goddard Space Flight Center
Mission objectives[174]	• To provide the first global and seasonal measurements of the Earth system, including such critical functions as biological productivity of the land and oceans, snow and ice, surface temperature, clouds, water vapor, and land cover • To improve our ability to detect human impacts on Earth's system and climate, identify the "fingerprint" of human activity on climate, and predict climate change by using the new global observations in climate models • To help develop technologies for disaster prediction, characterization, and risk reduction from wildfires, volcanoes, floods, and droughts • To start long-term monitoring of global climate change and environmental change
Orbit characteristics[175]	
Apogee	705 km (438 mi)
Perigee	705 km (438 mi)
Inclination (deg)	98.2
Period (min)	98.9
Weight	11,442 lb (5,190 kg)
Dimensions	22 ft (6.8 m) long, 11.5 ft (3.5 m) in diameter
Power source	Solar panel and batteries
Instruments[176]	CERES (2): Provided by NASA Langley Research Center and built by TRW, Inc. PI: Bruce Barkstrom, NASA Langley Research Center Measured the reflected and radiant energy coming from Earth's surface and atmosphere to help determine Earth's energy balance. Extended the dataset begun in the 1980s by the Earth Radiation Budget Experiment (ERBE). MODIS: Provided by Goddard Space Flight Center and built by Raytheon Santa Barbara Remote Sensing PI: Vincent Salomonson, Goddard Space Flight Center Measured atmospherics, land, and ocean processes, including surface temperature (land and ocean), ocean color, global vegetation, cloud characteristics, snow cover, and temperature and moisture profiles. Could view the entire globe daily at moderate resolutions with pixels ranging from 250 m^2 to 1 km^2 (about 0.386 mi^2). This global-scale multispectral instrument was useful for addressing questions in many scientific

[174] "Terra: Flagship of the Earth Observing System," Press Kit, November 1999, *http://terra.nasa.gov/Publications/terra_press_kit.pdf* (accessed March 7, 2006).

[175] "Terra's Near-Polar Orbit," *http://terra.nasa.gov/About/SC/am_orbit.html* (accessed January 17, 2007).

[176] "Terra: Flagship of the Earth Observing System," Press Kit, November 1999, pp. 9–10, *http://terra.nasa.gov/Publications/terra_press_kit.pdf* (accessed March 7, 2006).

	disciplines. Measurements of Pollution in the Troposphere (MOPITT): Provided by the Canadian Space Agency (CSA) and built by COM DEV International PI: James Drummond, University of Toronto This infrared gas-correlation radiometer measured gaseous concentrations of air pollutants, carbon monoxide, and methane in the troposphere (the lowest 10 mi [16.1 km] of the atmosphere) and provided global data about their location and season. Advanced Spaceborne Thermal Emission and Reflection Radiometer (ASTER): Provided by Japan's Ministry of International Trade and Industry and built by NEC, Mitsubishi Electronics Co., and Fujitsu, Ltd. PIs: Anne Kahle, Jet Propulsion Laboratory; Hiroji Tsu, Japan Geological Survey Measured cloud properties, vegetation index, surface mineralogy, soil properties, and surface temperature and topography for selected regions of Earth at very high resolution (up to 15 × 15 m^2/pixel, 161 × 161 ft^2/pixel). Obtained detailed three-dimensional measurements of surface topography. MISR: Built and provided by the Jet Propulsion Laboratory PI: David J. Diner, Jet Propulsion Laboratory Measured every part of Earth's system, including clouds, Earth's surface, and particles floating in the atmosphere that scatter light differently at different angles, using cameras pointed in nine different viewing directions. Measured the reflective characteristics to provide data about their changing physical properties and to quantify their effects on Earth's energy budget. Also provided unique three-dimensional views of clouds and volcanic plumes.
Prime contractor	Lockheed Martin

Table 2-58. EOSDIS Distributed Active Archive Centers

DAAC	Location	Discipline	Terra Instrument
Alaska Satellite Facility	Fairbanks, AK	Sea ice, polar processes, synthetic aperture radar imagery	Did not support Terra mission
Land Processes (EROS Data Center)	Sioux Falls, SD	Land processes	ASTER, MODIS
GSFC Earth Sciences	Greenbelt, MD	Upper atmosphere, global biosphere, atmospheric dynamics, global precipitation, ocean biology, ocean dynamics, solar irradiance	MODIS
Physical Oceanography, Jet Propulsion Laboratory	Pasadena, CA	Oceanic processes, air-sea interactions	Did not support Terra mission
Langley Atmospheric Science Data Center	Hampton, VA	Radiation budget, clouds, aerosols, tropospheric chemistry	CERES, MISR, MOPITT
National Snow and Ice Data Center	University of Colorado, Boulder, CO	Snow and ice, cryosphere and climate	MODIS
Oak Ridge National Laboratory	Oak Ridge, TN	Biogeochemical dynamics, ecological data, environmental processes	Did not support Terra mission
Socioeconomic Data and Applications Data Center	Columbia University, Palisades, NY	Population, sustainability, geospatial data, multilateral environmental agreements	Did not support Terra mission

Source: “About the Data Centers,” *http://nasadaacs.eos.nasa.gov/about.html* (accessed March 7, 2006). Also “EOS AM-1: The First EOS Satellite, NASA’s Earth Observing System,” NASA Publication NP-1998-03-018-GSFC, p. 24. King and Greenstone, eds., 1999 EOS Reference Handbook, p. 28.

Table 2-59. SeaWiFS Characteristics

Launch date/launch site	August 1, 1997/Vandenberg Air Force Base
Launch vehicle	Pegasus XL
NASA role[177]	To conduct product quality assurance, calibration, and validation programs; determine the degree to which the ocean color data fulfills NASA requirements; purchase SeaWiFS data for scientific research; and develop and operate a research data system to process, calibrate, validate, archive, and distribute SeaWiFS data for research
Responsible (lead) Center	Goddard Space Flight Center
Mission objectives[178]	• To acquire data critical for studying the role of the oceans, including the exchange of critical elements and gases between the atmosphere and oceans, and how these exchanges affect phytoplankton production • To examine oceanic factors affecting global change and assess the oceans' role in the global carbon cycle, as well as other biogeochemical cycles, through a comprehensive research program • To obtain accurate ocean color data from the world's oceans for a five-year (minimum) period; to process this data in conjunction with ancillary data into meaningful biological parameters, such as photosynthesis rates; and to make this data readily available to researchers
Orbit characteristics[179]	
Apogee	712 km (442 mi)
Perigee	697 km (433 mi)
Inclination (deg)	98.217
Period (min)	99
Weight	50 kg (110 lb) (SeaWiFS instrument only)[180]
Dimensions	SeaStar spacecraft: 213 cm (84 in) high × 112 cm (44 in) in diameter[181]
Power source	Solar panels and batteries[182]
Instrument[183]	SeaWiFS PI: Dr. Wayne E. Esaias, Goddard Space Flight Center

[177] "Sea-viewing Wide Field-of-view Sensor (SeaWiFS)," NASA Facts Online, FS-97 (03)-004-GSFC, *http://www.gsfc.nasa.gov/gsfc/service/gallery/fact_sheets/earthsci/seawifs.htm* (accessed January 23, 2006).
[178] "SeaWiFS Project—Detailed Description," *http://oceancolor.gsfc.nasa.gov/SeaWiFS/BACKGROUND/SEAWIFS_970_BROCHURE.html* (accessed January 10, 2006).
[179] "SeaWiFS Project—Announcements-SeaWiFS/SeaStar Launch Status," *http://oceancolor.gsfc.nasa.gov/SeaWiFS/ANNOUNCEMENTS/current_launch_status.html* (accessed January 10, 2006). Also "Monitoring the Earth from Space with SeaWiFS," *http://seadas.gsfc.nasa.gov/SeaWiFS/TEACHERS/sanctuary_5.html* (accessed January 10, 2006).
[180] "SeaStar Background Information," ORBIMAGE, Global Imaging Information. Also "OrbComm: Orbital Sciences Corporation," NASA History Division folder 011261, Historical Reference Collection, NASA Headquarters, Washington, DC.
[181] "SeaStar Background Information," ORBIMAGE, Global Imaging Information. Also "OrbComm: Orbital Sciences Corporation," NASA History Division folder 011261, Historical Reference Collection, NASA Headquarters, Washington, DC.
[182] "SeaWiFS Project—Spacecraft and Sensor Overview," *http://oceancolor.gsfc.nasa.gov/SeaWiFS/SEASTAR/SPACECRAFT.html* (accessed January 10, 2006).
[183] "NSSDC Master Catalog Display: Experiment Personnel—SeaWiFS, Ocean Color Scanner," *http://nssdc.gsfc.nasa.gov/nmc/tmp/1997-037A-01-personnel.html* (accessed February 27, 2006).

	The sensor consisted of an electronics module and an optical scanning telescope operating in eight spectral bands. The eight spectral bands operated in the visible/near-infrared regions of the spectrum with a spatial resolution of 1 km (0.6 mi). Scene radiation was collected by the telescope and reflected onto the rotating mirror. The radiation was then relayed through dichroic beam splitters to separate the radiation into four wavelength intervals, each encompassing two of the eight spectral bands. The four wavelength intervals were then directed by four corresponding aft-optics assemblies through two separate bandpass filters to separate the radiation into eight spectral bands. The radiation was amplified in the electronics module. The instrument was calibrated in flight using solar and lunar calibration procedures. The solar calibration used a solar radiation diffuser located outside the SeaWiFS scene-scan interval. Lunar calibration was accomplished by maneuvering the spacecraft to view the moon in the nighttime part of the orbit.
Prime contractor	Orbital Sciences Corporation

Table 2-60. Landsats 4 and 5 TM Band Designation

Band No.	Spectral Band	Spectral Range (microns)	Use
1	Blue-green	0.45–0.52	Performed bathymetric mapping and distinguished soil from vegetation and deciduous vegetation from coniferous
2	Green	0.525–0.60	Emphasized peak vegetation, useful for assessing plant vigor
3	Red	0.63–0.69	Discriminated vegetation slopes
4	Reflected IR	0.76–0.90	Emphasized biomass content and shorelines
5	Reflected IR	1.55–1.75	Discriminated moisture content of soil and vegetation; could penetrate thin clouds
6	Thermal IR	10.40–12.50	Performed thermal mapping and estimated soil moisture
7	Reflected IR	2.08–2.35	Mapped hydrothermally altered rocks associated with mineral deposits

Source: "Earth Resources Observation and Science (EROS)," U.S. Geological Survey (USGS), *http://edc.usgs.gov/products/satellite/band.html* (accessed February 16, 2006). Also "Landsat: A Global Land-Observing Program," Fact Sheet 023-03 (March 2003), *http://erg.usgs.gov/isb/pubs/factsheets/fs02303.html* (accessed February 15, 2006).

Table 2-61. MSS Band Characteristics

Band No.	Spectral Band	Spectral Range (microns)	Use
1	Green	0.5–0.6	Emphasized sediment-laden water and delineated areas of shallow water
2	Red	0.6–0.7	Emphasized cultural features
3	Near IR	0.7–0.8	Emphasized vegetation boundary between land and water, as well as landforms
4	Near IR	0.8–1.1	Penetrated atmospheric haze best; emphasized vegetation, boundaries between land and water, and landforms

Source: “Earth Resources Observation and Science (EROS),” USGS, *http://edc.usgs.gov/products/satellite/band.html* (accessed February 16, 2006). Also “Landsat: A Global Land-Observing Program,” Fact Sheet 023-03 (March 2003), *http://erg.usgs.gov/isb/pubs/factsheets/fs02303.html* (accessed February 15, 2006).

Table 2-62. Landsat 6 Characteristics

Launch date/launch site	October 5, 1993/Vandenberg Air Force Base
Launch vehicle	Titan 2
NASA role	Developed and launched the spacecraft, provided instrument through contract, developed the ground system.[184] Assumed program management responsibilities from NOAA in 1992 through provisions of the Land Remote Sensing Policy Act of 1992 establishing the Landsat Program Management (LPM).[185]
Responsible (lead) Center	Goddard Space Flight Center
Mission objectives	To ensure a collection of consistently calibrated Earth imagery. Landsat's Global Survey Mission was to establish and execute a data-acquisition strategy, ensuring the repetitive acquisition of observations over Earth's land mass, coastal boundaries, and coral reefs and ensuring that the data acquired was of maximum utility in supporting the scientific objectives of monitoring changes in Earth's land surface and associated environment.[186] Landsat 6 was designed to continue the Landsat program.
Orbit characteristics	Failed to reach orbit
Weight	4,800 lb (2,200 kg) (approx.)[187]
Dimensions	14 ft (4.3 m) long × 9 ft (2.8 m) in diameter[188]
Power source	Four-panel single solar array, two NiCd batteries
Instruments and experiments	Enhanced Thematic Mapper (ETM): Incorporated the existing capability of the Landsat 4 and 5 TMs and added a 15-m (49-ft) resolution panchromatic channel at 0.5–0.9 micrometer. Also added a second multiplexer that improved the reliability of the sensor, two selectable gain states for all data that provided added radiometric flexibility, and dual power supplies that allowed the simultaneous operation of both multiplexers and all spectral bands.[189]
Prime contractor	EOSAT

[184] "Landsat Program," *http://msl.jpl.nasa.gov/Programs/landsat.html* (accessed January 10, 2006). Also "Landsat 7 Basic Facts," *http://landsat.gsfc.nasa.gov/project/L7basix.html* (accessed February 14, 2006).
[185] "Landsat Program Chronology," *http://geo.arc.nasa.gov/sge/landsat/lpchron.html* (accessed January 11, 2006).
[186] "Science @ NASA: Landsat 7," *http://science.hq.nasa.gov/missions/satellite_48.htm* (accessed January 10, 2006).
[187] "Landsat 6 History," USGS Landsat Project, *http://landsat7.usgs.gov/project_facts/history/landsat_6.php* (accessed February 20, 2006).
[188] "Landsat 6 History," USGS Landsat Project, *http://landsat7.usgs.gov/project_facts/history/landsat_6.php* (accessed February 20, 2006).
[189] "Landsat 6," NSSDC Master Catalog, *http://nssdc.gsfc.nasa.gov/nmc/tmp/LNDSAT6.html* (accessed February 22, 2006).

Table 2-63. Landsat 7 ETM+ Band Designation

Band No.	Spectral Band	Spectral Range (microns)	Use
1	Blue-green	0.45–0.52	Performed bathymetric mapping and distinguished soil from vegetation and deciduous vegetation from coniferous
2	Green	0.53–0.61	Emphasized peak vegetation, useful for assessing plant vigor
3	Red	0.63–0.69	Discriminated vegetation slopes
4	Reflected IR	0.79–0.90	Emphasized biomass content and shorelines
5	Reflected IR	1.55–1.75	Discriminated moisture content of soil and vegetation; penetrated thin clouds
6	Thermal IR	10.40–12.50	Performed thermal mapping and estimated soil moisture
7	Reflected IR	2.09–2.35	Mapped hydrothermally altered rocks associated with mineral deposits
	Panchromatic	0.52–0.90	This band was visible through near IR and had 15-m (49.2-ft) resolution for "sharpening" of multispectral images

Source: "Earth Resources Observation and Science (EROS), USGS, *http://edc.usgs.gov/products/satellite/band.html* (accessed February 16, 2006). Also "Landsat: A Global Land-Observing Program," Fact Sheet 023-03, March 2003, *http://erg.usgs.gov/isb/pubs/factsheets/fs02303.html* (accessed February 15, 2006).

Table 2-64. Landsat Program Chronology, 1989–1998

Date	Event
1989	NOAA announces that its funds for Landsat operations are spent and directs EOSAT to turn off the satellites. The action results in a strong protest from Congress, foreign and domestic data users, and foreign governments.
1989	The National Space Council develops an interim funding plan to keep the Landsat system operating through the end of the fiscal year. NOAA rescinds its shutdown order. The Space Council also recommends that the President approve a policy statement committing the United States to ensuring the continuity of Landsat-type data.
1989	The President approves a policy statement and requests the Space Council to work with the Office of Management and Budget (OMB) on options for ensuring the continuity of Landsat data after Landsat 6.
1990	NOAA does not request operating funds for Landsat. Congress appropriates enough funds to keep the system operational for six months and requests that agencies using Landsat data reprogram sufficient funds to keep the system going for the remainder of the year.
1990	The Bush administration does not request funds for a follow-on to Landsat 6.
1990	EOSAT relinquishes exclusive rights to MSS data more than two years old.
1991	Funding problems and solutions from 1990 are repeated in 1991. The Bush administration fails to develop a policy regarding Landsat.
February 1992	National Space Policy Directive No. 5 is drafted and signed by President George H. W. Bush.[190] The directive reiterates the importance of Landsat data and outlines a strategy to • ensure the operation of Landsats 4 and 5 at least until the launch of Landsat 6; • acquire and launch Landsat 7 before the projected end-of-life of Landsat 6; • foster the development of advanced land remote sensing systems and opportunities for commercialization; • minimize the cost of Landsat data for U.S. government users; • provide data for use in global change research consistent with the administration’s Data Management for Global Change Research policy statements; • limit the role of the U.S. government in private sector remote sensing to that required for national security, foreign policy, and public safety; • maintain an archive in the United States of already existing Landsat-type data as well as Landsat-type data that will be gathered in the future; and • consider alternatives for maintaining data continuity after Landsat 7. • DOC is instructed to complete and launch Landsat 6 and ensure the operation of Landsats 4 and 5 until Landsat 6 becomes operational. The DOD and NASA are instructed to • develop and launch Landsat 7 with performance capabilities at least equal to those of Landsat 6; • define continuity requirements after Landsat 7; and • prepare a plan that “addresses management and funding responsibilities, operations, data archiving and dissemination, and commercial considerations associated with the Landsat program”
March 1992	NASA and DOD draft and sign a “Management Plan for the Landsat Program.” The plan • assigns responsibility for the space segment to DOD and responsibility for the ground segment to NASA;

[190] “Landsat Remote Sensing Strategy,” National Space Policy Directive No. 5, February 13, 1992, *http://www.fas.org/spp/military/docops/national/nspd5.htm* (accessed January 15, 2006).

Date	Event
	• establishes a Landsat Coordinating Group (NASA and DOD) to coordinate program plans, budgets, and policies; • establishes baseline funding for each agency for the life of the program (NASA: $410.0 million; DOD: $470.0 million); and • states that any improvement sought beyond the technical capabilities of Landsat 6 will be funded by the sponsoring agency.
September 1992	EOSAT loses the capability to process MSS data. No further acquisition of MSS data at U.S. receiving station is planned.
October 1992	DOD signs a contract with General Electric (later Martin Marietta Astro Space [MMAS]) for the construction and launch of Landsat 7. The High Resolution Multispectral Stereo Imager (HRMSI) is included as an option in the contract.
October 1992	The NASA budget appropriation request for $25.0 million for the Landsat Program is reduced to $10.0 million. The reduction threatens DOD's appropriation and its participation in the program.
October 28, 1992	Congress passes and President Bush signs the *Land Remote Sensing Policy Act of 1992* (P.L. 102-555).[191] The act recognizes that commercialization of Landsat has not worked and is unlikely to work in the future. Acknowledging the importance of Landsat data, the act establishes the LPM, consisting of NASA, DOD, and any other agency the President wishes to name.[192] The law instructs the LPM to • establish a management plan, • develop a Landsat Advisory Process and report on progress at established intervals, • procure Landsat 7, • begin negotiations with the contractor on data policy for Landsats 4–6, • assume Landsat 6 program responsibilities from DOC, • develop a data policy for Landsat 7 on the basis of the "cost of fulfilling user request, • conduct a technology demonstration program, and • assess options for a successor land remote sensing system.
January 1993	The Landsat Advisory Process is initiated with the first meeting of the Landsat Civil Agency Requirements Working Group.
March 1993	Funding for the HRMSI ground segment is not part of the NASA FY 1994 budget request.
April 1993	Congress restores $15 million to the NASA FY 1993 budget for the Landsat program.
June 1993	NASA submits a request for HRMSI funding as part of the New Technology Initiative.
June 1993	The House authorization committee approves $25 million for the NASA FY 1994 budget for HRMSI and full funding for the baseline program.
July 1993	The House appropriations committee approves NASA FY 1994 baseline budget for Landsat but does not approve any additional funding for HRMSI. HRMSI is removed from the New Technology Initiative.
September 1993	The House and Senate conference committee fails to add funding for HRMSI to the NASA FY 1994 budget.
September 1993	DOD receives an appropriation in FY 1994 for the HRMSI space segment, but no funds for the ground segment.
October 5,	Landsat 6 is launched from Vandenberg Air Force Base. The satellite fails to attain orbit.

[191] *Land Remote Sensing Policy Act of 1992*, October 28, 1992, Public Law 102-555, 102nd Congress, 2nd sess., *http://geo.arc.nasa.gov/sge/landsat/15USCch82.html* (accessed February 15, 2006).
[192] The term "Landsat Program Management," as defined in the legislation, means the integrated program management structure.

Date	Event
1993	
October 1993	The Office of Science and Technology Policy (OSTP) begins working with NASA, DOD, and NOAA to define the action required in light of the Landsat 6 loss.
December 8, 1993	NASA Administrator Goldin and Deputy Secretary of Defense John Deutch agree that the two organizations should go separate ways regarding Landsat: NASA will be responsible for the ETM, and DOD will be responsible for HRMSI.
January 1994	Rep. George Brown, chairman of the House Committee on Science and Technology, writes Vice President Gore describing the Landsat program as a “shambles” and expressing his concern for the program’s effects on other “convergence” efforts.
February 4, 1994	Vice President Gore responds to Rep. Brown reiterating the administration’s support for Landsat and desire to work with NASA, NOAA, and DOD to develop a successful implementation strategy.
February 7, 1994	The National Science and Technology Council votes to recommend continuing the Landsat program with the completion of the ETM instrument and the Landsat 7 spacecraft. NASA and NOAA are instructed to develop a management plan to implement the recommendation.
February 8, 1994	Representatives from DOD meet with NASA personnel to write a transition plan that will transfer the MMAS contract for the Landsat 7 space segment and the remaining FY 1994 DOD Landsat funds from DOD to NASA. The initial goal is to have the transfer complete by February 28, 1994.
February 9, 1994	Congress rescinds all remaining FY 1994 DOD Landsat funding ($139.0 million) pending resolution of the Emergency Supplemental Appropriations Act of 1994.[193]
February 11, 1994	Congress restores $90.0 million in FY 1994 funding to DOD for Landsat, stipulating that DOD may transfer up to the full amount to NASA—for Landsat 7 work only—after the NASA Administrator certifies that NASA has sufficient funding in FY 1995 and the out years to complete the program.
February 18, 1994	The schedule deadline for exercising the HRMSI option is reached. By prearrangement in the contract, MMAS and the Santa Barbara Research Center stop work on all HRMSI-related tasks.
March 1, 1994	DOD sends a letter to MMAS terminating selected tasks on the Landsat contract.
March 3, 1994	The NASA/DOD Landsat transition plan is signed and forwarded to OSTP.
March 3, 1994	The first NASA/NOAA/USGS meeting on the Landsat ground system is held at Goddard.
March 18, 1994	The first draft of the NASA/NOAA/USGS management plan is distributed to participants for comment.
March 23, 1994	A Landsat 7 status review is held at Goddard.
March 29, 1994	The ETM+ Critical Design Review (CDR) is held at the Santa Barbara Research Center. The calibrator door becomes the primary unresolved technical issue. The CDR for the door assembly is scheduled for June 1994.
April 7, 1994	The second NASA/NOAA/USGS meeting on the Landsat ground system is held at the EROS Data Center.
April 11,	Landsat program management and EOSAT agree to terms for the continued operation of

[193] U.S. Congress, *Emergency Supplemental Appropriations Act of 1994*, Public Law 103-211, February 12, 1994, 103rd Cong., 2nd sess. This act also provided relief to southern California following the January 1994 earthquake.

Date	Event
1994	Landsats 4 and 5, along with a data distribution and pricing schedule that conforms to goals established in P.L. 102-555, the *Land Remote Sensing Policy Act of 1992*.
May 5, 1994	The NASA Administrator certifies funding for the Landsat 7 program as required by P.L. 103-211, the *Emergency Supplemental Appropriations Act of 1994*. Notification of certification is sent to the appropriate congressional committees.[194]
May 10, 1994	The White House announces a Presidential Decision Directive continuing the Landsat 7 program, restructuring Landsat Program Management (NASA, NOAA, and DOI), and transferring Landsat 7 procurement responsibility from DOD to NASA.
May 18, 1994	MMAS's contract for Landsat 7 is transferred from DOD to NASA.
June 28, 1994	The Santa Barbara Research Center subcontract to Martin Marietta for the ETM+ is separated from the Martin Marietta contract and assigned to Goddard.
July 15, 1994	DOC (NOAA) and EOSAT sign a modification to the contract extending EOSAT operations of the Landsat system through December 31, 1994. The extension includes only one provision from the April 11 EOSAT/LPM agreement, and the cost of data is reduced to $3,500.00 per scene.
July 16, 1994	The original DOC contract with EOSAT for the Landsat program operations expires.
August 10, 1994	"Management Plan for the Landsat Program," a document describing program objectives and agency responsibilities, is signed by representatives of NASA, NOAA, and USGS.[195]
September 28, 1994	The FY 1995 budget for NASA is passed by Congress. The NASA appropriation includes the full amount requested for Landsat 7.
November 7, 1994	DOC places a notice in the *Commerce Business Daily* of Commerce's intent to contract with EOSAT for continued operation of Landsats 4 and 5 at no cost to the U.S. government.
December 1994	DOC notifies EOSAT that, based on expressions of interest in response to the notice in the *Commerce Business Daily*, Commerce will conduct a competitive procurement for the continued operation of Landsats 4 and 5.
December 1994	EOSAT responds to DOC notification by filing suit in the U.S. District Court for the District of Columbia to block the competitive procurement.
December 1994	DOC and EOSAT sign a contract modification extending the existing contract for operating the Landsat system through February 28, 1995. Two option periods are included that, if exercised, will extend the contract through June 30, 1995.
February 27, 1995	DOC exercises the first option in a contract modification with EOSAT.
March 10, 1995	A panel of experts reviews the Landsat 6 failure on October 5, 1993. They conclude that the rupture of a hydrazine manifold seven minutes after launch kept fuel from reaching the satellite's engines, thereby preventing Landsat 6 from reaching orbit.[196]
March 16,	The U.S. District Court orders LPM to notify Congress within 10 days of the status of

[194] U.S. Congress, *Emergency Supplemental Appropriations Act of 1994*, Public Law 103-211, February 12, 1994, 103rd Cong., 2nd sess.

[195] The National Aeronautics and Space Administration, the National Oceanic and Atmospheric Administration, and the U.S. Geological Survey, "Management Plan for the Landsat Program," *http://geo.arc.nasa.gov/sge/landsat/mgmtplan.html* (accessed February 15, 2006).

[196] "Landsat 6 Failure Attributed to Ruptured Manifold," NOAA Release 95-13, March 10, 1995, *http://www.publicaffairs.noaa.gov/pr95/mar95/landsat7.html*. Also Richard Monastersky, "Fuel Explosion Downed Landsat 6 Satellite: Earth-Sensing Satellite Never Reached Orbit After October 5, 1993, Launch," *Science News*, March 18, 1995, *http://www.findarticles.com/p/articles/mi_m1200/is_n11_v147/ai_16783246* (both accessed January 22, 2007).

<table>
<tr><th>Date</th><th>Event</th></tr>
<tr><td>1995</td><td>negotiations with EOSAT. The current contract is extended through June 30, and the government is instructed not to take any action toward conducting a competitive procurement.</td></tr>
<tr><td>June 22, 1995</td><td>The quarterly meeting of the Landsat Civil Agency Requirements Working Group convenes at USGS offices in Reston, VA. The major item of discussion is the degradation in the equatorial crossing time for Landsat 5. A review by Goddard staff of the risk in performing a maneuver to correct the crossing time concludes that the peril to the spacecraft is low, so this maneuver should be performed. There is general agreement that this operation should take place in the fall after the end of the Northern Hemisphere’s growing season.</td></tr>
<tr><td>June 27, 1995</td><td>U.S. District Judge Emmet G. Sullivan, in the case of Earth Observation Satellite Company vs. National Aeronautics and Space Administration et al., rules that P.L. 102-555 (the Land Remote Sensing Policy Act of 1992) requires the U.S. government to contract with EOSAT for operation of Landsats 4 and 5. Following the decision, EOSAT announces it will honor all provisions of its April 11, 1994, agreement with LPM pending formal extension of EOSAT’s contract with DOC for the operation of Landsats 4 and 5.[197]</td></tr>
<tr><td>August 22, 1995</td><td>The chief of the Landsat Commercialization Division at NOAA sends a letter to the president of EOSAT Corporation requesting EOSAT, as the operator of Landsat 5, to perform a maneuver to bring the orbital crossing time of Landsat 5 back to the mission standard of 9:45 a.m. +/– 15 minutes. A maneuver to correct the crossing time has not been performed since 1992. The crossing time at the end of June 1995 was approximately 9:18 a.m., and it had become progressively earlier. NOAA requested that the maneuver be conducted in the fall following the conclusion of the Northern Hemisphere’s growing season.</td></tr>
<tr><td>November 30, 1995</td><td>EOSAT Corporation successfully completes the last of five maneuvers to correct the equatorial crossing time for Landsat 5. The orbit of the satellite is now moving back to the nominal crossing time window of 9:45 a.m. +/– 15 minutes at the rate of 4.2 seconds per day. The crossing time will reach 9:30 a.m. in mid-September 1996 and will peak at 9:56 a.m. in the spring of 1999. Orbital information from before and after the correction maneuver:
<table>
<tr><th></th><th>10/25/95</th><th>12/1/95</th></tr>
<tr><td>Semimajor axis</td><td>7,077.44 km (4,397.72 mi)</td><td>7,077.95 km (4,398.03 mi)</td></tr>
<tr><td>Inclination</td><td>98.0965 deg</td><td>98.3639 deg</td></tr>
<tr><td>Equatorial Crossing Time (EQT)</td><td>09:12:01 a.m.</td><td>09:12:27 a.m.</td></tr>
<tr><td>EQT rate of change</td><td>–3.17 sec/day</td><td>+4.20 sec/day</td></tr>
</table></td></tr>
<tr><td>February 8, 1996</td><td>Held at JPL in Pasadena, CA, a workshop on NMP addresses the technical capabilities and requirements for an Earth observation satellite to be built under the NMP’s sponsorship. This program is described as a potential opportunity to test new technology for the follow-on instrument to the ETM+ on Landsat 7. Workshop participants present a series of options for the experimental satellite and ask for recommendations. The responses from the participants</td></tr>
</table>

[197] “Current Status and Summary of Agreement Between Landsat Program Management and EOSAT Corporation on Cost and Reproduction Rights for Landsat 4/5 Thematic Mapper Data,” April 11, 1994, *http://geo.arc.nasa.gov/sge/landsat/apr11.html* (accessed February 16, 2006).

Date	Event
	form the basis for a proposal for an advanced land imager (ALI), a hyperspectral visible and shortwave instrument. The recommendations are forwarded to NASA for consideration under the NMP.
March 22, 1996	The appropriate offices at NASA Headquarters review plans for the NMP and select the lightweight, visible, and shortwave infrared imager of Earth's land surface as the focus of the first NMP mission focused on Earth science. The instrument selected is the one discussed at the February 8 workshop on the NMP.
April 2–3, 1996	The CDR for the Landsat 7 ground system is held at Greenbelt, MD. No design elements are identified that threaten the successful completion of the ground system or the implementation of the system as scheduled.
April 11, 1996	NASA Headquarters announces the selection of the first Earth science mission in the NMP. It would consist of a land remote sensing satellite called Earth Observing-1 (EO-1).
April 15–18, 1996	The Technical Working Group of the Landsat Ground Station Operators Working Group (LGSOWG) meets in Annapolis, MD. It is the second meeting of the technical working group since the LGSOWG meeting in May 1995. Representatives from eight stations attend. Key technical issues discussed include the processing of data received from Landsat 7 and metadata and browse file formats and data distribution. New action items are generated as well as recommendations to be presented to the LGSOWG meeting in May 1996.
May 21–24, 1996	The 25th meeting of the LGSOWG convenes in Pretoria, South Africa. Representatives from 11 ground stations attend. Updates on activities at each ground station are presented, and NASA and NOAA representatives update the attendees on the status of the Landsat program. The recommendations from the technical working group are discussed and adopted, including preparations for the ground stations to receive, process, and distribute data from Landsat 7. A draft of terms for the agreement that will allow the international ground stations to receive Landsat 7 data is distributed for comment. Negotiations between NOAA and the ground stations will begin next year.
May 23, 1996	NASA's Program Management Council (PMC) accepts the recommendation from the Independent Annual Review (IAR) panel to include systematic processing of Landsat 7 data as part of the Landsat 7 processing system. The action assures data users access to unenhanced data similar to that distributed from the previous Landsat satellites. Under the recommendation, the EOSDIS will process and archive all Landsat 7 data acquired at the primary receiving station in the United States as Level 0R and will generate a systematically corrected product (Level 1G) on request from the user.
July 1, 1996	NASA announces the selection of the team leader and other members of the science team for the future Landsat 7 remote-sensing satellite. Dr. Samuel Goward of the University of Maryland in College Park, MD, will lead the science team. Other team members are based at universities in Arizona, Colorado, Florida, Hawai'i, and New York, as well as USGS, the Department of Agriculture (USDA), Goddard, and JPL.[198]
July 13, 1997	A major thunderstorm of softball-sized hail causes extensive damage to the EROS Data Center (EDC) in South Dakota. The recently installed antenna that receives Landsat 7 data suffers damage that will require several months to repair, but the damage is not expected to delay the launch of the system.
July 23, 1997	The 25th anniversary of the launch of ERTS-1 (Landsat 1).
October 6, 1997	The Landsat Coordinating Group (LCG) convenes at USGS offices in Reston, VA. Representing the three agencies in LPM are William Townsend (NASA), Gregory Withee

[198] "NASA Names Landsat 7 Science Team and Funds Promising Young Earth Scientists," July 1, 1996, *ftp://ftp.hq.nasa.gov/pub/pao/pressrel/1996/96-125.txt* (accessed February 15, 2006).

Date	Event
	(NOAA), and Bonnie McGregor (USGS). Presentations from staff focus on the Landsat 7 data policy, data pricing policy, and the status of the ground system for support of Landsat 7 data acquisition, processing, and distribution. The LCG agrees to meet quarterly until the launch of Landsat 7. The next meeting will occur in late January 1998.
October 9, 1997	The ETM+ is delivered to Lockheed Martin Missiles and Space (LMMS) in Valley Forge, PA, from Hughes Santa Barbara Remote Sensing. The instrument will undergo further environmental testing at LMMS before it is integrated with the Landsat 7 spacecraft. Delivery of the ETM+ maintains the schedule toward a July 9, 1998, launch of Landsat 7.
October 31, 1997	USGS issues a "Technical Announcement" on prices of Landsat 7 data. Level 0R scenes will be sold initially for $475.00 per scene. Level 1R and 1G data products will be sold for no more than $600.00 per scene. The products are described in the announcement and in the Landsat 7 Data Policy.[199]
December 3–5, 1997	A conference on "Land Satellite Data in the Next Century II: Sources and Applications" is held at the Omni Shoreham Hotel in Washington, DC. Approximately 600 attend the conference presented by the American Society for Photogrammetry and Remote Sensing (ASPRS) and North American Remote Sensing Industries Association (NARSIA) with sponsorship from, among others, NASA, NOAA, and USGS. Attendees hear the latest on the land satellites scheduled for launch in the next three to five years and summaries of major applications for land satellite data.
January 21, 1998	NASA announces that the Mission to Planet Earth Enterprise will now be called the Earth Science Enterprise.[200]
February 4, 1998	The LCG convenes at DOC.
February 26, 1998	The Landsat Civil Agency Requirements Working Group convenes at NASA Headquarters.
March 12, 1998	NASA announces that Landsat 7 will not be launched in July 1998 as planned due to necessary changes in the design of the electrical power supply hardware for the spacecraft's main instrument. A new target launch date is to be set by NASA officials after the completion of instrument thermal vacuum tests scheduled for July 1998.
April 14–16, 1998	The Landsat Science Team convenes at Goddard. The meeting, co-chaired by Darrel Williams (NASA/GSFC) and Samuel Goward (University of Maryland), hears updates on research and the status of Landsat 7 and Resource21 from the team members and discusses, among other items, requirements for a post-Landsat 7 system.
October 28, 1998	The President signs the *Commercial Space Act of 1998* (formerly the *Commercial Space Act of 1997*), Public Law 105-303.[201]
November 19, 1998	NASA selects a new launch date of April 15, 1999, for Landsat 7. The delay was caused by a need for changes in the design of the electrical power-supply hardware for the spacecraft's instrument. During instrument-level thermal vacuum tests that began in December 1997, a power supply on the ETM+ instrument failed twice.[202]
April 15, 1999	Landsat 7 launches successfully from Vandenberg Air Force Base, CA, on a Delta II launch vehicle.

[199] "Landsat 7 Data Policy," *http://geo.arc.nasa.gov/sge/landsat/l7policyn.html* (accessed February 16, 2006).
[200] "Mission to Planet Earth Enterprise Name Changed to Earth Science," *NASA News* Release 98-12, January 21, 1998 *http://www.nasa.gov/home/hqnews/1998/98-012.txt* (accessed January 17, 2007).
[201] *Commercial Space Act of 1998*, Public Law 105-303, 105th Congress, 1st sess., *http://geo.arc.nasa.gov/sge/landsat/sec107.html* (accessed February 16, 2006).
[202] "Landsat-7 Launch Scheduled for April 15," GSFC Release 98-188 (HQ Release 98-209), November 19, 1998, *http://www.gsfc.nasa.gov/news-release/releases/1998/98-188.htm* (accessed January 17, 2007).

Source: "Landsat Program Chronology," *http://geo.arc.nasa.gov/sge/landsat/lpchron.html* (accessed January 11, 2006).

Table 2-65. Landsat 7 Characteristics

Launch date/launch site	April 15, 1999/Vandenberg Air Force Base
Launch vehicle	Delta II
NASA role	Developed and launched the spacecraft, provided instrument through contract, developed the ground system, and performed mission management
Responsible (lead) Center	Goddard Space Flight Center
Mission objectives[203]	• Provide data continuity with Landsats 4 and 5 • Offer 16-day repetitive Earth coverage • Build and periodically refresh a global archive of sunlit, substantially cloud-free, land images • Make data widely available for the cost of fulfilling a user request • Support government, international, and commercial communities • Play a vital role in NASA’s Earth Observing System by promoting interdisciplinary research via synergism with other EOS observations (in particular, orbit in tandem with EOS-AM-1 for near-coincident observations)
Orbit characteristics[204]	
Apogee	438 mi (705 km)
Perigee	438 mi (705 km)
Inclination (deg)	98
Period (min)	99
Weight	4,800 lb (2,200 kg) at launch
Dimensions	1.4 ft (4.3 m) long × 9 ft (2.8 m) in diameter
Power source	Solar array and battery
Instruments	ETM+: An eight-band multispectral scanning radiometer providing high-resolution imaging information of Earth’s surface. Detects spectrally filtered radiation at visible, near-infrared, shortwave, and thermal infrared frequency bands from the sunlit Earth.[205]
Prime contractor	Lockheed Martin

[203] *Landsat 7 Science Data Users Handbook*, chapter 1—Landsat 7 Program, *http://ltpwww.gsfc.nasa.gov/IAS/handbook/handbook_htmls/chapter1/chapter1.html* (accessed March 14, 2006).
[204] “Landsat 7 Press Kit,” April 1999, NASA, USGS, p. 27, *http://landsat.gsfc.nasa.gov/announcements/landsat7.pdf* (accessed February 16, 2006). Also *Landsat 7 Science Data Users Handbook*, chapter 5—Orbit and Coverage, *http://ltpwww.gsfc.nasa.gov/IAS/handbook/handbook_htmls/chapter5/chapter5.html* (accessed March 14, 2006).
[205] “Landsat 7 Press Kit,” April 1999, NASA, USGS, p. 25, *http://landsat.gsfc.nasa.gov/announcements/landsat7.pdf* (accessed February 16, 2006).

Table 2-66. Landsat 7 Science Teams

Team Member	Research Focus	Affiliation
Robert Bindschalder	Enhanced Antarctic research with Landsat: ice-sheet dynamics, history, and cartography	Goddard Space Flight Center, Greenbelt, MD
Robert F. Cahalan	Clear sky and cloud characterization and correction for Landsat	Goddard Space Flight Center, Greenbelt, MD
Luke P. Flynn	Analysis of volcanic eruptions and fires using Landsat 7	Hawai'i Institute of Geophysics and Paleontology, University of Hawai'i, Manoa, HI
Alexander Goetz	Land and land-use change in the climate-sensitive high plains: an automated approach with Landsat	University of Colorado, Boulder, CO
Samuel N. Goward	Terrestrial monitoring at high spatial resolution: the role of Landsat-type sensors in MTPE	Department of Geography, University of Maryland, College Park, MD
Susan Moran	L TM and ETM+ data for resource monitoring and management	Water Conservation Laboratory, USDA
Frank Muller-Karger	Bottom assessment and water-constituent algorithms for the ETM in the coastal zone	Department of Marine Science, University of South Florida, Petersburg, FL
Frank D. Palluconi	Landsat 7: Calibration and atmospheric correction for thermal band 6	JPL, Pasadena, CA
John Price	Surface classification for MODIS, radiometric calibration, and project support	None listed
John R. Schott	Absolute calibration, atmospheric correction, and application of L ETM+ Thermal Infrared Data	Rochester Institute of Technology Center for Imaging Science, Rochester, NY
David L. Skole	Acquisition and analysis of large quantities of Landsat 7 data for measuring tropical land cover change	Michigan State University, East Lansing, MI
Kurtis J. Thome	Absolute radiometric calibration and atmospheric correction of Landsat 7 TM	University of Arizona, Tucson, AZ
James E. Vogelman	Characterization of Landsat 7 geometry and radiometry for land cover analysis	Hughes STX Corporation and USGS, EDC, Sioux Falls, SD
Curtis E. Woodcock	Changes in temperate in coniferous forest ecosystems	Department of Geography, Boston University, Boston, MA

Source: "Landsat 7 Press Kit," April 1999, NASA, USGS, pp. 31–32, *http://landsat.gsfc.nasa.gov/announcements/landsat7.pdf* (accessed February 16, 2006).

Table 2-67. LAGEOS II Characteristics

Launch date/launch site	October 22, 1992/Kennedy Space Center (KSC)
Launch vehicle	Space Shuttle *Columbia*, STS-52
NASA role	NASA launched LAGEOS II aboard the STS-52 mission and provided the Italian space agency (or Agenzia Spaziale Italiana [ASI]) with LAGEOS I drawings, specifications, handling fixtures, and other materials.[206]
Responsible (lead) Center	Goddard Space Flight Center
Mission objective[207]	Use laser ranging to: • Provide long-term datasets to monitor the motion of Earth's tectonic plates • Measure Earth's gravitational field • Measure the "wobble" in Earth's axis of rotation • Better determine the length of an Earth day
Orbit characteristics[208]	
Apogee	5,950 km (3,697 mi)
Perigee	5,616 km (3,490 mi)
Inclination (deg)	52.6
Period (min)	223
Weight	405 kg[209] (893 lb)
Dimensions	0.6-m (2-ft)-diameter sphere
Power source	None
Instruments and experiments	Satellite Laser Ranging (SLR): Ground-based lasers transmitted intense, short pulses of light to retroreflector-equipped satellites, such as LAGEOS II. The retroreflectors on the surface of LAGEOS II were three-dimensional prisms reflecting light (in this case a laser beam) back to its source. By recording the round-trip travel time required for the pulse to be transmitted to the satellite and return to Earth, scientists could determine the location of the laser station on Earth's surface. Using this information, they could accurately determine the distance between the stations. Thus, the relative distances between the locations, and hence their changes over time, could be determined. This enabled scientists to study the motion of Earth's crust between various points on Earth's surface.[210]
Prime contractor	Alenia Spazio for ASI.

[206] "NASA Facts Online: LAGEOS: A Tool for Understanding Our Constantly Changing Earth," *http://www.gsfc.nasa.gov/gsfc/service/gallery/fact_sheets/spacesci/lageos.htm* (accessed January 12, 2006).
[207] "40+ Years of Earth Science: Laser Geodynamics Satellite—2," *http://www.earth.nasa.gov/history/lageos/lageos2.html* (accessed January 12, 2006).
[208] "40+ Years of Earth Science: Laser Geodynamics Satellite—2," *http://www.earth.nasa.gov/history/lageos/lageos2.html* (accessed January 12, 2006). Also "LAGEOS-1, 2 Mission Objectives," *http://ilrs.gsfc.nasa.gov/satellite_missions/list_of_satellites/lageos.html* (accessed January 12, 2006).
[209] "NASA Facts Online: LAGEOS: A Tool for Understanding Our Constantly Changing Earth," *http://www.gsfc.nasa.gov/gsfc/service/gallery/fact_sheets/spacesci/lageos.htm* (accessed January 12, 2006).
[210] "NASA Facts Online: LAGEOS: A Tool for Understanding Our Constantly Changing Earth," *http://www.gsfc.nasa.gov/gsfc/service/gallery/fact_sheets/spacesci/lageos.htm* (accessed January 12, 2006).

Table 2-68. LAGEOS II Investigations

PI	Investigation	Affiliation
NASA Investigations:		
Crustal Deformation		
Erik R. Ivins	Lateral Earth Structure and Tidal Seismology	JPL, Pasadena, CA
Leigh H. Royden	Proposal for the Study of Rates and Geometries of Deformation in an Active Back-Arc Extensional Regime: Northern and Western Greece	Massachusetts Institute of Technology, Cambridge, MA
M. Nafi Toksoz	Investigation of Ongoing Continental Collision and its Tectonic Consequences in the Eastern Mediterranean: Global Positioning System (GPS) Densification of the SLR Network in Turkey	Massachusetts Institute of Technology, Cambridge, MA
Earth Dynamics		
Dennis D. McCarthy	Study of the Use of SLR in the Routine Rapid Determination of Earth Orientation Parameters and Predictions	U.S. Naval Observatory
Richard D. Rosen	Dynamic Interactions Within the Earth-Ocean-Atmosphere System and Variations in Earth Orientation	Atmospheric and Environmental Research, Inc.
David E. Smith	Geodynamics from Laser Ranging	Goddard Space Flight Center, Greenbelt, MD
David A. Yuen	Geophysical and Geodynamical Investigations Based on LAGEOS II Satellite Data	Department of Geology and Geophysics, University of Minnesota, Minneapolis, MN
Gravity		
Jean O. Dickey	Temporal Variations of the Geopotential	JPL, Pasadena, CA
Orbit Determination		
Peter L. Bender	Regional Translocation Analysis: Comparison of LAGEOS II and LAGEOS I Results	Quantum Physics Division, National Bureau of Standards, Gaithersburg, MD
Chreston F. Martin	Proposal for Analysis of Relativistic Effects and the Anomalous Alongtrack Acceleration on the LAGEOS Satellites	EG&G Washington Analytical Services Center, Inc., Rockville, MD
George Rosborough	Sequential Estimation of Regional Station Positions for High Temporal Resolution	Colorado Center for Astrodynamics Research, University of Colorado, Boulder, CO
Byron D. Tapley	Determination of Crustal Motions Using Satellite Laser Ranging to LAGEOS II and LAGEOS I	Center for Space Research, Department of Aerospace Engineering and Engineering

PI	Investigation	Affiliation
		Mechanics, University of Texas at Austin, Austin, TX
Agenzia Spaziale Italiana Investigations:		
Crustal Deformation		
Alessandro Caporali	Determination and Analysis of Time Series of European Baselines and Earth Rotation Parameters Using LAGEOS I and LAGEOS II Data	Department of Physics, University of Bari, Italy
Enzo Mantovani	Identification of Major Constraints for Plate Kinematics in the Mediterranean Area from Geological and Geodetic Data	Department of Earth Sciences, University of Siena, Italy
Fernando Sanso	Local Satellite Geodesy by Short-Arc Processing of Laser Ranging Data	Institute of Topography, Photogrammetry, and Geolophysics, Politecnico di Milano, Italy
Gerhard Soltau	Earth Orientation and the Terrestrial Coordinate Reference	Institut für Angewandte Geodasie, Germany
George Weber	Tectonic Plate Motion and the Terrestrial Coordinate Reference	Institut für Angewandte Geodasie, Germany
Susanna Zerbini	Modeling Tectonic Motions and Deformation in the Central-Eastern Mediterranean Basin	Department of Physics, University of Bologna, Italy
Earth Dynamics		
Anny Cazenave	Global Geodynamics with LAGEOS II	Groupe de Recherches de Géodesie Spatiale (GRGS), Centre National d'Études Spatiales (CNES), France
Istvan Fejes	Scope and Perspective of Combined Satellite Laser Ranging and Space VLBI Data Applications	FOMI Satellite Geodetic Observatory, Hungary
J. Hinderer	Earth Rotation: Excitation Struction and Induced Gravimetric Effects	Institut de Physique du Globe, France
Jochem Zschau	Model Improvements for Earth Tides, Ocean and Atmospheric Loading Effects	Instuit für Geophysik, Neue Universitat, Germany
Orbit Determination		
Wolfgang Schluter	Studies to Improve the Effectiveness of Satellite Laser Ranging	Institut für Angewandte Geodasie, Germany
Karel F. Wakker	LAGEOS I and LAGEOS II Data Analysis and Interpretation	Faculty of Aerospace Engineering, Delft University of Technology, the Netherlands

Source: "LAGEOS II/IRIS Prelaunch Mission Operations Report," Office of Space Science and Applications, Report No. S-465-92-52-01, pp. 10–12, NASA History Division folder 6081, Historical Reference Collection, NASA Headquarters, Washington, DC.

Table 2-69. SAR Generalized Applications

General Application	Advantage
Tropical/coastal studies	Radar penetrates cloud, fog, and rain
Coastal/lakes studies	HH polarization (horizontal transmit, horizontal receive) best for land/water discrimination
Discerning human-made features	Features strongly reflect radar energy
Assessing soil and vegetation moisture content	The amount of SAR backscatter is related to this
Disaster studies (volcanic eruptions, dust storms, flooding)	Radar penetrates dust and clouds
Remote area studies	Global coverage
Geology	Structural studies, exploration
Land use (including agriculture and forestry)	Mapping and change assessment

Source: "RADARSAT," Australian Government, Geoscience Australia, *http://www.ga.gov.au/acres/prod_ser/radadata.jsp* (accessed May 23, 2007).

Table 2-70. RADARSAT-1 Characteristics

Launch date/launch site	November 4, 1995/Vandenberg Air Force Base
Launch vehicle	Delta II
NASA role	Launch site and launch vehicle in exchange for RADARSAT-1 data
Responsible (lead) Center	JPL
Mission objectives[211]	To provide detailed information on sea ice and terrestrial ice sheets for climate research; produce radar imagery for geographical applications in oceanography, agriculture, forestry, hydrology, and geology; and provide real-time products for Arctic Ocean navigation, including ice surveillance. Mission also designed to provide data products for commercial applications such as fishing, shipping, oil exploration, offshore oil drilling, and resource management.
Orbit characteristics[212]	
Apogee	821 km (510 mi)
Perigee	793 km (493 mi)
Inclination (deg)	98.6
Period (min)	100.7
Weight	2,750 kg[213] (6,062 lb)
Dimensions	1.2-m (3.9-ft) cube, antenna 1.5 m × 1.5 m[214] (4.9 ft × 4.9 ft)
Power source	Solar array, three NiCd batteries[215]
Instruments and experiments	SAR PI: E. J. Langham, CSA, RADARSAT Project Office, Ottawa, Canada[216] SAR Analysis Team PI: Ronald Kwok, JPL, Pasadena, CA[217] Transmitted and received signals to capture (through clouds, haze, smoke, and darkness) high-quality images of Earth in all kinds of weather, day or night. This provided significant advantages for viewing Earth under conditions that precluded observation by aircraft or optical satellites.[218] Antarctic Mapping Project PI: Kenneth C. Jezek, Byrd Polar Research Center, Ohio State University, Columbus, OH[219]

[211] "NSSDC Master Catalog Display: Spacecraft—Radarsat 1," *http://nssdc.gsfc.nasa.gov/database/MasterCatalog?sc=1995-059A* (accessed February 13, 2006).
[212] "CSA—RADARSAT-1: Components and Specifications," *http://radarsat.space.gc.ca/asc/eng/satellites/radarsat1/components.asp* (accessed February 13, 2006).
[213] "CSA—RADARSAT-1: Components and Specifications."
[214] "Radarsat Quicklook," JPL Mission and Spacecraft Library, *http://msl.jpl.nasa.gov/QuickLooks/radarsatQL.html* (accessed February 13, 2006).
[215] "CSA—RADARSAT-1: Components and Specifications."
[216] "NSSDC Master Catalog Display: Experiment Personnel, Synthetic Aperture Radar," *http://nssdc.gsfc.nasa.gov/nmc/tmp/1995-059A-01-personnel.html* (accessed February 27, 2006).
[217] "EO DAAC Study: Ice and Sky," *http://eobglossary.gsfc.nasa.gov/Study/IceSky/* (accessed on February 13, 2006).
[218] "CSA—RADARSAT-1: Components and Specifications."
[219] "EO DAAC Study: RAMPing Up," *http://eobglossary.gsfc.nasa.gov/Study/RampingUp/* (accessed February 13, 2006).

Prime contractor	SPAR Aerospace

Table 2-71. ERBS Characteristics

Launch date/launch site	October 5, 1984/KSC
	Challenger, STS-41-G
NASA role	OSSA oversaw the ERBE program; Goddard was responsible for overall project management. Langley Research Center (LRC) had responsibility for the three instruments and science data reduction.[220]
Responsible (lead) Center	Goddard Space Flight Center
Mission objectives[221]	• Obtain the measurements required to determine Earth's radiation budget on several spatial and temporal scales • Use the ERBE scanner and nonscanner to derive the solar-absorbed radiation and emitted thermal radiation monthly on regional, zonal, and global scales • Use the SAGE II instrument to monitor the vertical global distribution of aerosols and gases in the stratosphere by measuring the attenuation (reduction in intensity) of the Sun's energy through Earth's atmosphere
Orbit characteristics[222]	
Apogee	650 km (404 mi)
Perigee	650 km (404 mi)
Inclination (deg)	57
Period (min)	96.8
Weight	2,250 kg[223] (4,960 lb)
Dimensions[224]	15 ft (4.6 m) wide, 12.5 ft (3.8 m) high, 5.2 ft (1.6 m) long
Power source	Two solar arrays, two NiCd batteries[225]
Instruments and experiments	SAGE II PI: M. Patrick McCormick, LRC Measured sunlight through the limb of Earth's atmosphere in seven spectral wavelengths (from 0.385 to 1.02 micrometers). The measured sunlight, which was scattered and absorbed by trace gases and aerosols, was converted into vertical profiles of ozone, water vapor, nitrogen dioxide, and aerosol concentrations. The instrument vertically scanned the limb of the atmosphere during spacecraft sunsets and sunrises (15 sunsets and 15 sunrises each day).[226] ERBE PI: Bruce Barkstrom, LRC

[220] "STS-41-G Press Kit," October 1984, pp. 17–18, *http://www.jsc.nasa.gov/history/shuttle_pk/pk/Flight_013_STS-41G_Press_Kit.pdf* (accessed March 20, 2006).
[221] "STS-41-G Press Kit," October 1984, pp. 17–18.
[222] "SAGE II Instrument," *http://www-sage2.larc.nasa.gov/instrument/* (accessed March 20, 2006).
[223] "Earth Radiation Budget Satellite Prelaunch Mission Operation Report," Report No. E-420-41-G-10, October 1, 1984, NASA History Division electronic record 30811, Historical Reference Collection, NASA Headquarters, Washington, DC.
[224] "STS-41-G Press Kit," October 1984, p. 17.
[225] "NSSDC Master Catalog Display: Spacecraft—ERBS," *http://nssdc.gsfc.nasa.gov/database/MasterCatalog?sc=1984-108B* (accessed February 27, 2006).
[226] "SAGE II: Understanding the Earth's Stratosphere," *http://www.nasa.gov/centers/langley/news/factsheets/SAGE.html* (accessed February 13, 2006).

	• ERBE scanner: a set of three co-planar detectors (longwave, shortwave, and total energy), all of which scanned from one limb of Earth to the other, across the satellite track (in its normal operational mode). • ERBE nonscanner: a set of five detectors: one measuring the total energy from the Sun, two measuring the shortwave and total energy from the entire Earth disk, and two measuring the shortwave and total energy from a medium-resolution area beneath the satellite.[227]
Prime contractor	Ball Aerospace

[227] "The Earth Radiation Budget Experiment (ERBE)," *http://asd-www.larc.nasa.gov/erbe/ASDerbe.html* (accessed February 13, 2006).

Table 2-72. Microlab-1/OrbView-1 Characteristics

Launch date/launch site	April 3, 1995/Vandenberg Air Force Base
Launch vehicle	Pegasus
NASA role	Instrument management; provided the OTD and the GPS Met instrument
Responsible (lead) Center	JPL
Mission objectives	To acquire affordable high-quality imagery of Earth for a variety of customers, including local governments, telecommunication companies, architects, civil engineers, real estate managers, farmers, and environmental monitoring agencies[228]
Orbit characteristics[229]	
Apogee	740 km (460 mi)
Perigee	740 km (460 mi)
Inclination (deg)	70
Period (min)	100
Weight	76 kg[230] (168 lb)
Dimensions	104 cm (41 in) in diameter × 49.5 cm (19 in) high (including spacecraft bus and payload compartment)[231]
Power source	Two solar panels
Instruments and experiments	GPS Met instrument PI: Randolph H. Ware, University Corporation for Atmospheric Research[232] Received and tracked the radio signals broadcast by 24 high-orbiting satellites of the U.S. military's GPS network; precisely measured the signals' increased travel time due to the effect of Earth's atmosphere and fluctuating signal strength to recover highly accurate profiles of atmospheric density, pressure, and temperature; contributed to a long-term observation program on how trace greenhouse gases may modify Earth's atmosphere and climate; and was used to study the amount of water vapor in the lower atmosphere.[233] Optical Transient Detector (OTD) PI: Hugh J. Christian, MSFC[234] Detected the full spectrum of lightning flashes, including cloud to

[228] "eoPortal director: Orbview-1," *http://directory.eoportal.org/pres_OrbView1.html* (accessed January 18, 2006).
[229] "Optical Transient Detector," Space Research & Observations, *http://thunder.nsstc.nasa.gov/otd/* (accessed February 28, 2006).
[230] "Orbital's Satellite Programs in Chronological Order," Orbital Space Systems Group (SSG), Orbital Sciences Inc., NASA History Division folder 011261, Historical Reference Collection, NASA Headquarters, Washington, DC.
[231] "MicroStar Satellite Platform Technical Specifications," *http://rsdo.gsfc.nasa.gov/rapidii/Specs/microstar.pdf* (accessed February 28, 2006). Personal conversation with Greg Smith, Chief, GSFC, Rapid Spacecraft Development Office, February 28, 2006.
[232] "GPS/MET Preliminary Report, July 1995," *http://www.cosmic.ucar.edu/gpsmet/over/septsumm_top.html* (accessed February 6, 2006).
[233] "JPL Instrument Will Measure Earth's Atmospheric Temperature, Jet Propulsion Laboratory," *Universe* 25, no. 7 (April 7, 1995): 1, *http://www.jpl.nasa.gov/releases/95/release_1995_9524.html* (accessed January 12, 2006).
[234] "Optical Transient Detector (Lightning Detector in Space)," *http://wwwghcc.msfc.nasa.gov/otd_old.html* (accessed January 12, 2006).

	ground, cloud to cloud, and intra-cloud lightning events. Aided scientists in determining the global distribution of lightning activity and thunderstorms and the characteristics of Earth's electric circuit.[235]
Prime contractor	ORBIMAGE

[235] "Optical Transient Detector (Lightning Detector in Space)."

Table 2-73. UARS Characteristics

Launch date/launch site	September 12, 1991/KSC
Launch vehicle	Space Shuttle *Discovery*, STS-48
NASA role	Performed mission management, furnished the MMS bus, designed the UARS ground station and data-handling facility, and participated in SOLSTICE, MLS, HALOE, and ACRIM development
Responsible (lead) Center	Goddard Space Flight Center
Mission objectives[236]	• To measure upper atmospheric dynamics; energy inputs; temperature; pressure; and key source, reservoir, and radical species concentrations on a global scale with accuracies close to or better than those defined as adequate in the UARS Science Working Group Final Report • To carry out these measurements during significant portions of two Northern Hemisphere winter seasons • To make these measurements during significant portions of the time period in which the Antarctic ozone hole is formed • To process UARS data to level 3 and make it available to the general scientific community according to the schedule defined by the UARS Policy for Data Use and Sharing[237] • To reveal and further understand the mechanisms controlling the structure and variability of the upper atmosphere, improve the predictability of ozone depletion, and define the role of the upper atmosphere in Earth's climate system
Orbit characteristics[238]	
Apogee	585 km (364 mi)
Perigee	585 km (364 mi)
Inclination (deg)	57
Period (min)	96
Weight	6,540 kg[239] (14,418 lb)
Dimensions	35 ft (10.7 m) long × 15 ft (4.6 m) in diameter[240]
Power source	One solar array and three 50 amp-hr batteries

[236] "Upper Atmosphere Research Satellite (UARS) Prelaunch Mission Operations Report," 7. Also "Upper Atmosphere Research Satellite (UARS)," NASA Facts Online, Goddard Space Flight Center, *http://www.gsfc.nasa.gov/gsfc/service/gallery/fact_sheets/earthsci/uars.htm* (accessed January 12, 2006).
[237] Level 3 data is smoothed and gridded geophysical data. Variables are mapped on uniform space-time grid scales, usually with some completeness and consistency. (Earth Science Data Terminology and Formats, *http://science.hq.nasa.gov/research/earth_science_formats.html* (accessed February 1, 2007).
[238] "UARS Science Highlights: A Summary of the Upper Atmosphere Research Satellite (UARS)," *http://uars.gsfc.nasa.gov/www_root/homepage/uars-science/science_highlights1.html* (accessed January 12, 2006). Also "UARS," NSSDC Master Catalog, *http://nssdc.gsfc.nasa.gov/nmc/tmp/1991-063B-traj.html* (accessed February 12, 2006).
[239] "UARS Post-Launch Mission Operation Report," Report 5-678-48-91-0, December 1994, p. 5.
[240] "SVS Science Story: The Upper Atmosphere Research Satellite (UARS)."

Instruments, Principal Investigators[241]	***Chemistry Studies*** Cryogenic Limb Array Etalon Spectrometer (CLAES) PI: Aidan E. Roache, Lockheed Palo Alto Research Laboratory Searched for spectra indicating the presence of certain chemicals. Determined concentrations and distributions by altitude of nitrogen and chlorine compounds, ozone, water vapor, and methane, all of which play a part in the chemistry of ozone depletion. Developed and operated by the Lockheed Martin Advanced Technology Center. Improved Stratospheric and Mesospheric Sounder (ISAMS) PI: Fred W. Taylor, University of Oxford, Department of Atmospheric Physics, Oxford, U.K. Studied atmospheric water vapor, carbon dioxide, nitrous oxide, nitric acid, ozone, methane, and carbon monoxide. Also detected infrared radiation from the atmosphere and used it to derive information on atmospheric temperature and composition. An instrument team based at Oxford University, U.K., built ISAMS. MLS PI: Joseph W. Waters, JPL Provided the first global dataset on chlorine monoxide, the key intermediate compound in the ozone destruction cycle. Generated three-dimensional maps of ozone distribution and detected water vapor in the microwave spectral range. Developed by JPL. HALOE PI: James M. Russell III, LRC Observed the vertical distribution of hydrofluoric acid, hydrochloric acid, methane, carbon dioxide, ozone, water vapor, and members of the nitrogen family. Observed 28 solar occultations (that is, it looked through Earth's atmosphere toward the Sun to measure the energy absorption of the Sun's rays by these gases). HALOE was a collaborative project conducted by LRC; the Max Planck Institute for Chemistry (Germany); the University of Chicago; the University of Michigan; the University of California, Irvine; NOAA/Environmental Research Laboratory; and Imperial College (U.K.). ***Dynamics*** HRDI PIs: Paul B. Hays and Wilbert R. Skinner, Space Physics Research Laboratory, University of Michigan, Ann Arbor, MI

[241] "40+ Years of Earth Science: Upper Atmosphere Research Satellite (UARS)," *http://www.earth.nasa.gov/history/uars/uars.html*. Also "Space Shuttle Mission STS-48 Press Kit," September 1991, 16, *http://www.jsc.nasa.gov/history/shuttle_pk/pk/Flight_043_STS-048_Press_Kit.pdf* (both accessed May 23, 2007). Also "HRDI/UARS: Personnel," *http://hrdi.engin.umich.edu/personnel.htm*; "CLAES Home Page," *http://www.spasci.com/CLAES/*; "Halogen Occultation Experiment (HALOE)," *http://haloedata.larc.nasa.gov/home/index.php*; "WINDII—The Wind Imaging Interferometer," *http://www.windii.yorku.ca/windii_e.html*; "SUSIM: An NRL Program to Measure Solar Ultraviolet Irradiance," *http://wwwsolar.nrl.navy.mil/susim.html*; "SOLSTICE," *http://lasp.colorado.edu/solstice/main.shtml*; "NASA UARS-PEM," *http://wwwpem.space.swri.edu/pem-science.html* (all accessed January 12, 2006).

	Measured Doppler shifts of atmospheric chemicals. Specifically measured atmospheric winds between 6.2 mi and 28 mi (10 km and 45 km) and above 34 mi (55 km). This data was important for understanding the role of atmospheric motion on the distribution of chemicals in the upper atmosphere. Sponsored by the University of Michigan Space Physics Research Laboratory. WINDII PI: Gordon G. Shepherd, York University, Ontario, Canada Used a Doppler-shift measurement technique to develop altitude profiles of horizontal winds in the upper atmosphere. The measurements provided information about the winds at and above 49 mi (79 km). WINDII was an international project sponsored by the CSA, the French Centre National d'Études Spatiales, and NASA. ***Energy Inputs*** SUSIM PI: Guenter E. Brueckner, Naval Research Laboratory, Washington, DC Measured solar ultraviolet energy, the most important spectral range in ozone chemistry. NASA sponsored the SUSIM program of the Solar Physics Branch in the Space Science Division at the Naval Research Laboratory. SOLSTICE PI: Gary J. Rottman, University of Colorado, Boulder, CO Conducted in-depth ultraviolet studies of the Sun. Compared the Sun's ultraviolet energy with the ultraviolet radiation of bright blue stars, providing a standard against which the solar energy level could be measured in future long-term monitoring of the Sun. SOLSTICE was a NASA project operated by the Laboratory for Atmospheric and Space Physics (LASP) at the University of Colorado. PEM PI: J. David Winningham, Southwest Research Institute, Boulder, CO Researched the effect of energetic particles from the Sun on the upper atmosphere, detecting and measuring the particles as they entered the atmosphere. PEM used four primary instrument subunits to take detailed particle measurements in different energy ranges: the Atmospheric X-Ray Imaging Spectrometer (AXIS), High Energy Particle Spectrometer (HEPS), Medium Energy Particle Spectrometer (MEPS), and Vector Magnetometer (VMAG). PEM was sponsored by the Southwest Research Institute. ACRIM II PI: Dr. Richard Willson, JPL Provided accurate monitoring of total solar activity for long-term climate studies. Though not a part of the UARS program, ACRIM II was added to UARS after the engineering team determined the spacecraft could fly a 10th instrument. ACRIM II was sponsored by JPL.
Prime contractor	GE Astro-Space Division

Table 2-74. ACRIM Characteristics

Launch date/launch site	December 20, 1999/Vandenberg Air Force Base
Launch vehicle	Pegasus
NASA role[242]	Mission management (GSFC). Managed instrument design, fabrication, and testing, as well as subcontract with Orbital Sciences (JPL)
Responsible (lead) Center	GSFC
Mission objectives[243]	• Continue the precision TSI database during solar cycle 23 for an EOS 5-year minimum mission • Determine its precise relationship to previous and successive experiments • Analyze TSI variability on all time scales with respect to their climatological and solar physics significance
Orbit characteristics[244]	
Apogee	425 mi (685 km)
Perigee	425 mi (685 km)
Inclination (deg)	98.13
Period (min)	99
Weight	AcrimSat: 253 lb (115 kg); ACRIM III instrument: 29 lb (13 kg)
Dimensions	AcrimSat: 30.5 in (77.5 cm) wide × 26 in (66 cm) high; total span with solar arrays deployed: 70 in (178 cm)
Power source	Solar arrays
Instrument	ACRIM: measured total solar irradiance precisely and continuously and solar energy in the far ultraviolet to far infrared wavelengths
Prime contractor	JPL

[242] "ACRIMSAT Mission Overview," *http://acrim.jpl.nasa.gov/mission.html* (accessed January 23, 2007).
[243] Richard C. Willson, "The ACRIMSAT/ACRIM III Experiment—Extending the Precision, Long-Term Total Solar Irradiance Climate Database," *The Earth Observer* 13, no. 3 (May/June 2001): 14, *http://www.acrim.com/Reference%20Files/Earth%20Observer_may_jun01.pdf* (accessed January 23, 2007).
[244] "AcrimSat Launch Press Kit," December 1999, pp. 6, 17, *http://www.jpl.nasa.gov/news/press_kits/acrimsat.pdf*. Also "ACRIMSAT Fact Sheet," *http://acrim.jpl.nasa.gov/missions/fact_sheet.html*; "ACRIMSAT," *http://science.hq.nasa.gov/missions/satellite_55.htm*; and *Aeronautics and Space Report of the President, Fiscal Year 2000 Activities* (Washington, DC: National Aeronautics and Space Administration, 2001), p. 100, *http://history.nasa.gov/presrep00/pdf_files/appndx_b.pdf* (all accessed January 23, 2007).

Table 2-75. AVIRIS Spectral Bands

Spectrometer	Wavelength, Micrometers	No. of Bands	Bandwidth, Nanometers
1	0.41–0.70	31	9.4
2	0.68–1.27	63	9.4
3	1.25–1.86	63	9.7
4	1.84–2.45	63	9.7

Source: “Airborne Visible and Infrared Imaging Spectrometer,” *http://www.nasa.gov/centers/dyden/research/AirSci/ER-2/aviris.html* (accessed January 23, 2007).

Table 2-76. TOMS Missions

	Nimbus-7 TOMS	**Meteor-3 TOMS**	**TOMS-EP**	**ADEOS TOMS**
Launch date/launch site	October 24, 1978/Vandenberg Air Force Base, CA	August 15, 1991/Plesetsk, Russia	July 2, 1996/Vandenberg Air Force Base, CA	August 17, 1996/Tanegashima Space Center, Japan
Launch vehicle	Delta 2910	Cyclone	Pegasus-XL	H-II
Data production	November 1, 1978–May 5, 1993	August 22, 1991–December 27, 1994	July 25, 1996–present	September 11, 1996–June 29, 1997
NASA role	NASA mission	Provided instrument	NASA mission	Provided instrument
Responsible (lead) Center	GSFC	GSFC	GSFC	GSFC
Mission objectives	To observe gases and particulates in the atmosphere to determine the feasibility of mapping sources, sinks, and dispersion mechanisms of atmospheric pollutants. To make baseline measurements of variations in longwave radiation fluxes outside the atmosphere and atmospheric constituents to determine the effect of these variations on Earth's climate.[245]	To continue monitoring global ozone levels by measuring the total ozone content in Earth's atmosphere.[246]	To measure total ozone by observing both incoming solar energy and backscattered ultraviolet radiation at six wavelengths.[247]	To provide daily global coverage of the sunlit portions of Earth by scanning perpendicular to the suborbital track and measuring backscattered ultraviolet radiation at six discrete wavelength channels.[248]
Orbit characteristics	Sun-synchronous, near polar	212-day precessing, near polar	Polar	Polar, Sun-synchronous

[245] "The Nimbus-7 Spacecraft System," *http://jwocky.gsfc.nasa.gov/n7toms/nimbus7tech.html* (accessed March 1, 2006).
[246] "Soviets To Launch NASA Instrument To Study Ozone Levels," *NASA News* Release 91-127, August 12, 1991, *ftp://ftp.hq.nasa.gov/pub/pao/pressrel/1991/91-127.txt* (accessed March 1, 2006).
[247] "Total Ozone Mapping Spectrometer/Earth Probe (TOMS/EP-94)," NASA Facts, Office of Mission to Planet Earth, February 1994.
[248] Arlin J. Krueger et al., "ADEOS Total Ozone Mapping Spectrometer (TOMS) Data Products User's Guide," p. 1, *http://jwocky.gsfc.nasa.gov/datainfo/adeos_userguide.pdf* (accessed March 2, 2006).

	Nimbus-7 TOMS	Meteor-3 TOMS	TOMS-EP	ADEOS TOMS
Apogee	955 km (593 mi)	1,202 km (747 mi)	515 km (320 mi)/740 km (460 mi)[249]	805 km[250] (500 mi)
Perigee	955 km (593 mi)	1,202 km (747 mi)	490 km (304 mi)/740 km (460 mi)	789 km (1,490 mi)
Inclination (deg)	99.1[251]	85.5	97.4/98.4[252]	98.6
Period (min)	104	109	96.6/99.65[253]	100.8
Weight	61.6 lb (28 kg)	61.6 lb (28 kg)[254]	34.3 kg (75.6 lb)	34.3 kg (75.6 lb)[255]
Dimensions	3.04 m (10 ft) high, 1.52 m (5 ft) in diameter at the base, 3.96 m (13 ft) wide with solar paddles fully extended[256]	26.4 in (66 cm) × 13.2 in (33 cm) × 19.6 in (49 cm)[257]	1.73 m (68 in) high × 1.11 m (43.76 in) in diameter[258]	1.73 m (68 in) high × 1.11 m (43.76 in) in diameter[259]
Power source	Solar panels and batteries	Solar panels and batteries	Solar panels and batteries	Solar panels and batteries
Prime contractor	Beckman Instruments, Inc.	Beckman Instruments, Inc.	Perkin Elmer	Orbital Sciences Corp.

[249] Satellite was boosted into higher orbit in December 1997 after the failure of ADEOS in June 1997. "Earth Probe Satellite Information," *http://toms.gsfc.nasa.gov/eptoms/epsat.html* (accessed January 10, 2006).
[250] "ADEOS TOMS Instrument and Satellite Information," Total Ozone Mapping Spectrometer, *http://jwocky.gsfc.nasa.gov/adeos/adsat.html* (accessed January 10, 2006).
[251] "The Nimbus-7 Spacecraft System," *http://jwocky.gsfc.nasa.gov/n7toms/nimbus7tech.html* (accessed March 1, 2006).
[252] Inclination for higher orbit flown beginning in December 1997 after the failure of ADEOS in June 1997.
[253] Period for higher orbit flown beginning in December 1997 after the failure of ADEOS in June 1997.
[254] "NASA Meteor-3/TOMS Press Kit," August 12, 1991, 5.
[255] The design of the ADEOS TOMS was identical to that of the TOMS-EP. "README for the Total Ozone Mapping Spectrometer (TOMS), Level 2 Orbital Data Set," *http://disc1.gsfc.nasa.gov/FTP_DATA/toms/README.TOMSL2* (accessed March 2, 2006).
[256] "The Nimbus-7 Spacecraft System."
[257] "NASA Meteor-3/TOMS Press Kit," August 12, 1991, p. 5, NASA History Division electronic record 33757, Historical Reference Collection, NASA Headquarters, Washington, DC.
[258] "Earth Probe TOMS (Total Ozone Mapping Spectrometer)," Ozone Processing Team—NASA/GSFC Code 613.3, *http://jwocky.gsfc.nasa.gov/eptoms/eptech2.html* (accessed March 1, 2006).
[259] The design of the ADEOS TOMS was identical to that of the TOMS-EP.

Table 2-77. TRMM Characteristics

Launch date/launch site	November 27, 1997/Tanegashima Space Canter, Japan
Launch vehicle	H-II
NASA role[260]	Mission management. Provided the observatory (fabricated by GSFC) and support systems, four instruments, integration and test of the observatory, and the science data processing system. Operated TRMM via the TDRSS. GSFC provided two of the four instruments. LRC and MSFC provided the other two.
Responsible (lead) Center	GSFC
Mission objectives[261]	Science objectives: • Obtain and study multiyear science datasets of tropical and subtropical rainfall measures • Research how interactions among the sea, air, and land masses produce changes in global rainfall and climate • Improve modeling of tropical rainfall processes and their influence on global circulation to predict rainfall and variability at various times • Test, evaluate, and improve satellite rainfall measurement techniques
Orbit characteristics[262]	
Apogee	351.8 km (218.6 mi)
Perigee	350.4 km (217.7 mi)
Inclination (deg)	35
Period (min)	92
Weight	7,290 lb[263] (3,307 kg)
Dimensions	5.1 m (16.8 ft) × 14.7 m (48.1 ft) × 4.2 m (13.8 ft)[264]
Power source	Gallium arsenide solar array/NiCd battery subsystem[265]
Instruments[266]	Visible Infrared Scanner (VIRS) PI: William L. Barnes, GSFC This scanning radiometer measured radiance in five bandwidths from the

[260] "TRMM Background," *http://tsdis.gsfc.nasa.gov/tsdis/tsdis_redesign/TRMMBackground.html* (accessed on January 12, 2006). Also "Tropical Rainfall Measuring Mission Set for October 31 Launch," *NASA News* Release 97-143, June 25, 1997, NASA History Division electronic record, Historical Reference Collection, NASA Headquarters, Washington, DC.
[261] "TRMM Background," *http://tsdis.gsfc.nasa.gov/tsdis/tsdis_redesign/TRMMBackground.html* (accessed January 12, 2006).
[262] "TRMM Injected into the Desired Orbit for Rainfall Measurement," NASDA Press Release 1997/12, December 9, 1997 (archived site), *http://warp.ndl.go.jp/REPOSWP/000000001418/00000000000005995/www.nasda.go.jp/press/1997/12/trmm_971209_e.html* (accessed May 23, 2007).
[263] "TRMM Background," *http://tsdis.gsfc.nasa.gov/tsdis/tsdis_redesign/TRMMBackground.html* (accessed January 12, 2006).
[264] E-mail from Clyde Woodall, Deputy Project Manager, EOS Project, Goddard Space Flight Center, March 1, 2006, based on the TRMM Mission Readiness Review Package, October 10, 1997, and H-II Launch Vehicle Interface Control Document drawings.
[265] "TRMM Instrument Overview," *http://tsdis.gsfc.nasa.gov/trmmrt/instov.htm* (accessed January 12, 2006).
[266] "TRMM Field Campaign Sounding Data Quality Control," *http://trmm.gsfc.nasa.gov/trmm_soundings/soundings.html* (accessed February 3, 2006). Also "NSSDC Master Catalog Display: Experiment List: TRMM," *http://nssdc.gsfc.nasa.gov/database/MasterCatalog?sc=1997-074A&ex=** (accessed February 3, 2006); "TRMM Background," *http://tsdis.gsfc.nasa.gov/tsdis/tsdis_redesign/TRMMBackground.html* (accessed January 12, 2006).

	visible through the IR spectral regions, similarly to the Advanced Very High Resolution Radiometer (AVHRR) on NOAA's operational polar-orbiting satellites. The VIRS had two thermal IR channels that permitted split-window techniques to be used to compute sea- and land-surface temperatures and to determine the atmospheric moisture content. VIRS provided 2-km (1.2-mi) resolution at nadir with a cross-track scan of 720 km (447 mi) and an instantaneous field of view (FOV) of 5.72 mrad. TRMM Microwave Imager (TMI) PI: Thomas T. Wilheit, Jr., GSFC This nine-channel passive microwave radiometer combined signals measured rainfall with greatest accuracy over oceans and lesser accuracy over land. It was similar to the Special Sensor Microwave/Imager (SSM/I) on the Defense Meteorological Satellite Program series of satellites. TMI provided better rain remote sensing than previous microwave instruments by adding a channel at 10 GHz, where the brightness temperatures were nearly linearly related to the rain rate. Precipitation Radar (PR) PI: K. Okamoto, National Space Development Agency (NASDA) (Japan) The PR determined the vertical distribution of precipitation by measuring the "radar reflectivity" of the cloud system and the weakening of a signal as it passed through the precipitation. When properly constrained by passive microwave measurements, the PR provided height profiles of precipitation content from which the profile of latent heat release could be obtained. The instrument was a single-frequency radar at 14 GHz. It had an instantaneous FOV of 5 km (3.1 mi) at nadir with a minimum vertical resolution of 250 m (820 ft). The instrument was able to detect rain rates of 0.5 mm per hour. Cloud and Earth Radiant Energy Sensor (CERES) PI: Bruce R. Barkstrom, LRC This visible/infrared sensor measured energy rising from the surface of Earth and the atmosphere, including its constituents. This flight-of-opportunity instrument was an EOS-era instrument that was flown before the launch of the EOS spacecraft. It measured the longwave channel in addition to a total-wavelength channel to measure the radiant fluxes. The total channel covered the spectral region from 0.3 to 50 microns with a radiometric accuracy of 0.5 percent; the shortwave channel covered the wavelength range from 0.3 to 5 microns with a radiometric accuracy of 1.0 percent; and the longwave channel covered the spectral region from 8 to 12 microns with a radiometric accuracy of 0.3 percent. It provided measurements at 10-km (6.2-mi) resolution at nadir. The instrument was similar to the ERBE scanner flown on the ERBS and NOAA polar-orbiting satellites. Lightning Imaging Sensor (LIS) PI: Hugh J. Christian, Jr., MSFC This optical telescope and filter imaging system investigated the distribution and variability of both atmospheric and cloud-to-ground lightning over Earth. This flight-of-opportunity instrument was an EOS-era instrument that was flown prior to the launch of the EOS spacecraft. It

	was a calibrated optical instrument designed to measure global lightning and its correlation with rainfall. LIS detected both intracloud and cloud-to-ground lightning at storm-scale resolution over Earth's surface. It used an expanded optics wide FOV lens combined with a narrow-band interference filter to focus the image on a small, high-speed, charge-coupled device focal plane. The signal was read from the focal plane into a real-time processor for event detection and data compression. Four methods were used to measure lightning: 1) a spatial filter matched the instantaneous FOV of each detector element in the LIS focal plane (about 10 km/6.2 mi), 2) spectral filtering was applied using a narrow-band interference filter centered on the optical emission line OI (1) at 777.4 nm in the lightning spectrum, 3) temporal filtering was applied to reduce the signal-to-noise ratio between the lightning event and the background, and 4) a modified frame-to-frame background subtraction removed the slowly varying background signal from the raw data from the LIS focal plane. The LIS provided 3.8-km (2.4-mi) × 3.8-km (2.4-mi) resolution at nadir.
Prime contractor	In-house NASA project

Table 2-78. NOAA Polar-Orbiting Satellite Instruments

Instrument/Mission	NOAA-12 (D)	NOAA-13 (I)	NOAA-14 (J)	NOAA-15 (K)
Advanced Very High Resolution Radiometer (AVHRR)	Five channels	Five channels	Five channels	AVHRR/3 (six channels)
TIROS Operational Vertical Sounder System (TOVS)	Three-instrument suite	Three-instrument suite	Three-instrument suite	No
High Resolution Infrared Radiation Sounder (HIRS)	HIRS/2I	HIRS/2I	HIRS/2I	HIRS/3 (not part of TOVS)
Stratospheric Sounding Unit (SSU)	No (carried a dummy SSU)	Yes	Yes	No
Microwave Sounding Unit (MSU)	Yes	Yes	Yes	No
Advanced Microwave Sounding Unit (AMSU)-A	No	No	No	Yes
AMSU-B	No	No	No	Yes
Solar Backscatter Ultraviolet Radiometer (SBUV)/2	Yes	Yes	Yes	No
Space Environment Monitor (SEM)	Yes	Yes	Yes	SEM/2
Data Collection System (DCS)	Yes	Yes	Yes	DCS/2
Search and Rescue Repeater (SARR)	No	Yes	Yes	Yes
Search and Rescue Processor (SARP)	No	Yes	Yes	Yes

Table 2-79. NOAA-12 (NOAA-D) Characteristics

Launch date/launch site	May 14, 1991/Vandenberg Air Force Base
Launch vehicle	Atlas-E
NASA role	Procuring and developing the spacecraft, instruments, and associated ground stations; launching the spacecraft; conducting on-orbit checkout of the spacecraft
Responsible (lead) Center	GSFC
Mission objectives[267]	To launch the spacecraft into a Sun-synchronous orbit of sufficient accuracy to enable it to accomplish its operational mission requirements, to conduct an in-orbit evaluation and checkout of the spacecraft, and, upon completion of this evaluation, to turn operational control of the spacecraft over to NOAA
Orbit characteristics	
Apogee	833 km (518 mi)
Perigee	833 km (518 mi)
Inclination (deg)	98.70
Period (min)	101.35
Weight	At liftoff: 1,418 kg (3,127 lb); on-orbit: 735 kg (1,620 lb)
Dimensions	Main body: 3.71 m (12.2 ft) long, 1.88 m (6.2 ft) in diameter; solar array: 2.37 m (7.8 ft) × 4.91 m (16.1 ft)
Power source	Solar arrays and batteries
Instruments[268]	AVHRR/2: A radiation-detection instrument that remotely determined cloud cover and surface temperature. It used five detectors that collected different bands of radiation wavelengths, allowing multispectral analysis to define hydrologic, oceanographic, and meteorological parameters more precisely. Provided by ITT. HIRS/2: Detected and measured energy emitted by the atmosphere to construct a vertical temperature profile from Earth's surface to an altitude of about 40 km (24.9 mi). Measurements were made in 20 spectral regions in the IR band (one frequency lay at the high end of the visible range). Provided by ITT. MSU: Detected and measured the energy from the troposphere to construct a vertical temperature profile to an altitude of about 10 km (6.2 mi). Measurements were made by radiometric detection of microwave energy divided into four frequency channels. Each measurement was made by comparing the incoming signal from the troposphere with the ambient temperature reference load. Since MSU data was not seriously affected by clouds, the MSU was used in conjunction with the HIRS/2 to remove measurement ambiguity when clouds were present. Provided by JPL. SEM: A multichannel charged-particle spectrometer that measured the population of Earth's radiation belts and the particle precipitation phenomena resulting from solar activity contributing to the

[267] "NOAA-D Prelaunch Mission Operation Report," Report No. E-615-91-01, May 1991.
[268] "NOAA-D," NASA Goddard Space Flight Center, pp. 5–10.

	solar/terrestrial energy interchange. Its objectives were to determine the energy deposited by solar particles in the upper atmosphere and provide a solar "warning system." It consisted of two separate sensor units and a common data-processing unit. The lower-energy total-energy detector (TED) and proton and electron telescopes of the medium-energy proton/electron detector (MEPED) had pairs of sensors with different orientations because the direction of the particle fluxes was important for characterizing the energy interchanges taking place. Provided by Loral/NOAA Space Environmental Laboratory. Argos DCS: Consisted of approximately 2,000 platforms (buoys, free-floating balloons, and remote weather stations) that measured temperature, pressure, and altitude and transmitted the data to the satellite. The on-board DCS received the signal, measured the frequency and relative time of occurrence of each transmission, and transmitted the data to the central processing facility. The DCS information was decommutated and sent to the CNES Argos processing center for processing, distribution, and archiving on magnetic tape. Provided by France.
Prime contractor	General Electric Astro Space Division[269]

[269] "NASA To Launch NOAA-D Meteorological Satellite," *NASA News* Release 91-72, May 9, 1991, *ftp://ftp.hq.nasa.gov/pub/pao/pressrel/1991/91-060.txt* (accessed February 22, 2006).

Table 2-80. NOAA-13 (NOAA-I) Characteristics

Launch date/launch site	August 9, 1993/Vandenberg Air Force Base
Launch vehicle	Atlas-E
NASA role	Procuring and developing the spacecraft, instruments, and associated ground stations; launching the spacecraft; conducting on-orbit checkout of the spacecraft
Responsible (lead) Center	GSFC
Mission objectives[270]	• To maintain a two-satellite system that meets NOAA/NESDIS operational environmental requirements of providing continuous observation of Earth and its atmosphere from Sun-synchronous orbit • To procure, develop, test, and launch an operational polar-orbiting satellite system that meets stated NOAA/NESDIS requirements • To continue research and development of low-Earth orbiting (LEO) satellite techniques as necessary to support NOAA/NESDIS
Orbit characteristics	
Apogee	870 km (541 mi)
Perigee	870 km (541 mi)
Inclination (deg)	98.86
Period (min)	102.12
Weight	At liftoff: 1,712 kg (3,775 lb); on-orbit: 1,030 kg (2,288 lb)
Dimensions	Main body: 4.18 m (13.7 ft) long, 1.88 m (6.2 ft) in diameter; solar array: 2.37 m (7.8 ft) × 4.91 m (16.1 ft)
Power source	Solar arrays and batteries
Instruments	SBUV/2: A spectrally scanning ultraviolet radiometer measuring solar irradiance and scene radiance over the spectral range of 160 to 400 nm. This instrument made measurements from which the total concentration of atmospheric ozone could be determined to an absolute accuracy of 1 percent and the vertical distribution of atmospheric ozone could be determined to an absolute accuracy of 5 percent. TOVS: Consisted of three instruments: the HIRS/2I, SSU, and MSU. All three instruments measured radiant energy from various altitudes of the atmosphere. The data was used to determine the atmosphere's temperature profile from Earth's surface to the upper stratosphere. SSU: Measured temperature in the upper stratosphere derived from radiance measurements made in three channels using a pressure-modulated gas (CO_2) to accomplish selective bandpass filtration of the sampled radiances. The gas was of a pressure chosen to yield weighting functions peaking in the altitude range of 25 km (15.5 mi) to 50 km (31 mi), where atmospheric pressure was 15.5 mbar to 1.5 mbar, respectively. The gas was contained in three cells, one of which was located in the optical path of each channel. Provided by Matra Marconi/U.K. Search-and-Rescue Instruments: Consisted of a three-band (121.5, 243, and 406.05 MHz) SARR and a 406.025-MHz SARM. The SARR was provided by Canada, and the SARM was provided by France. See the

[270] "POES Project Plan, NOAA-H, -I, and -J," p. 2-1.

	section on Search and Rescue later in this chapter for additional details. Argos DCS: Consisted of approximately 2,000 platforms (buoys, free-floating balloons, and remote weather stations) that collected and transmitted relevant data to the satellite. The on-board DCS received the incoming signal and measured the frequency and relative time of occurrence of each transmission. The spacecraft then transmitted the data to the central processing facility. The DCS information was decommutated and sent to the Argos processing center for processing, distribution, and archiving on magnetic tape. Provided by France. Energetic Heavy Ion Composition Experiment (EHIC): Designed to measure the chemical and isotopic composition of energetic particles between hydrogen and nickel over the energy range of 0.5 million electron volts (MeV)/nucleon to 200 MeV/nucleon. It was to measure trapped energetic particles in the magnetosphere and energetic solar flare particles in the polar regions, where Earth's magnetic field connected to the interplanetary field carried in the solar wind.[271] Provided by the University of Chicago and the Canadian National Research Council Herzberg Institute of Astrophysics. Magnetospheric Atmospheric X-Ray Imaging Experiment (MAXIE): Designed to map the intensities and energy spectra of x-rays produced by electrons precipitating into the atmosphere. It would use mechanical scanning to obtain new high-resolution x-ray imaging data on auroral and substorm processes with a temporal resolution and repetition rate that were previously unavailable. Provided by the Lockheed Missiles and Space Company Palo Alto Research Laboratory, Aerospace Corporation, and the University of Bergen, Norway.[272]
Prime contractor	Martin Marietta Astro Space[273]

[271] *Advanced TIROS-N (ATN), NOAA-I*, Goddard Space Flight Center, pp. 15–16. Also "Energetic Heavy Ion Composition (EHIC)," NSSDC Master Catalog, *http://nssdc.gsfc.nasa.gov/database/MasterCatalog?sc=1993-050A&ex=7* (accessed February 5, 2007).
[272] *Advanced TIROS-N (ATN), NOAA-I*, NASA Goddard Space Flight Center, pp. 15–16.
[273] "Investigation Panel Releases Report on NOAA-13 Failure," *NASA News* Release 94-157, September 20, 1994, *ftp://ftp.hq.nasa.gov/pub/pao/pressrel/1994/94-157.txt* (accessed February 23, 2006).

Table 2-81. NOAA-14 (NOAA-J) Characteristics

Launch date/launch site	December 30, 1994/Vandenberg Air Force Base
Launch vehicle	Atlas-E
NASA role	Procuring and developing the spacecraft, instruments, and associated ground stations; launching the spacecraft; conducting on-orbit checkout of the spacecraft
Responsible (lead) Center	GSFC
Mission objectives[274]	• To procure, develop, test, and launch an operational polar-orbiting satellite system that meets stated NOAA/NESDIS requirements • To maintain a two-satellite system that meets NOAA/NESDIS operational environmental requirements of providing continuous observation of Earth and its atmosphere from Sun-synchronous orbit • To continue the research and development of low-Earth orbiting satellite techniques as necessary to support NOAA/NESDIS
Orbit characteristics	
Apogee	870 km (541 mi)
Perigee	870 km (541 mi)
Inclination (deg)	98.86
Period (min)	102.12
Weight	At liftoff: 1,712 kg (3,775 lb); on-orbit: 1,030 kg (2,288 lb)
Dimensions	Main body: 4.18 m (13.7 ft) long, 1.88 m (6.2 ft) in diameter; solar array: 2.37 m (7.8 ft) × 4.91 m (16.1 ft)
Power source	Solar arrays and batteries
Instruments	SBUV/2: A spectrally scanning ultraviolet radiometer that measured solar irradiance and scene radiance over the spectral range of 160 to 400 nm. It made measurements from which total ozone concentration in the atmosphere could be determined to an absolute accuracy of 1 percent and the vertical distribution of atmospheric ozone could be determined to an absolute accuracy of 5 percent.
Prime contractor	Martin Marietta Astro Space[275]

[274] "POES Project Plan, NOAA-H, -I, and -J," p. 2-1.
[275] "December 4 Launch Planned for NOAA-J," *NASA News* Release 94-189, November 15, 1994, *ftp://ftp.hq.nasa.gov/pub/pao/pressrel/1994/94-189.txt* (accessed February 23, 2006).

Table 2-82. NOAA-15 (NOAA-K) Characteristics

Launch date/launch site	May 13, 1998/Vandenberg Air Force Base
Launch vehicle	Titan II
NASA role	Procuring and developing the spacecraft, instruments, and associated ground stations; launching the spacecraft; conducting on-orbit checkout of the spacecraft
Responsible (lead) Center	GSFC
Mission objectives	To procure, develop, test, and launch an operational polar-orbiting satellite system that will meet the observational requirements as specified by NOAA and to develop and integrate instrument sets for the Metop spacecraft[276]
Orbit characteristics	
Apogee	833 km (518 mi)
Perigee	833 km (518 mi)
Inclination (deg)	98.70
Period (min)	101.35
Weight	At liftoff: 2,232 kg (4,920 lb), including 756.7 kg (1,668.2 lb) of expendable fuel
Dimensions	Main body: 4.2 m (13.75 ft) long, 1.88 m (6.2 ft) in diameter; solar array: 2.73 m (8.96 ft) × 6.14 m (20.16 ft)
Power source	Solar arrays and batteries
Instruments	AVHRR/3: A six-channel imaging radiometer monitoring reflected energy in the visible and near-IR portions of the electromagnetic spectrum to observe vegetation, clouds, lakes, shorelines, snow, aerosols, and ice. It also determined the radiative energy from the temperature of the land, water, and sea surface, as well as the clouds above them. Provided by ITT. AMSU-A: Measured scene radiance in the microwave spectrum. Data from this instrument was used in conjunction with the HIRS to calculate global atmospheric temperature and humidity profiles from Earth's surface to the upper stratosphere, approximately 48 km (28 mi). The data was also used to provide precipitation and surface measurements including snow cover, sea ice concentration, and soil moisture. AMSU-A was divided into two physically separate modules, each of which operated and interfaced with the spacecraft independently. Module A-1 contained 13 channels, and Module A-2 contained two channels. Provided by Aerojet. AMSU-B: Calculated vertical water vapor profiles from Earth's surface to about 12 km (7.5 mi). It had five channels from 89 GHz to 183 GHz and completed one scan every 2.66 seconds. HIRS/3: An atmospheric sounding instrument that measured scene radiance in the IR spectrum. It had 1 visible channel, 7 shortwave IR channels, and 12 longwave IR channels. Data from the instrument was used in conjunction with the AMSU instruments to calculate the

[276] "Polar Operational Environmental Satellites (POES) Program Plan," GSFC-S-480-125, April 1999, NASA Goddard Space Flight Center.

	atmosphere's vertical temperature profile from Earth's surface to about 40 km (24.9 mi) altitude. The data was also used to determine ocean surface temperatures, total atmospheric ozone levels, precipitable water, cloud height and coverage, and surface radiance. The instrument completed one scan line every 6.4 seconds. Provided by ITT. SEM/2: Provided measurements to determine the intensity of Earth's radiation belts and flux of charged particles at satellite altitude. It provided information relating to solar-terrestrial phenomena and warned of solar wind occurrences that might impair long-range communication and high-altitude space operations, damage satellite circuits and solar panels, and cause changes in drag and magnetic torque on satellites. Consisted of two separate sensor units and a common data processing unit. The TED sensed and quantified the intensity of particles with energies ranging from 0.05 keV to 20 keV in the sequentially selected energy bands. The MEPED sensed protons, electrons, and ions with energies from 30 keV to levels exceeding 6.9 MeV. Provided by Panametrics via the NOAA Space Environment Center. Search-and-Rescue Instruments: Consisted of a three-band (121.5, 243, and 406.05 MHz) SARR and the 406.050-MHz SARP-2. The instruments were part of the international Cospas-Sarsat system designed to detect and locate emergency locator transmitters (ELTs), emergency position-indicating radio beacons (EPIRBs), and personal locator beacons (PLBs) operating at 121.5, 243, and 406 MHz. The SARR was provided by Canada; the SARP was provided by France. Similar instruments were carried by the Russian COSPAS polar-orbiting satellites. See the section on Search and Rescue later in this chapter for additional details. DCS: Consisted of platforms (buoys, free-floating balloons, and remote weather stations) that collected and transmitted relevant data to the satellite. The system measured environmental factors such as atmospheric temperature and pressure and velocity and direction of ocean and wind currents. The on-board DCS received the incoming signal and measured each transmission's frequency and relative time of occurrence, and the spacecraft transmitted this data to the ground once per orbit. Subsequently, the data was sent to the Centre National d'Études Spatiales in Toulouse, France, and the Service Argos Facility in Lanham, MD, for processing, distribution to users, and archiving. Provided by France.
Prime contractor	Martin Marietta Astro Space[277]

Source: "NOAA-K," National Aeronautics and Space Administration, National Oceanic and Atmospheric Administration, NASA Publication-1997-12-052-GSFC.

[277] "December 4 Launch Planned for NOAA-J," *NASA News* Release 94-189, November 15, 1994, *ftp://ftp.hq.nasa.gov/pub/pao/pressrel/1994/94-189.txt* (accessed February 23, 2006).

Table 2-83. GOES-8 (GOES-I) Mission Characteristics

Launch date/launch site	April 13, 1994/Cape Canaveral Air Force Station
Launch vehicle	Atlas I
NASA role[278]	• Procurement, development, and verification testing of the spacecraft, instruments, and unique ground equipment • Activities at the launch site Payload Processing Facility and satellite performance testing at the launch site before and after mating operations with the launch vehicle • Arranging for communications data lines and circuits during spacecraft launch simulations • Providing engineering support to NOAA during the design and development of the ground telemetry and command system • Mission phase leading to injection into geostationary orbit after deployment of the spacecraft from the launch vehicle and initial in-orbit satellite checkout and evaluation
Responsible (lead) Center	GSFC
Mission objectives[279]	• To maintain continuous service from a GOES system that meets the remote sensing requirements specified by NOAAM—that is, to provide for continuous observation of Earth and its atmosphere from a geosynchronous orbit • To continue the research and development of GOES techniques as appropriate to support NOAA
Orbit characteristics[280]	
Apogee	22,236 mi (35,786 km)
Perigee	22,236 mi (35,786 km)
Inclination (deg)	0.41
Period (min)	1,436
Weight	At liftoff: 2,105 kg (4,641 lb)
Dimensions	2.0 m (6.6 ft) × 2.1 m (6.9 ft) × 2.3 m (7.5 ft)
Power source	Solar array and two NiCd batteries
Instruments	Imager: This five-channel (one visible, four infrared) imaging radiometer simultaneously sensed radiant and solar reflected energy from sampled areas of Earth. By means of a servo-driven, two-axis gimbaled mirror scanning system along with a Cassegrain telescope, the Imager's multispectral channels alternately swept an 8-km (5-mi) north-to-south swath along an east-to-west and west-to-east path at a rate of 20 degrees (optical) east-to-west per second. This translated into being able to scan a 3,000 × 3,000 km (1,864 × 1,864 mi) "box" centered over the United States in 41 seconds.[281] The Imager was developed by ITT Aerospace/Communications Division.[282]

[278] "Execution Phase Project Plan for Geostationary Operational Environmental Satellites (GOES-I/M)," April 1993, NASA Goddard Space Flight Center, p. 1-2.
[279] "Execution Phase Project Plan for Geostationary Operational Environmental Satellites (GOES-I/M)," pp. 2-2–2-3.
[280] "NOAA's Geostationary and Polar-Orbiting Weather Satellites," *http://noaasis.noaa.gov/NOAASIS/ml/genlsatl.html* (accessed February 24, 2006).
[281] "GOES Imager Instrument," *http://noaasis.noaa.gov/NOAASIS/ml/imager.html* (accessed February 24, 2006).
[282] *GOES I-M Databook, Rev. 1*, Space Systems/Loral, DRL 101-08, August 31, 1996, p. 5.

	Sounder: This 19-channel radiometer probed the atmosphere and measured radiated energy at different depths (altitudes). It recorded surface and cloud-top temperatures and ozone distribution for emitted radiation in one visible band and 18 thermal bands that were sensitive to temperature, moisture, and ozone, as well as to reflected solar radiation. The Sounder looked at conditions in "columns" of the atmosphere—cylindrical sections extending from Earth's surface to the upper reaches of the atmosphere. The Sounder operated by means of a scan mirror that stepped across the disk of Earth in a west-to-east and east-to-west direction along a north-to-south path as a 28.2-cm (11.1-in) filter wheel rotated. Incoming radiation passed through a set of filters before reaching the detectors. The Sounder was developed by ITT Aerospace/Communications Division. SAR Transponder: The SAR system on board each GOES satellite consisted of a dedicated transponder that detected the presence of distress signals broadcast by ELTs carried on general aviation aircraft and by EPIRBs aboard some classes of marine vessels. Search and rescue was performed by relaying the distress signals emitted from the ELT/EPIRBs via the GOES satellite to a SARSAT ground station located within the FOV of the spacecraft. Through a Rescue Coordination Center (RCC), help was dispatched to the downed aircraft or ship in distress.[283] DCS: This system collected environmental data transmitted from more than 10,000 domestic and international data-collection platforms consisting of buoys and remote environmental monitoring stations. Each data-collection platform contained one or more sensors that gathered and transmitted the data at ultra high frequency to the GOES-East or -West spacecraft. To use the service, a data-collection platform had to be located within the footprint of a GOES. The data was used to develop analyses, warnings, and forecasts of environmental events such as tsunamis, tropical cyclones, floods, river stages, soil conditions, and snow depth.[284] WEFAX Data Relay System: The NASA Wallops ground station retransmitted images and meteorological analyses to users through the WEFAX service. Data originated from the National Weather Service and NOAA image processing facilities and was provided to users appropriately configured with ground receiving stations.[285] SEM: The SEM instruments consisted of a magnetometer, an x-ray sensor (XRS), a high energy proton and alpha detector (HEPAD), and an energetic particles sensor (EPS). All surveyed the Sun, measuring in situ its effect on the near-Earth solar-terrestrial electromagnetic environment and providing real-time data to the Space Environment Services Center (SESC). Changes in this "space weather" can affect the operational reliability of ionospheric radio; over-the-horizon radar; electric power transmission; and human crews of high-altitude aircraft, the Space Shuttle,

[283] *GOES I-M Databook, Rev. 1*, Space Systems/Loral, DRL 101-08, August 31, 1996, pp. 95–96.
[284] "Execution Phase Project Plan for Geostationary Operational Environmental Satellites (GOES-I/M)," p. 4-27.
[285] "Execution Phase Project Plan for Geostationary Operational Environmental Satellites (GOES-I/M)," p. 4-27.

	or a space station. The XRS, mounted on an x-ray positioning platform, monitored the Sun's total x-ray activity. The EPS and HEPAD detected energetic electron and proton radiation trapped by Earth's magnetic field as well as direct solar protons, alpha particles, and cosmic rays. Two redundant three-axis magnetometers mounted on a deployed 3-m (9.8-ft) boom operated one at a time to monitor Earth's geomagnetic field strength in the vicinity of the spacecraft and variations caused by ionospheric and magnetospheric current flows. Panametrics provided all the sensors except for the magnetometer, which was built by Schonstedt Instrument Company.[286]
Prime contractor	Space Systems/Loral

[286] *GOES I-M Databook, Rev. 1*, Space Systems/Loral, DRL 101-08, August 31, 1996, pp. iii, v, 6, 58,).

Table 2-84. GOES-9 (GOES-J) Mission Characteristics

Launch date/launch site	May 23, 1995/Cape Canaveral Air Force Station
Launch vehicle	Atlas I
NASA role[287]	• Procurement, development, and verification testing of the spacecraft, instruments, and unique ground equipment • Activities at the launch site Payload Processing Facility and satellite performance testing at the launch site before and after mating operations with the launch vehicle • Arranging for communications data lines and circuits during spacecraft launch simulations • Providing engineering support to NOAA during the design and development of the ground telemetry and command system • Mission phase leading to injection into geostationary orbit after deployment of the spacecraft from the launch vehicle and initial in-orbit satellite checkout and evaluation
Responsible (lead) Center	GSFC
Mission objectives[288]	• To maintain continuous service from a GOES system that meets the remote sensing requirements as specified by NOAA, that is, to provide for continuous observation of Earth and its atmosphere from a geosynchronous orbit • To continue the research and development of GOES techniques as appropriate to support NOAA
Orbit characteristics[289]	
Apogee	22,236 mi (35,786 km)
Perigee	22,236 mi (35,786 km)
Inclination (deg)	0.41
Period (min)	1,436
Weight	At liftoff: 2,105 kg (4,641 lb)
Dimensions	2.0 m (6.6 ft) × 2.1 m (6.9 ft) × 2.3 m (7.5 ft)
Power source	Solar array and two NiCd batteries
Instruments	Same as GOES-8
Prime contractor	Space Systems/Loral

[287] "Execution Phase Project Plan for Geostationary Operational Environmental Satellites (GOES-I/M)," p. 1-2.
[288] "Execution Phase Project Plan for Geostationary Operational Environmental Satellites (GOES-I/M)," pp. 2-2–2-3.
[289] "NOAA's Geostationary and Polar-Orbiting Weather Satellites," *http://noaasis.noaa.gov/NOAASIS/ml/genlsatl.html* (accessed February 24, 2006).

Table 2-85. GOES-10 (GOES-K) Characteristics

Launch date/launch site	April 25, 1997/Cape Canaveral Air Force Station
Launch vehicle	Atlas I
NASA role[290]	• Procurement, development, and verification testing of the spacecraft, instruments, and unique ground equipment • Activities at the launch site Payload Processing Facility and satellite performance testing at the launch site before and after mating operations with the launch vehicle • Arranging for communications data lines and circuits during spacecraft launch simulations • Providing engineering support to NOAA during the design and development of the ground telemetry and command system • Mission phase leading to injection into geostationary orbit after deployment of the spacecraft from the launch vehicle and initial in-orbit satellite checkout and evaluation
Responsible (lead) Center	GSFC
Mission objectives[291]	• To maintain continuous service from a GOES system that meets the remote sensing requirements as specified by NOAA, that is, to provide for continuous observation of Earth and its atmosphere from a geosynchronous orbit • To continue the research and development of GOES techniques as appropriate to support NOAA
Orbit characteristics[292]	
Apogee	22,236 mi (35,786 km)
Perigee	22,236 mi (35,786 km)
Inclination (deg)	0.41
Period (min)	1,436
Weight	At liftoff: 2,105 kg (4,641 lb)
Dimensions	2.0 m (6.6 ft) × 2.1 m (6.9 ft) × 2.3 m (7.5 ft)
Power source	Solar array and two NiCd batteries
Instruments	Same as GOES-8 and GOES-9
Prime contractor	Space Systems/Loral

[290] "Execution Phase Project Plan for Geostationary Operational Environmental Satellites (GOES-I/M)," p. 1-2.
[291] "Execution Phase Project Plan for Geostationary Operational Environmental Satellites (GOES-I/M)," pp. 2-2–2-3.
[292] "NOAA's Geostationary and Polar-Orbiting Weather Satellites," *http://noaasis.noaa.gov/NOAASIS/ml/genlsatl.html* (accessed February 24, 2006).

Table 2-86. TOPEX/Poseidon Characteristics

Launch date/launch site	August 10, 1992/Kourou, French Guiana
Launch vehicle	Ariane 42P
NASA's role	Supplied the dual-frequency radar altimeter, the laser retroreflector array, the TOPEX microwave radiometer, and the global positioning receiver
Responsible (lead) Center	JPL
Mission objectives[293]	To map ocean topography and circulation to better understand the oceans' role in regulating global climate change
Orbit characteristics[294]	
Apogee	1,336 km (830 mi)
Perigee	1,336 km (830 mi)
Inclination (deg)	66
Period (min)	112
Weight	2,402 kg[295] (5,295 lb)
Dimensions	2.8 m (9.2 ft) × 5.5 m (18 ft); solar panel 3.3 m (10.8 ft) × 8.7 m (28.5 ft)[296]
Power source	Single solar panel and three batteries
Instruments and experiments[297]	Dual-Frequency (C- and Ku-band) Radar Altimeter: This was the primary instrument. It measured wave and satellite-to-sea-surface heights, provided ionospheric corrections, and measured wind speed directly beneath the spacecraft. Provided by NASA. Single-Frequency (Ku-band) Solid-State Altimeter (SSALT): Was a low-power, low-mass sensor that measured the height of the satellite above the sea. Designed and built by ALCATEL-ESPACE for CNES. Laser Retroreflector Array (LRA): Was used to calibrate the other location systems (Doppler Orbitography and Radiopositioning Integrated by Satellite [DORIS] and Turbo Rogue Space Receiver [TRSR]) on the satellite with a very high degree of precision. By measuring the length of time a laser beam took to travel from Earth to the spacecraft and back, scientists could calculate TOPEX/Poseidon's orbital radial position. Designed and built by the Johns Hopkins University Applied Physics

[293] "Ocean Surface Topography from Space: MISSIONS—TOPEX/Poseidon Fact Sheet," *http://topex-www.jpl.nasa.gov/mission/tp-fact-sheet.html* (accessed January 12, 2006).
[294] "Ocean Surface Topography from Space: MISSIONS—TOPEX/Poseidon Fact Sheet." Also "TOPEX/Poseidon Mission Objectives," *http://ilrs.gsfc.nasa.gov/satellite_missions/list_of_satellites/topex/index.html* (accessed January 12, 2006).
[295] "Ocean Surface Topography from Space: MISSIONS—TOPEX/Poseidon Fact Sheet."
[296] "Current Missions—Topex/Poseidon," *http://www.jpl.nasa.gov/missions/current/topex.html* (accessed February 3, 2006).
[297] "Ocean Surface Topography from Space: Missions—TOPEX/Poseidon Fact Sheet." "Ocean Surface Topography from Space: Technology," *http://topex-www.jpl.nasa.gov/technology/technology.html*; "Ocean Surface Topography from Space: Technology—Instrument Description, Altimeter(s)," *http://topex-www.jpl.nasa.gov/technology/instrument-altimeter.html*; "Ocean Surface Topography from Space: Technology—Instrument Description, LRA—Laser Retroreflector Array," *http://topex-www.jpl.nasa.gov/technology/instrument-lra.html*; "Ocean Surface Topography from Space: Technology—Instrument Description, Radiometer," *http://topex-www.jpl.nasa.gov/technology/instrument-radiometer.html* (all accessed January 12, 2006). "Topex/Poseidon," NSSDC Master Catalog, *http://nssdc.gsfc.nasa.gov/database/MasterCatalog?sc=1992-052A* (accessed February 22, 2006).

	Laboratory for NASA. TOPEX Microwave Radiometer (TMR): Was a three-frequency sensor used to estimate the atmospheric water vapor content in the nadir column through which the altimeter signal travels. Radiometer data enabled researchers to determine how water vapor affects radar signal propagation. It was also used to study other atmospheric phenomena. Provided by NASA. GPS/TRSR: Supported precise, continuous orbit determination by the DORIS system by monitoring range and timing signals from up to six GPS spacecraft at the same time. Also helped improve gravity field models. Provided by NASA. DORIS Tracking System: Located the satellite on orbit in real time. Anchored by approximately 50 ground-based beacons, the DORIS receiver measured the Doppler shift of microwave signals to support precise orbit determination. Provided by CNES.
Prime contractor	Fairchild Space Company

Table 2-87. TOPEX/Poseidon Investigations

Investigation	Principal Investigator
Altimetry Analysis with Sea Floor Electric Data	P. Tarits, Institut de Physique du Globe Paris, France
The Antarctic Circumpolar Current	D. Chelton, Oregon State University, U.S.
Data Assimilation by Ocean Models	P. de Mey, Groupe de Recherches de Géodésie Spatiale, France
Equatorial and Eastern Boundary Currents	T. Strub, Oregon State University, U.S.
Geophysical Validation of Altimetry	Y. Menard, Groupe de Recherches de Géodésie Spatiale, France
Global Ocean Circulation	C. Wunsch, Massachusetts Institute of Technology, U.S.
Global Ocean Tides	C. Le Provost, Institut de Mécanique de Grenoble, France
Global Ocean Tides	B. Sanchez, Goddard Space Flight Center, U.S.
Gyres of the World Oceans	L-L. Fu, Jet Propulsion Laboratory, U.S.
Hem Balance of Global Oceans	T. Liu, Jet Propulsion Laboratory, U.S.
Marine Geodesy and Geophysics	J. Segawa, University of Tokyo, Japan
Marine Geophysics	A. Cazenave, Groupe de Recherches de Géodésie Spatiale, France
Marine Research	P. Woodworth, Proudman Oceanographic Laboratory, U.K.
Mean Sea Surface and Gravity	R. Rapp, Ohio State University, U.S.
Mesoscale and Basin-Scale Ocean Variability	J. Minster, Groupe de Recherches de Géodésie Spatiale, France
The Mid-Latitude Western Boundary Currents	J. Mitchell, Naval Oceanographic and Atmospheric Research Laboratory, U.S.
The Nordic Seas	L. Pettersson, University of Bergen, Norway
Ocean Circulation and the Geoid	C. Koblinsky, Goddard Space Flight Center, U.S.
Ocean Circulation Modeling	J. Schroeter, Alfred Wegener Institute for Polar and Marine Research, Germany
Ocean Dynamics and Geophysics	R. Cheney, NOAA/National Geodetic Survey, U.S.
Ocean Surface Topography	B. Tapley, University of Texas at Austin, Austin, TX, U.S.
Oceanic Effects on Earth's Interior	J. Wahr, University of Colorado, Boulder, CO, U.S.
The Oceans Around South Africa	M. Grundlingh, National Research Institute for Oceanography, South Africa
Orbit Computation and Sea-Surface Modeling	K. Wakker, Delft University of Technology, the Netherlands
Plate Motions	A. Souriau, Groupe de Recherches de Géodésie Spatiale, France
The South Atlantic Ocean	M. Ollitrault, Institut Français de Recherche pour l'Exploration de la Mer, France
The South Pacific, Southern, and Indian Oceans	J. Church, Commonwealth Scientific and Industrial Research Organisation, Australia
Terrestrial Reference Systems	C. Boucher, Institut Géographique National, France

Investigation	Principal Investigator
The Pacific Ocean	C. K. Tai, NOAA/National Geodetic Survey, U.S.
Tropical Atlantic Ocean	E. Katz, Columbia University, New York, NY, U.S.
The Tropical Atlantic Ocean	S. Amault, University of Paris VI, France
Tropical Ocean Dynamics	R. Lukas, University of Hawai'i, U.S.
The Tropical Pacific Ocean	J. Picaut, Groupe SURTROPAC, ORSTOM, New Caledonia
Weakly Defined Ocean Gyres	G. Born, University of Colorado, Boulder, CO, U.S.
Western Equatorial Atlantic Ocean	Y. Desaubies, Institut Français de Recherche pour l'Exploration de la Mer, France
The Western Mediterranean Sea	F. Barlier, Groupe de Recherches de Géodésie Spatiale, France
The Western North Pacific Ocean	S. Imawaki, Kyushu University, Japan
The Yorth-Australian Tropical Seas	D. Burrage, Australian Institute of Marine Sciences, Australia

Source: All Principal Investigator information: Lee-Lueng Fu, Edward Christensen, Charles Yamarone, Jr., "TOPEX/Poseidon Mission Overview," Jet Propulsion Laboratory, pp. 37–38, *http://trs-new.jpl.nasa.gov/dspace/bitstream/2014/34628/1/94-0983.pdf* (accessed February 3, 2006).

Table 2-88. NASA Scatterometer Characteristics

Launch date/launch site	August 16, 1996/Tanegashima Space Center, Japan
Launch vehicle	H-II on ADEOS spacecraft
Mission objectives[298]	• Acquire all-weather high-resolution measurements of near-surface winds over the global oceans • Determine atmospheric influences, ocean response, and air–sea interactions on various spatial and temporal scales • Develop improved methods of assimilating wind data into numerical weather and wave prediction models • Combine wind data with measurements from various scientific disciplines to understand processes of global climatic change and weather
NASA role	Provided scatterometer
Responsible (lead) Center	JPL
Orbit characteristics[299]	
Apogee	805 km (500 mi)
Perigee	789 km (490 mi)
Inclination (deg.)	98.6
Period (min.)	100.8
Lead NASA Center	JPL
Weight	280 kg (1,617 lb)
Dimensions	With solar array paddle and NSCAT antenna deployed: 11 m (36 ft) high; with solar array extended: 29 m (95 ft)
Power source	Solar array
Prime contractor	Jet Propulsion Laboratory

[298] "Missions—NSCAT, Winds—Measuring Ocean Winds from Space," *http://winds.jpl.nasa.gov/missions/nscat/index.cfm* (accessed March 2, 2006).
[299] "ADEOS TOMS Instrument and Satellite Information," Total Ozone Mapping Spectrometer, *http://jwocky.gsfc.nasa.gov/adeos/adsat.html* (accessed January 10, 2006).

Table 2-89. ACTS Experiments (1993–2000)

Investigation	Principal Investigator
ACTS Adaptive Rain Fade Compensation	Thom A. Coney, NASA Glenn Research Center
ACTS and Supercomputing in Remote, Cooperative Medical Triage Support and Radiation Treatment Planning	David Y. Y. Yun, University of Hawai'i
ACTS Autotrack Control Performance Experiment	Roberto Acosta, Glenn Research Center (GRC)
ACTS Demonstrations	Various investigators for NASA and other organizations
ACTS Fade Compensation Algorithm Characterization in I/O	Roberto Acosta, GRC
ACTS Mobile Terminal on a Guided Missile Cruiser (AMT/CG)	Roy Askew, Naval Research and Development (NRaD)
ACTS Multibeam Antenna Performance Verification Experiment	Roberto Acosta, GRC
ACTS Propagation Experiments in Alaska	Charles Mayer, University of Alaska, Fairbanks
ACTS Propagation Measurements	A. Karahisar, Teleglobe Canada
ACTS Propagation Measurements Program	Louis Ippolito, Stanford Telecommunications
ACTS Propagation Project	Bruce Dow, University of British Columbia
ACTS Propagation Studies	Robert M. Manning, GRC
ACTS Triangulation Experiment	Tina Cox, GRC/Analex Corporation
ACTS Unmanned Ground Vehicle (UGV) Experiment/Demonstration	Charles Shoemaker, ARPA/JPL
ACTS Uplink Transmit Power Control Measurement Experiment	Asoka Dissanayake, COMSAT Laboratories
ACTS Wide Area Diversity Experiment	Asoka Dissanayake, COMSAT Laboratories
ACTS/AMT Telemedical Experiment	Stephen J. Carter, University of Washington
Advanced Air Transportation Technology (AATT)	Konstantinos Martzaklis, GRC
Advanced Applications to Validate ACTS Technologies	David Y. Y. Un, PACSPACE
Aeronautical Tracking and High Data Rate Experiment	Robert Sternowski, Rockwell International
Aero-X Experiment Plan	Ernie Spisz, GRC
Antenna Characterization Using ACTS	George O'Brien, Lockheed Martin Western Development Laboratories
Application of NASA ACTS System to the Group Practice: A Paradigm for Clinical Outreach Programs	Bijoy Khandheria, Mayo Clinic Foundation
Application of the NASA ACTS System to the Practice of Medicine in an Integrated Group Practice	R. R. Hattery, Mayo Clinic Foundation
Applications of Small Earth Stations in Conducting Telescience and Telemedicine	Gerald R. Taylor, Krug Life Sciences

Investigation	Principal Investigator
Architecture and Protocols Testing	Ben Bennington, Carnegie Mellon University
Army ACTS Experiments	Peter Cafaro, U.S. Army Space Command
ATM/TCP Interaction	Mark Allman, GRC
Coding Gain Evaluation	Kerry D. Lee, Motorola Inc., Strategic Electronics Division
Communications Link Performance	Roberto Acosta, GRC
Comparative Demo of Interactive Multimedia Services at Ku/Ka-band	Mohammed E. Ouid Yahya, INTELSAT
CO-OP 3D: NCAR (National Center for Atmospheric Research) Participation in the DARPA-NASA ACTS Project	William Kuo, National Center for Atmospheric Research
Demonstration of Advanced Networking Concepts	Asoka Dissanayake, COMSAT/INTELSAT
Depolarization–Propagation in Inclined Orbit	Roberto Acosta, GRC
Digital Imaging and Communications in Medicine	Robert Kerczewski, GRC
Disaster Recovery, Backup and Communications Augmentation Experiment Using ACTS	Don Flournoy, Ohio University/Huntington Banks
Distance Learning in Hazardous Materials and Environment Safety	Sherry Randolph, Lockheed Space Operations/KSC
Distributed Global Climate Modeling	Larry Bergman, NASA High Performance Computing and Communications (HPCC)
Emergency Medical Land Mobile Satellite Experiment	Bruce P. Jackson, EMSAT
Encryption and Error Correction Using Random Time Smearing Applications to Mobile and Personal Satcom	Kent Penwarden, Globalstar
Experiment Plan for 622 Mbps Network Tests Between ATDNeT and MAGIC via ACTS	Michael Zernic, GRC
Experimentation with Satellite-Based Personal Communications Services (PCS)	Richard Wolff, Bellcore
Experiments and Field Trials Using the ACTS	Irene Triantafallou, AT&T Bell Labs
Frame Relay Experiment over ACTS: LAN Interconnection Services	Timothy Kirkwood, Maryland CCDS
Georgetown Hemispheric Intercultural Network for Knowledge (G-THINK)	Harold C. Bradley, Georgetown University
HBR SMSK Interference Experiment (INTEX)	Robert Kerczewski, GRC
High Performance TCP/IP Investigations: The Foundation for Internet in Space Implementation	Michael Zernic, GRC
High Speed Data Traffic Measurements Over the ACTS HDR System	Steve Mainger, GRC/Bellcore
High Speed Global Satellite Experiment for Remote HDTV Post-Production	Frank Gargione, Lockheed Martin Aerospace

Investigation	Principal Investigator
Inclined Orbit Link Performance Evaluation	Roberto Acosta, GRC
Integrated Services Digital Network (ISDN) via Satellite	Jay Gowens, Army Research Laboratory (ARL)
Internet Protocol Performance and Coding Effects	Hans Kruse, Ohio University/GRC
ISDN Experiment	Moorthy Hariharan, COMSAT Labs
Isolated User Access	Frank Dixon, National Communications System
Joint Advanced Comm Tech Satellite/Student Satellite Testbed	Alex Bordetsky, California State University–Hayward
Ka-Band Ground Experiment	Kenneth L. Perko, GSFC
Ka-Band Ground Experiment Proposal	Richard Reinhart, GRC/Analex Corporation
Ka-Band Product Validation	Jared Smith, Raytheon Telecommunications
Ka-band Propagation Effects on Communication Link Performance	Roberto Acosta, GRC
Ka-Band Propagation Measurements Experiment Using ACTS Spacecraft	Asoka Dissanayake, COMSAT Laboratories
Ka-Band Propagation Studies Using ACTS Propagation Terminal and the CSU-CHILL Multiparameter Doppler Radar	V. N. Bringi, Colorado State University
Keck Telescope Data Acquisition, Visualization, and Control	Larry Bergman, HPCC
Land Mobile Satellite Measurements in Central Maryland & Alaska Using ACTS: Passive Antenna Tracking System & Mobile Receiver System	Julius Goldhirsh/Wolfhard Vogel, Johns Hopkins University/University of Texas
LBR Transmit Window Characterization	Kerry D. Lee, Motorola Inc., Strategic Electronics Division
Lifelink	Sterling Kinkler, Southwest Research Institute (SWRI)
Live from Antarctica 2	Ann Devereaux, JPL
Live from the Rain Forest	Geoffrey Hines Stiles, GRC/Passport to Knowledge (PTK)
Low Cost SCADA Network	R. A. Fernandes, Southern California Edison
MMIC (Monolithic Microwave Integrated Circuit) Arrays for Satellite Comm-on-the-Move (MASCOM)	Konstantinos S. Martzaklis, GRC/Army
Mobile Experiments	Tom Jedrey, JPL
Narrowband ISDN Applications Using ACTS	Haniph A. Latchman, University of Florida
No title given (Product Service Enhancement Through Advanced SatComm)	Saliba Shanine, Caterpillar
No title given (Testing New Modalities of Space Communications)	Martin Skudlarek, Lockheed Martin Services, Inc. (LMSI)
Performance Measurements of Applications Using ISDN over ACTS	William Kissick, National Telecommunications and Information Administration/Institute for Telecommunication Science (NTIA/ITS)

Investigation	Principal Investigator
Performance Study of a SONET/ATM (Synchronous Optical Network/Asynchronous Transfer Mode) Satellite and Terrestrial Network and Engine Inlet Simulation	Saragur M. Srinidhi, GRC/Sterling Software
Propagation Experiments Using ACTS	Rudolph Henning/Henry Helmken, University of South Florida/Florida Atlantic University
Protocol Evaluation for Advanced Space Data Interchange	Quoc T. Nguyen, MITRE Corporation
Prototype Intelsat Operations	Alfred Goldman, Jr., COMSAT World Systems
PSN (Public Switched Network) Restoration	Frank Dixon, National Communications System
PSN Trunking	Frank Dixon, National Communications System
Quantifying ACTS End-to-End Communications System Performance	Marjorie Wiebel, National Telecommunications and Information Administration/Institute for Telecommunication Science (NTIA/ITS)
Rain Attenuation Statistics for the ACTS Propagation Experiment for Central Oklahoma	Robert Crane, University of Oklahoma
Real-Time Data/Video/Voice Uplink and Downlink for the Kuiper Airborne Observatory (KAO)	Wendy Whiting, Ames Research Center (ARC)
Real-Time, High-Bandwidth Data Links	Stephen Horan, New Mexico State University
RF Propagation Effects and ACTS Satellite Channel Characterization	Paul Steffes, Georgia Technical Research Institute
Satellite and Wireless Networking	Michael Rupar, Naval Research Laboratory
Satellite Communications for Transmission of Corrections GPS Users	Andrew Austin, U.S. Army Topographic Engineering Center
Satellite Networking Research in Scalable Networking Technology	Gretchen Bivens, Air Force Research Laboratory–Rome Laboratory
Satellite Networking Research in Scalable Networking Technology	David Legare, USAF Rome Laboratory
Satellite News Vehicle (AMT)	Robert Sisko, NBC Network Distribution Engineering
SCADA (Supervisory Control and Data Acquisition) Testing	Roberto Acosta, GRC
Secure Mobile Communications	Frank Dixon, National Communications System
Service Availability–Rain Only	Thom A. Coney, GRC
Shipboard HDR ACTS Ka-band Experiment (SHAKE)	Michael Rupar, Naval Research Laboratory
Site Diversity	Roberto Acosta, GRC
Small Telemammography Network (STN) Experiment	Robert Kerczewski, GRC
T1VSAT Backhaul Experiment	Robert Sisko, NBC Network Distribution Engineering
USAT Checkout	Philip Sohn, GRC
VAMA: VSAT Access to Medical Archives	Rodney Long, National Library of Medicine
Video Data Transmission Using ACTS	Henry Helmken, Florida Atlantic University/FL CCDS

Investigation	Principal Investigator
VSAT Statistical Performance in Inclined Orbit	Roberto Acosta, GRC
Web Browsing Protocol Test	Richard Gedney, ACT Corporation
Wideband Dispersion Experiment	Roberto Acosta, GRC

Source: Paul R. McMasters, Analex Corporation, GRC, Science Division, 17 February 2006.

Table 2-90. ACTS Characteristics

Launch date/launch site	September 12, 1993/Kennedy Space Center
Launch vehicle	Space Shuttle *Discovery*, STS-51
NASA role	Mission management; provided the Master Ground Station (MGS) at Lewis Research Center[300]
Responsible (lead) Center	Lewis Research Center
Mission objectives	• To prove that a Ka-band system with on-board switching could reliably provide digital integrated services for all types of applications and data rates and could operate seamlessly with terrestrial networks[301] • To test and prove advanced communications technologies and evaluate the potential applications of the technologies[302]
Orbit characteristics[303]	
Apogee	3,957 km (2,458 mi)
Perigee	323 km (201 mi)
Inclination (deg)	15.3
Period (min)	719
Weight	3,250 lb[304]
Dimensions[305]	47.1 ft (14.4 m) (including solar arrays) × 29.9 ft (8.9 m) (including main receiving and transmitting antenna reflectors) × 15.2 ft (4.6 m) (from spacecraft separation plane to the tip of the highest antenna)
Power source	Solar arrays and batteries
Instruments	Multi-Beam Communications Package: This package performed receiving, switching, momentary storage, selectable coding and decoding, and amplifying and transmitting functions for Ka-band time division multiple access (TDMA) communications signals. The multi-beam antenna (MBA) had fixed beams and hopping spot beams to service traffic needs on a dynamic basis. The receiving antenna provided signals to the autotrack receiver, generating input error signals to the attitude control system for spacecraft pointing operations. Beam forming networks (BFNs) used hopping beams to provide independent coverage of the east and west scan sectors, plus coverage for isolated locations outside of either sector. The MBA also had three fixed spot beams. A steerable beam antenna had been incorporated into ACTS to provide antenna coverage of the entire disk of Earth as seen from l00°W longitude and to any aircraft

[300] "Advanced Communications Technology Satellite (ACTS): Technology, System Overview" *http://acts.grc.nasa.gov/technology/index.shtml* (accessed January 12, 2006).
[301] "Applications," *On-Line Journal of Space Communication*, Issue 8 (Fall 2005), *http://satjournal.tcom.ohiou.edu/issue02/applications.html* (accessed February 16, 2006).
[302] "Switchboard in the Sky: The Advanced Communications Technology Satellite (ACTS)," NASA Facts, FS-2002-06-013-GRC, June 2002, *http://www.nasa.gov/centers/glenn/about/fs13grc.html* (accessed February 16, 2006).
[303] "NSSDC Master Catalog Display: Spacecraft Launch/Orbital Information: ACTS," *http://nssdc.gsfc.nasa.gov/nmc/tmp/1993-058B-traj.html* (accessed February 13, 2006). Orbit was maintained at 100°W longitude.
[304] "Advanced Communications Technology Satellite (ACTS): About ACTS, History," *http://acts.grc.nasa.gov/about/history.shtml* (accessed January 12, 2006).
[305] "Advanced Communications Technology Satellite (ACTS): Technology, Spacecraft," *http://acts.grc.nasa.gov/technology/spacecraft/index.shtml* (accessed January 12, 2006).

	or low-Earth orbit spacecraft, including the Space Shuttle, within view of ACTS.[306]
Prime contractor	Lockheed Martin

[306] "Space Shuttle Mission STS-51 Press Kit," July 1993, p. 15, *http://www.jsc.nasa.gov/history/shuttle_pk/pk/Flight_057_STS-051_Press_Kit.pdf* (accessed March 22, 2006).

Table 2-91. SLS-1 Investigations

Investigation	Principal Investigator
Cardiovascular/Cardiopulmonary System	
Cardiovascular Adaptation to Microgravity	C. Gunnar Blomqvist, University of Texas Southwestern Medical Center, Dallas, TX
Inflight Study of Cardiovascular Deconditioning	Leon E. Farhi, State University of New York at Buffalo, Buffalo, NY
Influence of Weightlessness Upon Human Autonomic Cardiovascular Controls	Dwain L. Eckberg, Medical College of Virginia, Richmond, VA
Pulmonary Function During Weightlessness	John B. West, University of California, San Diego, San Diego, CA
Renal/Endocrine System	
Fluid-Electrolyte Regulation During Spaceflight	Carolyn Leach-Huntoon, JSC
Blood System	
Influence of Spaceflight on Erythrokinetics in Man	Clarence Alfrey, Baylor College of Medicine, Houston, TX
Regulation of Blood Volume During Spaceflight	Clarence Alfrey, Baylor College of Medicine, Houston, TX
Regulation of Erythropoiesis in Rats During Spaceflight	Robert D. Lange, University of Tennessee Medical Center, Knoxville, TN
Immune System	
Lymphocyte Proliferation in Weightlessness	Augusto Cogoli, Swiss Federal Institute of Technology, Zurich, Switzerland
Musculoskeletal System	
Bone, Calcium, and Spaceflight	Emily Morey-Holton, ARC
Effects of Microgravity on Biochemical and Metabolic Properties of Skeletal Muscle in Rats	Kenneth M. Baldwin, University of California, Irvine, Irvine, CA
Effects of Microgravity on the Electron Microscopy, Histochemistry, and Protease Activities of Rat Hind-Limb Muscles	Danny A. Riley, Medical College of Wisconsin, Milwaukee, WI
Pathophysiology of Mineral Loss During Spaceflight	Claude D. Arnaud, University of California–San Francisco, San Francisco, CA
Protein Metabolism During Spaceflight	T. Peter Stein, University of Medicine and Dentistry of New Jersey, Camden, NJ
Skeletal Myosin Isoenzymes in Rats Exposed to Microgravity	Joseph Foon Yoong Hoh, University of Sydney, Sydney, Australia
Neurovestibular System	
Effects of Microgravity-Induced Weightlessness on Aurelia Ephyra Differentiation and Statolith Synthesis	Dorothy B. Spangenbert, Eastern Virginia Medical School, Norfolk, VA

Investigation	Principal Investigator
Study of the Effects of Space Travel on Mammalian Gravity Receptors	Muriel Ross, ARC
Vestibular Experiments in Spacelab	Laurence R. Young, Massachusetts Institute of Technology, Cambridge, MA

Source: "STS-40 Press Kit," *http://science.ksc.nasa.gov/shuttle/missions/sts-40/sts-40-press-kit.txt* (accessed July 12, 2005).

Table 2-92. SLS-2 Investigations

Investigation	Principal Investigator
Cardiovascular/Cardiopulmonary System	
Cardiovascular Adaptation to Zero Gravity	C. Gunnar Blomqvist, University of Texas Southwestern Medical Center at Dallas, Dallas, TX
Inflight Study of Cardiovascular Deconditioning	Leon E. Farhi, State University of New York at Buffalo, Buffalo, NY
Pulmonary Function During Weightlessness	John B. West, University of California, San Diego, San Diego, CA
Regulatory Physiology	
Fluid-Electrolyte Regulation During Spaceflight	Carolyn S. Leach, JSC, Houston, TX
Influence of Spaceflight on Erythrokinetics in Man	Clarence P. Alfrey, Baylor College of Medicine, Houston, TX
Regulation of Blood Volume During Spaceflight	Clarence P. Alfrey, Baylor College of Medicine, Houston, TX
Regulation of Erythropoiesis in Rats During Spaceflight	Albert T. Ichiki, University of Tennessee Medical Center, Knoxville, TN
Neuroscience	
Study of the Effects of Space Travel on Mammalian Gravity Receptors	Muriel D. Ross, ARC
Vestibular Experiments in Spacelab	Daniel M. Merfeld (Acting), Massachusetts Institute of Technology, Cambridge, MA
Musculoskeletal System	
Bone, Calcium, and Spaceflight	Emily R. Morey-Holton, ARC
Effects of Zero Gravity on the Functional and Biochemical Properties of Antigravity Skeletal Muscle in Rats	Kenneth M. Baldwin, College of Medicine, University of California, Irvine, Irvine, CA
Electron Microscopy, Electromyography, and Protease Activities of Rat Hindlimb Muscles	Dan A. Riley, Medical College of Wisconsin, Milwaukee, WI
Pathophysiology of Mineral Loss During Spaceflight	Claude D. Arnaud, University of California, San Francisco, San Francisco, CA
Protein Metabolism During Spaceflight	T. Peter Stein, University of Medicine and Dentistry of New Jersey, Camden, NJ

Source: "Spacelab Life Sciences 2 (SLS-2) Post Launch Mission Operation Report," pp. 3–10, NASA History Division folder 00891, Historical Reference Collection, NASA Headquarters, Washington, DC, and "Space Shuttle Mission STS-58 Press Kit," September 1993, pp. 16–26.

Table 2-93. IML-1 Hardware

Hardware	Developer
Materials Sciences Experiment Hardware	
Critical Point Facility	ESA
Cryostat	Deutsche Agentur für Raumfahrtangelegenheiten (DARA) (German space agency)
Fluids Experiment System	NASA
Mercury Iodide Crystal Growth	CNES
Organic Crystal Growth Facility	NASDA
Protein Crystal Growth	NASA
Space Acceleration Measurement System	NASA
Vapor Crystal Growth System	NASA
Life Sciences Experiment Hardware	
Biorack	ESA
Biostack	Deutschen Zentrum für Luft und Raumfahrt (DLR) (German Aerospace Center)
Gravitational Plant Physiology Facility	NASA
Mental Workload and Performance Experiment	NASA
Microgravity Vestibular Investigations	NASA
Radiation Monitoring Container Device	NASDA
Space Physiology Experiments	CSA

Source: "ESA—IML-1," European Space Agency Public Relations, NASA History Division folder 008629, Historical Reference Collection, NASA Headquarters, Washington, DC.

Table 2-94. IML-1 Investigations

Investigation	Principal Investigator/Provider
IML-1 Life Science Experiments	
Biorack Facility	*ESA*
Chondrogenesis in Micromass Cultures of Mouse Limb Mesenchyme Exposed to Microgravity (CELLS)	P. J. Duke, Dental Science Institute, University of Texas, Houston, TX
Dosimetric Mapping Inside Biorack (DOSIMTR)	G. Reitz, Institute for Flight Medicine, Cologne, Germany
Dynamic Cell Culture System (CULTURE)	Augusto Cogoli, ETH Institute of Biotechnology Space Biology Group, Zurich, Switzerland
Effects of Microgravity and Mechanical Stimulation on the In-Vitro Mineralization and Resorption of Fetal Mouse Bones (BONES)	Jacobos-Paul Veldhuijzen, ACTA Free University, Amsterdam, the Netherlands
Effects of Microgravity Environment on Cell Wall Regeneration, Cell Divisions, Growth and Differentiation of Plants From Protoplasts (PROTO)	Ole Rasmussen, Institute of Molecular Biology and Plant Physiology, University of Aarhus, Aarhus, Denmark
Effects of Space Environment on the Development of *Drosophila melanogaster* (FLY)	Roberto Marco, Department of Biochemistry, UAM Institute of Biomedical Investigations CSIC, Madrid, Spain
Embryogenesis and Organogenesis of *Carausius* (MOROSUS)	H. Buecker, Institute for Flight Medicine, DLR, Cologne, Germany
Genetic and Molecular Dosimetry of HZE Radiation (RADIAT)	Gregory A. Nelson, JPL
Genotype Control of Graviresponse, Cell Polarity, and Morphological Development of *Arabidopsis thaliana* in Microgravity (SHOOTS)	Edmund Maher, Open University of Scotland, Edinburgh, Scotland Greg Briarty, University of Nottingham, Nottingham, England
Gravity-Related Behavior of the Acellular Slime Mold *Physarum polycephalum* (SLIME)	Ingrid Block, Institute for Flight Medicine, DLR, Cologne, Germany
Growth and Sporulation in *Bacillus subtilis* Under Microgravity (SPORES)	Horst-Dieter Menningmann, Institute of Microbiology, University of Frankfurt, Frankfurt am Main, Germany
Leukemia Virus Transformed Cells to Microgravity in the Presence of Dimethylsufoxide (DMSO)	Augusto Cogoli, ETH Institute of Biotechnology Space Biology Group, Zurich, Switzerland
Microgravitational Effects on Chromosome Behavior (YEAST)	Carlo V. Bruschi, Cell and Molecular Biology Division, Lawrence Berkeley Laboratory, Berkeley, CA
Proliferation and Performance of Hybridoma Cells in Microgravity (HYBRID)	Augusto Cogoli, ETH Institute of Biotechnology Space Biology Group, Zurich, Switzerland
Studies on Penetration of Antibiotics in Bacterial Cells in Space Conditions (ANTIBIO)	Rene Tixador, National Institute of Health and Medical Research, Toulouse, France
Transmission of the Gravity Stimulus in Statocyte of the Lentil Root (ROOTS)	Gerald Perbal, Laboratory of Cytology, Pierre et Marie Curie University, Paris, France
Why Microgravity Might Interfere With Amphibian	Geertje A. Ubbels, Hubrecht Laboratory, Utrecht, the

Investigation	Principal Investigator/Provider
Egg Fertilization and the Role of Gravity in Determination of the Dorsal/Ventral Axis in Developing Amphibian Embryos (EGGS)	Netherlands
Gravitational Plant Physiology Facility Experiments	
Gravitational Plant Physiology Facility	*Provided by NASA*
Gravity Threshold (GTHRES)	Allan H. Brown, University of Pennsylvania, Philadelphia, PA
Response to Light Stimulation: Phototropic Transients (FOTRAN)	David G. Heathcote, University City Science Center, Philadelphia, PA
Microgravity Vestibular Investigations	Millard F. Reschke, JSC
Mental Workload and Performance Experiment	Provided by NASA; PI: Harold L. Alexander, Massachusetts Institute of Technology, Cambridge, MA
Canadian Space Physiology Experiments	
Space Adaptation Syndrome Experiments (SASE)	Douglas G. D. Watt, McGill University, Montreal, Quebec, Canada
Proprioceptive Experiments	
Rotation Experiment	
Sled Experiment	
Tactile Acuity Experiment	
Visual Stimulator Experiment	
Assessment of Back Pain in Astronauts (BPA)	Peter C. Wing, University of British Columbia, University Hospital, Vancouver, British Columbia, Canada
Energy Expenditure in Spaceflight (EES)	Howard G. Parsons, University of Calgary, Calgary, Alberta, Canada
Measurement of Venous Compliance (MVC) and Evaluation of an Experimental Anti-Gravity Suit	Robert B. Thirsk, CSA, Ottawa, Ontario, Canada
Phase Partitioning Experiment (PPE)	Donald E. Brooks, University of British Columbia, University Hospital, Vancouver, British Columbia, Canada
Position and Spontaneous Nystagmus (PSN)	Joseph A. McClure, London Ear Clinic, London, Ontario, Canada
Biostack Apparatus (4 packages)	H. Buecker, Institute for Flight Medicine, DLR, Cologne, Germany
Radiation Monitoring Container Device (RMCD)	S. Nagaoka, NASDA, Tokyo, Japan
IML-1 Materials Science Experiments	
Protein Crystal Growth (PCG)	Charles E. Bugg, University of Alabama at Birmingham, Birmingham, AL
Cryostat Facility	*DARA*
Crystal Growth of the Electrogenic Membrane	G. Wagner, University of Giessen Plant Biology

Investigation	Principal Investigator/Provider
Protein Bacteriorhodopsin	Institute 1, Giessen, Germany
Crystallization of Proteins and Viruses in Microgravity by Liquid-Liquid Diffusion	Alexander McPherson, University of California, Riverside, Riverside, CA
Single Crystal Growth of Beta-Galactosidase and Beta-Galactosidase/Inhibiter Complex	W. Littke, University of Freiburg, Freiburg, Germany
Fluids Experiment System	*NASA*
Optical Study of Grain Formation: Casting and Solidification Technology (CAST)	Mary H. McCay, University of Tennessee Space Institute, Tullahoma, TN
Study of Solution Crystal Growth in Low Gravity (TGS)	Ravindra B. Lal, Alabama A&M University, Normal, AL
Vapor Crystal Growth System (VCGS)	*NASA*
Vapor Crystal Growth Studies of Single Mercury Iodide Crystals	Lodewijk van den Berg, EG&G, Inc., Goleta, CA
Mercury Iodide Crystal Growth (MICG) System	*CNES*
Mercury Iodide Nucleations and Crystal Growth in Vapor Phase	Robert Cadoret, University of Clermont-Ferrand, Aubiere, France
Organic Crystal Growth Facility	*Dr. A. Kanbayashi, NASDA, Tokyo, Japan*
Critical Point Facility (CPF)	*ESA*
Critical Fluid Thermal Equilibration Experiment	Allen Wilkinson, Lewis Research Center
Heat and Mass Transport in a Pure Fluid in the Vicinity of a Critical Point	Daniel Beysens, C.E.N., Saclay, France
Phase Separation of an Off-Critical Binary Mixture	Daniel Beysens, C.E.N., Saclay, France
Study of Density Distribution in a Near-Critical Simple Fluid	Antonius C. Michels, Van der Waals Laboratory, Amsterdam, the Netherlands

Source: “Space Shuttle Mission STS-42 Press Kit,” January 1992, pp. 17–39. Also “First International Microgravity Laboratory,” NASA, pp. 7–150, 58–59, NASA History Division folder 008629, Historical Reference Collection, NASA Headquarters, Washington, DC.

Table 2-95. IML-2 Investigations

Investigation	Principal Investigator
Life Sciences	
Biorack	
Activation Signals of T Lymphocytes in Microgravity (Adhesion)	A. Cogoli, Swiss Federal Institute of Technology, Zurich, Switzerland
Biological Investigations of Animal Multi-Cell Aggregates Reconstituted Under Microgravity Conditions (Aggregates)	U. A. O. Heinlein, Heinrich Heine Universität, Düsseldorf, Germany
Cell Microenvironment and Membrane Signal Transduction in Microgravity (Signal)	P. Bouloc, University of Paris-Sud, Orsay, France
Effect of Microgravity and Varying Periods of 1-g Exposure on Growth, Mineralization, and Resorption in Isolated Fetal Mouse Long Bones (Bones)	J. P. Veldhuijzen, Amsterdam Academic Center for Dentistry, Amsterdam, the Netherlands
Effect of Microgravity on Cellular Activation in Lymphocytes: Protein Kinase C Signal Transduction (Phorbol) and Cytokine Synthesis (Cytokine)	D. A. Schmitt and J. P. Hatton, Laboratory of Immunology, CHU Rengueil, Toulouse, France
Effect of Stirring and Mixing in a Bioreactor Experiment in Microgravity (Bioreactor)	A. Cogoli, Space Biology Group of ETH, Zurich, Switzerland
The Influence of Microgravity on Repair of Radiation-Induced DNA Damage in Bacteria and Human Fibroblasts (Repair and Kinetics)	G. Horneck, DLR, Institute for Aerospace Medicine, Cologne, Germany
Investigation of the Mechanics Involved in the Effects of Space Microgravity on *Drosophila* Development, Behavior, and Aging (*Drosophila*)	R. March, Universidad Autónoma de Madrid, Madrid, Spain
Movements and Interactions of Lymphocytes in Microgravity (Motion)[307]	A. Cogoli, Swiss Federal Institute of Technology, Zurich, Switzerland
Plant Growth and Random Walk (Random)	A. Johnsson, University of Trondheim, Dragvoll, Norway
Regulation of Cell Differentiation by Gravity in the Lentil Root (Lentil)	G. Perbal and D. Driss-Ecole, Pierre and Marie Curie University, Paris, France
Replication of Cell Growth and Differentiation by Microgravity: Retinoic Acid-Induced Cell Differentiation (Mouse)	S. W. de Laat, Netherlands Institute for Developmental Biology, Utrecht, the Netherlands
The Role of Gravity in the Establishment of the Corso-Ventral Axis in the Amphibian Embryo (Eggs)	G. A. Ubbels, Hubrecht Laboratory, Utrecht, the Netherlands
Root Orientation, Growth Regulation, Adaptation, and Agravitropic Behavior of Genetically Transformed Roots (Transform)	T.-H. Iversen, Norwegian University of Science and Technology, Dragvoll, Norway

[307] This experiment took place in both the Biorack and the NIZEMI facilities. The cells were activated with concavalir-A and incubated in the 37°C (about 98.6°F) Biorack facility. The crew removed a lymphocyte cuvette from the incubation rack and placed the sample in the NIZEMI facility.

Investigation	Principal Investigator
Sea Urchin Larva, a Suitable Model for Biomineralization Studies in Space (Urchin)	H. J. Marthy, Centre National de la Recherche Scientifique (CNRS), Observatoire Océanologique, Banyuls Sur Mer, France
Extended Duration Orbiter Medical Program (EDOMP)	
Airborne Microbiological Contamination	D. L. Pierson, Life Sciences Research Laboratories, JSC
Lower Body Negative Pressure (LBNP): Countermeasure Investigation for Reducing Postflight Orthostatic Intolerance	J. B. Charles, Medical Sciences Division, JSC
Spinal Changes in Microgravity (SCM)	
Spinal Changes in Microgravity	J. R. Ledsome, University of British Columbia, Vancouver, Canada
Slow Rotating Centrifuge Microscope (NIZEMI)	
Chara Rhizoids: Studies During a Long Period of Microgravity (Chara)	Andreas Sievers, M. Braun, and B. Buchen, University of Bonn, Bonn, Germany
Convective Stability of Solidification Fronts (Moni) (Materials Science Experiment)	K. Leonartz, Engineering, Aachen, Germany
Effects of Microgravity on *Aurelia* Ephyra Behavior and Development (Jellyfish)	D. B. Spangenberg, Eastern Virginia Medical School, Norfolk, VA
Graviorientation in the Flagellate *Euglena gracillis* Is Controlled by an Active Gravireceptor (Euglena)	D.-P. Häedar, Friedrich-Alexander-University, Erlangen, Germany
Graviresponse of Cress Roots Under Varying Gravitational Forces Below Earth Acceleration (1-g) (Cress)	D. Wolkmann, University of Bonn, Bonn, Germany
Gravisensitivity and Gravi(Geo)taxis of the Slime Mold *Physarum polycephalum* (Slide mold)	I. Block, DLR, Institute for Aerospace Medicine, Cologne, Germany
Influence of Accelerations on the Spatial Orientation of *Loxodes* and *Paramecium* (Loxodes)	R. Hemmersbach, DLR, Institute for Space Medicine, Cologne, Germany
Aquatic Animal Experiment Unit (AAEU)	
Early Development of a Gravity-Receptor Organ in Microgravity	M. L. Wiederhold, University of Texas Health Science Center, San Antonio, TX
Fertilization and Embryonic Development of Japanese Newt in Space	M. Yamashita, Institute for Space and Astronomical Science, Kanagawa, Japan
Mating Behavior of the Fish (Medaka) and Development of Their Eggs in Space	K. Ijiri, University of Tokyo, Tokyo, Japan
Mechanism of Vestibular Adaptation of Fish Under Microgravity	A. Takabayashi, Fujita Health University, Tokyo, Japan
Free Flow Electrophoresis Unit (FFEU)	
Applications of Continuous Flow Electrophoresis to Rat Anterior Pituitary Particles (Part 1) Feeding Frequency Affects Cultured Rat Pituitary	Dr. W. C. Hymer, Pennsylvania State University, University Park, PA

Investigation	Principal Investigator
Cells in Low Gravity (Part 2)	
Experiments of Separating Animal Cell Culturing Solution in High Concentration in Microgravity	T. Okusawa, Hitachi, Ltd., Ibaraki, Japan
Separation of a Nematode *C. elegans* Chromosome DNA by FFEU	H. Kobayashi, Josai University, Saitama, Japan
Real-Time Radiation Monitoring Device (RRMD)	
Measurement of LET Distribution and Dose Equipment on Board the Space Shuttle STS-65 (IML-2) (RRMD, Part 1) Effect of Microgravity on DNA Repair of *Deinococcus radiodurans* (RRMD, Part 2)	T. Doke, Waseda University, Tokyo, Japan
Thermoelectric Incubator (TEI)/Cell Culture Kit (CCK)	
Differentiation of *Dictyostelium discoideum* in Space	T. Ohnishi and K. Okaichi, Nara Medical University, Nara, Japan
Gravity and the Stability of the Differentiated State of Plant Somatic Embryos	A. D. Krikorian, State University of New York at Stony Brook, Stony Brook, NY
Microgravity Effects on the Growth and Function of Rat Normal Osteoblasts	Y. Kumei, Tokyo Medical and Dental University, Tokyo, Japan
Performance Assessment Workstation (PAWS)	
Microgravity Effects on Standardized Cognitive Performance Measures	S. G. Schiflett, USAF Armstrong Laboratory, Brooks Air Force Base, TX
Microgravity Science	
Advanced Protein Crystallization Facilities (APCF)	
Crystal Growth of a Thermophilic Aspartyl-tRNA Synthetase[308]	Richard Giege, IBMC of CNRS, Strasbourg, France
Crystal Growth of Ribonuclease S	L. Sjolin, Chalmers University of Technology and Göteborg University, Göteborg, Sweden
Crystallization of Apocrustacyanin C1	N. E. Chayen, Blackett Laboratory, Imperial College of Science, Technology and Medicine, London, England
Crystallization of Bacteriorhodopsin	G. Wagner, Justus-Liebig University of Giessen, Giessen, Germany
Crystallization of Collagenase and Photoreaction Center Under Microgravity	I. Broutin, M. Ries, and A. Ducruix, LEBS, CNRS, Gif sur Yvette, France
Crystallization of Octarellins and Copper Oxalate	J. Martial, Université de Liège Belgique, Brussels, Belgium L. Wyns, Université de Bruxelles, Brussels, Belgium

[308] This investigation was left out of the IML-2 Final Report. It was written up in "Second International Microgravity Laboratory (IML-2), Final Report," *http://spacescience.spaceref.com/newhome/msad/iml-2_final_report.html* (accessed January 25, 2006).

Investigation	Principal Investigator
Crystallization of Rhodopsin in Microgravity	W. J. de Grip, University of Nijmegen, Nijmegen, the Netherlands
Crystallization of Ribosomal Particles in Space	A. Yonath, Max-Planck-Laboratory for Ribosomal Structure, Hamburg, Germany
Crystallization of RNA Molecules	V. A. Erdmann and S. Lorenz, Institut für Biochemie, Freie Universität Berlin, Berlin, Germany
Microgravity Effects on Macromolecule and Virus Crystallization	A. McPherson, University of California, Riverside, Riverside, CA
Studies of Lysozyme Protein Crystal Perfection from Microgravity Crystallization	J. R. Helliwell, University of Manchester, Manchester, England
Bubble, Drop and Particle Unit (BDPU)	
Bubble Behavior Under Low Gravity	A. Viviani, Seconda Università di Napoli, Aversa, Italy
Bubble Migration, Coalescence, and Interaction with the Solidification Front	R. Monti, University of Napoli, Napoli, Italy R. Fortezza, MARS Center, Napoli, Italy
Dynamics of Liquids in Edges and Corners	D. Langbein, ZARM, University of Bremen, Bremen, Germany
Interfacial Phenomena I Multilayered Fluid Systems	J. N. Kosher and S. Biringen, University of Colorado, Boulder, CO
Nucleation, Bubble Growth, Interfacial Phenomena, Evaporation, and Condensation Kinetics	J. Straub, Technical University of Munich, Munich, Germany
Thermocapillary Convection in a Multilayer System	J. C. Legros and Ph. Georis, Université Libre de Bruxelles, Brussels, Belgium
Thermocapillary Migration and Interactions of Bubbles and Drops	R. S. Subramanian, Clarkson University, Potsdam, NY
Critical Point Facility (CPF)	
Critical Phenomena in Spaceflight Observed Under Reduced Gravity	D. Beysens, Commissariat à l'Energie Atomique, Grenoble, France
Density Equilibration Time Scales	H. Klein, DLR, Institute for Space Simulation, Cologne, Germany
Heat Transport and Density Fluctuations in a Critical Fluid	A. C. Michels, University of Amsterdam, Amsterdam, the Netherlands
Summary of Results from the Adiabatic Fast Equilibration (AFEQ) and Thermal Equilibration Bis (TEQB) Experiments	R. A. Ferrell, University of Maryland, College Park, MD
Large Isothermal Furnace (LIF)	
Effect of Weightlessness on Microstructure and Strength of Ordered TiAl Intermetallic Alloys	A. Sato, National Research Institute for Metals, Tokyo, Japan
Liquid Phase Sintering in a Microgravity LIS Environment	R. M. German, Pennsylvania State University, University Park, PA
Mixing of a Melt of a Multicomponent Compound	A. Hirata, Waseda University, Tokyo, Japan

Investigation	Principal Investigator
Semiconductor	
Applied Research on Separation Methods Using Space Electrophoresis (RAMSES)	
Electrohydrodynamic Sample Distortion During Electrophoresis	R. S. Snyder, MSFC
Purification of Biological Molecules by Continuous-Flow Electrophoresis in a Microgravity Environment	V. Sanchez, Université Paul Sabatier, Toulouse, France B. Schoot, Roussel Uclaf, Romainville, France
Electromagnetic Containerless Processing Facility (TEMPUS)	
Alloy Undercooling Experiments	M. Flemings, Massachusetts Institute of Technology, Cambridge, MA
Containerless Processing in Space: The TEMPUS Team Results	I. Egry, DLR, Institute for Space Simulations, Cologne, Germany
Effect of Nucleation by Containerless Processing	R. Bayuzick, Vanderbilt University, Nashville, TN
Measurement of the Viscosity and Surface Tension of Undercooled Metallic Melts and Supporting MHD Calculations	J. Szekely, Massachusetts Institute of Technology, Cambridge, MA
Non-Equilibrium Solidification of Deeply Undercooled Melts	D. M. Herlach, DLR, Institute for Space Simulations, Cologne, Germany
Structure and Solidification of Deeply Undercooled Melts of Quasicrystal-Forming Alloys	K. Urban, Institute for Solid State Physics Research Center, Julich, Germany
Thermodynamic and Glass Formation of Undercooled Metallic Melts	H. Fecht, University of Augsburg, Augsburg, Germany
Thermophysical Properties of Metallic Glasses and Undercooled Alloys	W. Johnson, California Institute of Technology, Pasadena, CA
Microgravity Environment and Countermeasures	
Quasi-Steady Acceleration Measurement (QSAM)	H. Hamacher, DLR, Institute for Space Simulation, Cologne, Germany
Space Acceleration Measurement System (SAMS) and Orbital Acceleration Research Experiment (OARE)	R. DeLombard, Lewis Research Center
Vibration Isolation Box Experiment System (VIBES)	
Influence of G-Jitter on Convection and Diffusion	H. Azuma, National Aerospace Laboratory, Chohu-shi, Japan
Thermally Driven Flow Experiments (TDFU)	M. Furukawa, NASDA Tsukuba Space Center, Ibaraki, Japan

Source: R. S. Snyder, Compiler, Second International Microgravity Laboratory (IML-2) Final Report, NASA Reference Publication 1405, *http://trs.nis.nasa.gov/archive/00000392/01/rp1405.pdf* (accessed January 25, 2006).

Table 2-96. ATLAS-1 Investigations

Investigation	Spectral Range	Selected Focus	Principal Investigator
Atmospheric Science			
Atmospheric Lyman-Alpha Emission (ALAE)	Far ultraviolet	Ratio of atmospheric hydrogen to deuterium	J. L. Bertraux, Service d'Aeronomie du CNRS, France
Atmospheric Trace Molecule Spectroscopy (ATMOS)	Infrared	Water vapor, ozone, methane, nitrogen compounds	M. Gunson, JPL, United States
Grille Spectrometer	Infrared	Water vapor, ozone, methane, nitrogen compounds	M. Ackerman, Institut d'Aeronomie Spatiale de Belgique, Belgium
Imaging Spectrometric Observatory (ISO)	Visible/ultraviolet	Atmospheric temperature, nitrogen, oxygen, ions	D. G. Torr, University of Alabama in Huntsville, United States
Millimeter Wave Atmospheric Sounder (MAS)	Microwave	Temperature, pressure, ozone, chlorine monoxide	G. Hartmann, Max Planck Institute for Aeronomy, Germany
Space Shuttle Backscatter Ultraviolet (SSBUV) Experiment	Near ultraviolet	Ozone	E. Hilsenrath, GSFC, Greenbelt, MD
Solar Science			
Active Cavity Radiometer Irradiance Monitor (ACRIM)	Total energy	Solar constant	R. Wilson, JPL, Pasadena, CA
Measurement of Solar Constant (SOLCON)	Total energy	Solar constant	D. Crommelynck, Institut Royal Météorologique de Belgique, Belgium
Solar Spectrum (SOLSPEC)	Infrared to ultraviolet	Solar spectrum	G. Thuillier, Service d'Aeronomy du CNRS, France
Solar Ultraviolet Spectral Irradiance Monitor (SUSIM)	Ultraviolet	Solar spectrum	G. Brueckner, Naval Research Laboratory, United States
Plasma Physics			
Atmospheric Emissions Photometric Imager (AEPI)	Visible	Natural aurora and airglow	S. Mende, Lockheed Palo Alto Research Laboratory, United States
Energetic Neutral Atom Precipitation (ENAP)	Visible/ultraviolet	Use ISO data to study emissions from energetic atoms	B. Tinsley, University of Texas at Dallas, Dallas, TX
Space Experiments with Particle Accelerators	—	Response of plasmas to known	J. Burch, Southwest Research Institute, United

Investigation	Spectral Range	Selected Focus	Principal Investigator
(SEPAC)		disturbances	States
Astrophysics			
Far Ultraviolet Space Telescope (FAUST)	Far ultraviolet	Large-scale astrophysical objects	S. Bowyer, University of California–Berkeley, United States, Berkeley, CA

Source: “Space Shuttle Mission STS-45 Press Kit,” March 1992, p. 16, *http://www.jsc.nasa.gov/history/shuttle_pk/pk/Flight_046_STS-045_Press_Kit.pdf* (accessed January 28, 2006).

Table 2-97. ATLAS-2 Investigations

Investigation	Spectral Range	Selected Focus	Principal Investigator
Atmospheric Science			
Atmospheric Trace Molecule Spectroscopy (ATMOS)	Infrared	Water vapor, ozone, methane, chlorine and nitrogen compounds, chlorofluorocarbons, others	M. Gunson, JPL, Pasadena, CA
Millimeter-Wave Atmospheric Sounder (MAS)	Microwave	Temperature, pressure, ozone, chlorine monoxide, water vapor	G. Hartmann, Max Planck Institute for Aeronomy, Germany
Shuttle Solar Backscatter Ultraviolet (SSBUV) Experiment	Near ultraviolet	Ozone	E. Hilsenrath, GSFC, Greenbelt, MD
Solar Science			
Active Cavity Radiometer Irradiance Monitor (ACRIM)	Total energy	Solar constant	R. Willson, JPL, Pasadena, CA
Solar Constant (SOLCON)	Total energy	Solar constant	D. Crommelynck, Belgian Royal Institute for Meteorology, Belgium
Solar Spectrum Measurement (SOLSPEC)	Infrared to ultraviolet	Solar spectrum	G. Thuillier, Aeronomy Service for Scientific Research, France
Solar Ultraviolet Irradiance Monitor (SUSIM)	Ultraviolet	Solar spectrum	G. Brueckner, Naval Research Laboratory, United States

Source: "Space Shuttle Mission STS-56 Press Kit," May 1993, p. 14, *http://www.jsc.nasa.gov/history/shuttle_pk/pk/Flight_054_STS-056_Press_Kit.pdf* (accessed January 29, 2006).

Table 2-98. ATLAS-3 Investigations

Instrument	Spectral Range	Selected Focus	Principal Investigator
Atmospheric Science			
Atmospheric Trace Molecule Spectroscopy (ATMOS)	Infrared	Water vapor, ozone, methane, chlorine and nitrogen compounds, chlorofluorocarbons, others	M. Gunson, JPL, Pasadena, CA
Millimeter-Wave Atmospheric Sounder (MAS)[309]	Microwave	Temperature, pressure, ozone, chlorine monoxide, water vapor	G. Hartmann, Max Planck Institute for Aeronomy, Germany
Shuttle Solar Backscatter Ultraviolet (SSBUV) Experiment	Near ultraviolet	Ozone	E. Hilsenrath, GSFC, Greenbelt, MD
Solar Science			
Active Cavity Radiometer Irradiance Monitor (ACRIM)	Total energy	Solar constant	R. Willson, JPL, Pasadena, CA
Solar Constant (SOLCON)	Total energy	Solar constant	D. Crommelynck, Belgian Royal Institute for Meteorology, Belgium
Solar Spectrum Measurement (SOLSPEC)	Infrared to ultraviolet	Solar spectrum	G. Thuillier, Aeronomy Service for Scientific Research, France
Solar Ultraviolet Irradiance Monitor (SUSIM)	Ultraviolet	Solar spectrum	G. Brueckner, Naval Research Laboratory, U.S.

Source: "Space Shuttle Mission STS-66 Press Kit," November 1994, pp. 16–25, *http://www.jsc.nasa.gov/history/shuttle_pk/pk/Flight_066_STS-066_Press_Kit.pdf* (accessed February 6, 2007).

[309] This instrument failed on the first day of the mission but still obtained 10 hours of data—enough to acquire nearly global maps of ozone and water vapor in the stratosphere and mesosphere, as well as some information on the distribution of chlorine monoxide in the stratosphere.

Table 2-99. USML-1 Investigations

Investigation	Principal Investigator
Crystal Growth Furnace (CGF)	
Crystal Growth of Selected II–VI Semiconducting Alloys by Directional Solidification	Sandor L. Lehoczky, MSFC
Orbital Processing of High-Quality Cadmium Telluride Compound Semiconductors	David J. Larson, Jr., Grumman CorporatION Research Center
The Study of Dopant Segregation Behavior During the Growth of Gallium Arsenide in Microgravity	David Matthiesen, GTE Laboratories, Waltham, MA
Vapor Transport Crystal Growth of Mercury Cadmium Telluride in Microgravity	Herbert Wiedemeier, Rensselaer Polytechnic Institute, Troy, NY
Drop Physics Module (DPM)	
Drop Dynamics Investigation	Taylor G. Wang, Vanderbilt University, Nashville, TN
Measurement of Liquid–Liquid Interfacial Tension and the Role of Gravity in Phase Separation Kinetics of Fluid Glass Melts	Michael C. Weinberg, University of Arizona, Tucson, AZ
Science and Technology of Surface-Controlled Phenomena	Robert E. Apfel, Yale University, New Haven, CT
Surface Tension Driven Convection Experiment (STDCE) Apparatus	
Surface Tension Driven Convection Experiment	Simon Ostrach, Case Western Reserve University, Cleveland, OH
Glovebox Facility (GBX)	
Candle Flames in Microgravity	Howard D. Ross, Lewis Research Center
Directed Orientation of Polymerizing Collagen Fibers	Louis S. Stodieck, Center for Bioserve Space Technologies, Boulder, CO
Fiber Pulling in Microgravity	Robert J. Naumann, University of Alabama in Huntsville, Huntsville, AL
Interface Configuration Experiment	Paul Concus, University of California–Berkeley and Lawrence Berkeley Laboratory, Berkeley, CA
Marangoni Convection in Closed Containers	Robert J. Naumann, University of Alabama in Huntsville, Huntsville, AL
Nucleation of Crystals from Solutions in a Low-g Environment	Roger L. Kroes, MSFC
Oscillatory Dynamics of Single Bubbles an Agglomeration in an Ultrasonic Sound Field in Microgravity	Philip L. Marston, Washington State University, Pullman, WA
Oscillatory Thermocapillary Flow Experiment	Simon Ostrach, Case Western Reserve University, Cleveland, OH
Particle Dispersion Experiment	John R. Marshall, ARC
Passive Accelerometer System	J. Iwan D. Alexander, University of Alabama in Huntsville, Huntsville, AL

Investigation	Principal Investigator
Protein Crystal Growth Glovebox Experiment	Lawrence J. DeLucas, University of Alabama at Birmingham, Birmingham, AL
Smoldering Combustion in Microgravity	A. Carlos Fernandez-Pello, University of California–Berkeley, Berkeley, CA
Solid Surface Wetting Experiment	Eugene H. Trinh, JPL
Stability of a Double Float Zone	Robert J. Naumann, University of Alabama in Huntsville, Huntsville, AL
Wire Insulation Flammability Experiment	Paul S. Greenberg, Lewis Research Center
Zeolite Glovebox Experiment	Albert Sacco, Jr., Worcester Polytechnic Institute, Worcester, MA
Extended Duration Orbiter Medical Project[310]	J. Travis Brown, Project Manager, JSC
In-Flight Lower Body Negative Pressure	
Blood Pressure Variability During Space Flight	
Environmental Monitoring (Microbial Air Sampler)	
Orthostatic Function During Entry, Landing, and Egress	
Metabolic Responses	
Visual-Vestibular Integration as a Function of Adaptation	
Energy Utilization	
Other Investigations	
ASTROCULTURE™-1 Facility and Experiment	Theodore W. Tibbitts, Wisconsin Center for Space Automation and Robotics, University of Wisconsin, Madison, WI
Generic Bioprocessing Apparatus (GBA)	Michael C. Robinson, Center for Bioserve Space Technologies, University of Colorado, Boulder, CO
Protein Crystal Growth (PCG) Payload	Charles E. Bugg, Center for Macromolecular Crystallography, University of Alabama at Birmingham, Birmingham, AL
Solid Surface Combustion Apparatus and Experiment	Robert A. Altenkirch, Mississippi State University, State College, MS
Space Acceleration Measurement System (SAMS)	Richard DeLombard, Project Manager, Lewis Research Center
Zeolite Crystal Growth (ZCG) Payload[311]	Albert Sacco, Jr., Worcester Polytechnic Institute, Worcester, MA

Source: "Space Shuttle Mission STS-50 Press Kit," June 1982, pp. 10–34. Also "First United States Microgravity Laboratory (USML-1) Prelaunch Mission Operation Report," pp. 12–13.

[310] The purpose of these experiments was to protect the health and safety of the crew during the mission. They took place in the Spacelab and in the middeck area of the orbiter. "First United States Microgravity Laboratory 1 (USML-1) Prelaunch Mission Operation Report," Report No. S-420-50-92-01, Office of Space Science and Applications, p. 13, NASA History Division folder 008887, Historical Reference Collection, NASA Headquarters, Washington, DC.
[311] ZCG, PCG, GBA, and ASTROCULTURE experiments were sponsored by NASA's Office of Commercial Programs.

Table 2-100. USML-2 Investigations

Investigation	Primary Investigator
Crystal Growth Furnace (CGF)	
Interface Demarcation Flight Test (IDFT)	M. Lichtensteiger, Universities Space Research Association, Marshall Space Flight Center, Huntsville, AL
Orbital Processing of High-Quality Cadmium Zinc Telluride (CdZnTe) Compound Semiconductors	D. Larson, The State University of New York at Stony Brook, Stony Brook, NY
The Study of Dopant Segregation Behavior During Crystal Growth of Gallium Arsenide (GaAs) in Microgravity	D. Matthiesen, Case Western Reserve University, Cleveland, OH
Vapor Transport Crystal Growth of Mercury-Cadmium-Telluride in Microgravity	H. Wiedemeier, Rensselaer Polytechnic Institute, Troy, NY
Drop Physics Module (DPM)	
Drop Dynamics Experiment	T. Wang, Vanderbilt University, Nashville, TN
Science and Technology of Surface-Controlled Phenomena	R. Apfel, Yale University, New Haven, CT
Geophysical Fluid Flow Cell (GFFC) Instrument and Experiment	J. Hart, University of Colorado, Boulder, CO
Surface Tension Driven Convection Experiment Apparatus	S. Ostrach, Case Western Reserve University, Cleveland, OH
Zeolite Crystal Growth Furnace and Experiment	A. Sacco, Jr., Worcester Polytechnic Institute, Worcester, MA
Commercial Generic Bioprocessing Apparatus	
Brine Shrimp Development in Space	A. Paulsen and B. S. Spooner, Kansas State University/BioServe Space Technologies, Manhattan, KS
CeReS-Mediated Cell Stabilization	T. Johnson, Kansas State University/BioServe Space Technologies, Manhattan, KS
Development, Growth, and Activation of Bone Marrow Macrophages–Phase II	K. Chapes, Kansas State University/BioServe Space Technologies, Manhattan, KS
E. coli Growth and Development	D. Klaus, University of Colorado/BioServe Space Technologies, Boulder, CO
Effect of Gravitational Unloading on Plant Gravity Response	J. Smith, University of Colorado/BioServe Space Technologies, Boulder, CO
Effects of Microgravity and Clinorotation on Ethylene Production in Mutants of *Arabidoopsis* with Altered Starch Regulation	G. Gallegos and J. Guikema, Kansas State University/BioServe Space Technologies, Manhattan, KS
Effects of Microgravity on Auxin-Inducible Gene Expression in *Arabidopsis*	Y. Li, Kansas State University/BioServe Space Technologies, Manhattan, KS
Effects of Microgravity on the Growth and Development of *Pseudomonas aeruginosa* Biofilms	B. Manfredi, University of Colorado/BioServe Space Technologies, Boulder, CO

Investigation	Primary Investigator
Effects of Microgravity on the Legume-*Rhizobium* Nodulation Process	P. Wong, Kansas State University/BioServe Space Technologies, Manhattan, KS
Effects of Space on Biochemical Reaction Kinetics	K. Chapes, Kansas State University/BioServe Space Technologies, Manhattan, KS
Plasmin Degradation of Fibrin Clots in Microgravity	T. Bateman and C. Nunes, University of Colorado/BioServe Space Technologies, Boulder, CO
Pre-Metatarsal Development	B. Klement and B. S. Spooner, Kansas State University/BioServe Space Technologies, Manhattan, KS
Starchless *Arabidopsis* Mutant	E. Hilaire, Kansas State University/BioServe Space Technologies, Manhattan, KS
Viral Infection of Mammalian Cells in Microgravity	R. Consigli, Kansas State University/BioServe Space Technologies, Manhattan, KS
Advanced Protein Crystallization Facility	
Crystal Structure Analysis of the Bacteriophage Lambda Lysozyme	J. P. Declercq and C. Evrard, University of Louvain, Louvain, Belgium
Crystallization in a Microgravity Environment of CcdB, a Protein Involved in the Control of Cell Death	L. Wyns, Free University of Brussels, Brussels, Belgium
Crystallization in Space of Designed and Natural (alpha/beta)-Barrel Structures	J. Martial, University of Liège, Liège, Belgium
Crystallization of Apocrustacyanin C	N. Chayen, Imperial College, London, England
Crystallization of Glutathione S-Transferase in Microgravity	L. Sjölin, University of Göteborg, Göteborg, Sweden
Crystallization of Photosystem I	W. Saenger and P. Fromme, Technische Universität and Freie Universität, Berlin, Germany
Crystallization of Ribosomes	A. Yonath, Max-Planck Laboratory for Ribosomal Structure, Hamburg, Germany
Crystallization of RNA Molecules Under Microgravity Conditions	V. Erdmann, University of Berlin, Berlin, Germany
Crystallization of the Epidermal Growth Factor (EGF) Receptor	W. Weber, University of Hamburg, Hamburg, Germany
Crystallization of the Protein Grb2 and Triclinic Lysozyme	A. Ducruix, Laboratoire de Biologie Structurale, CNRS, Paris, France
Crystallization of the Visual Pigment Rhodopsin	W. de Grip, University of Nijmegen, Nijmegen, the Netherlands
Crystallization of Turnip Yellow Mosaic Virus, Tomato Aspermy Virus, Satellite Panicum Mosaic Virus, Canavalin, Beef Liver Catalase, Concanavalin B, Thaumatin	A. McPherson, University of California, Riverside, Riverside, CA
Lower-Body Negative Pressure (LBNP)	
Microgravity Crystallization of *Sulfolobus solfataricus* Alcohol Dehydrogenase	A. Zarari, Biocrystallographic Center, University of Naples, Naples, Italy

Investigation	Primary Investigator
Microgravity Crystallization of Thermophilic Aspartyl-tRNA Synthetase and Thaumatin	R. Giegé, CNRS, Strasbourg, France
Protein Crystal Growth: Light-Driven Charge Translocation Through Bacteriorhodopsin	G. Wagner, University of Giessen, Giessen, Germany
ASTROCULTURE™ Facility and Experiment	R. J. Bula and T. W. Tibbits, University of Wisconsin, Madison, WI
Protein Crystal Growth (PCG)	
Commercial Protein Crystal Growth (CPCG)	L. J. DeLucas, University of Alabama at Birmingham, Birmingham, AL
Single-Locker Protein Crystal Growth (SPCG)	D. Carter, MSFC
Glovebox Facility (GBX)	
Colloidal Disorder-Order Transitions (CDOT)	P. Chaikin, Princeton University, Princeton, NJ
Fiber Supported Droplet Combustion (FSDC)	F. A. Williams, University of California, San Diego, San Diego, CA
Interface Configuration Experiment (ICE)	P. Concus, University of California–Berkeley, Berkeley, CA
Oscillatory Thermocapillary Flow Experiment (OTFE)	Y. Kamotani, Case Western Reserve University, Cleveland, OH
Particle Dispersion Experiment (PDE)	J. Marshall, ARC
Protein Crystal Growth–Glovebox (PCGG)	L. J. DeLucas, University of Alabama at Birmingham, Birmingham, AL
Zeolite Crystal Growth–Glovebox (ZCGG)	A. Sacco, Worcester Polytechnic Institute, Worcester, MA
Measuring Microgravity	
Microgravity Acceleration Workstation (MAWS)	L. French, Lead Engineer, Teledyne Brown Engineering, Huntsville, AL
Orbital Acceleration Research Experiment (OARE)	W. Wagar, Project Manager, Lewis Research Center
Space Acceleration Measurement System (SAMS)	R. Sicker, Project Manager, Lewis Research Center
Suppression of Transient Events by Levitation (STABLE)	G. S. Nurre and D. L. Edberg, MSFC and McDonnell Douglas Aerospace, Huntsville, AL
Three-Dimensional Microgravity Accelerometer (3DMA)	J. Bijvoet, University of Alabama in Huntsville, Huntsville, AL

Source: “The Second United States Microgravity Laboratory 90-Day Science Report,” March 1996, *http://liftoff.msfc.nasa.gov/shuttle/usml2/90-day/usml-2-90day.pdf* (accessed January 26, 2006).

Table 2-101. Spacelab J Investigations

Investigation	Principal Investigator
NASA Investigations	
Microgravity Science	
Protein Crystal Growth	Charles E. Bugg, University of Alabama at Birmingham, Birmingham, AL
Space Acceleration Measurement System	A. Krikorizn, State University of New York at Stony Brook, Stony Brook, NY
Life Sciences	
Amphibian Development in Microgravity: The STS-47 Frog Embryology Experiment	K. A. Souza, A. M. Ross, ARC; S. D. Black, Biology Department, Reed College; R. J. Wassersug, Department of Anatomy and Neurobiology, Faculty of Medicine, Dalhousie University
Countermeasure Against Orthostatic Intolerance After Space Flight: The Combination of Oral Fluid Loading and Lower Body Negative Pressure	John B. Charles, JSC
Inflight Demonstration of the Space Station Freedom Health Maintenance Facility Fluid Therapy System	Charles W. Lloyd, JSC
Magnetic Resonance Imaging After Exposure to Microgravity	Adrian LeBlanc, Baylor College of Medicine
Monitoring Astronauts' Functional State: Autogenic Responses to Microgravity	Patricia S. Cowings, ARC
NASA/NASDA Cosponsored Investigations	
Bone Cell Research	Nicola C. Partridge, School of Medicine, University of St. Louis
Plant Cell Research Experiment on Spacelab J Mission. Mitotic Disturbances in Daylily (*Hemerocallis*) Somatic Embryos After an 8-Day Spaceflight	A. D. Krikorian, Stevania A. O'Connor, R. P. Kann, Department of Biochemistry and Cell Biology, State University of New York at Stony Brook, Stony Brook, NY
NASDA Investigations	
Materials Science	
Bubble Behavior in Thermal Gradient and Stationary Acoustic Wave	Hisao Azuma, National Aerospace Laboratory
Casting of Superconducting Composite Materials	Kazumasa Togano, National Research Institute for Metals
Crystal Growth of Compound Semiconductors in a Low-Gravity Environment (InGaAs)	Masani Tatsumi, Sumitomo Electric Industries, Ltd.
Crystal-Growth Experiment on Organic Metals in Low Gravity	Hiroyuki Anzai, Electrotechnical Laboratory-Himeji Institute of Technology

Investigation	Principal Investigator
Diffusion in Liquid State and Solidification of Binary System	Takehiro Dan, National Research Institute for Metals
Drop Dynamics in an Acoustic Resonant Chamber and Interference with the Acoustic Field	Tatsuo Yamanaka, National Aerospace Laboratory
Fabrication of Si-As-Te Semiconductor in Microgravity Environment	Yoshihiro Hamakawa, Osaka University
Fabrication of Ultra-Low-Density, High-Stiffness Carbon Fiber/Aluminum Alloy Composite	Tomoo Suzuki, Hokkaido University
Formation Mechanism of Deoxidation Products in Iron Ingot Deoxidized with Two or Three Elements	Akira Fukuzawa, National Research Institute for Metals
Gas-Evaporation in Low-Gravity	Nobuhiko Wada, Faculty of Science at Nagoya University
Growth Experiment of Narrow Band-Gap Semiconductor Pb-Sn-Te Single Crystal in Space	Tomoaki Yamada, NTT Basic Research Laboratories
Growth of Pb-Sn-Te Single Crystal by Traveling Zone Method	Sohachi Iwai, The Institute of Physical and Chemical Research, RIKEN
Growth of Samarskite Crystal in Microgravity	Shunji Takekawa, National Institute for Research in Inorganic Materials
Growth of Semiconductor Compound Single Crystal InSb by Floating Zone Method	Isao Nakatani, National Research Institute for Metals
Growth of Silicon Spherical Crystals and the Surface Oxidation	T. Nishinaga, Faculty of Engineering, University of Tokyo
High-Temperature Behavior of Glass	Naohiro Soga, Kyoto University
Marangoni-Effect Induced Convection in Material Processing Under Microgravity	Shintaro Enya, Ishikawajima-Harima Heavy Industries Co., Ltd.
Preparation of Optical Materials Used in Non-Visible Region	Junji Hayakawa, Government Industrial Research Institute (GIRIO), Osaka
Preparation of Particle Dispersion Alloys	Yuji Muramatsu, National Research Institute for Metals
Solidification of Eutectic System Alloys in Space	Atsumi Ohno, Chiba Institute of Technology
Study of Solidification of Immiscible Alloy	Akihiko Kamio, Faculty of Engineering, Tokyo Institute of Technology
Study on Liquid Phase Sintering	Shiro Kohara, Science University of Tokyo
Life Sciences	
Circadian Rhythm of Conidiation in *Neurospora crassa*	Yahuhiro Miyoshi, University of Shizuoka
Comparative Measurement of Visual Stability in Earth and Cosmic Space	Kazuo Koga, SMRC/RIEM, Nagoya University
Crystal Growth of Enzymes in Low Gravity	Yuhei Morita, Fuji Oil Co. R&D Center
Effect of Low Gravity on Calcium Metabolism and Bone Formation in Chick Embryo	Tatsuo Suda, Showa University, School of Dentistry
Electrophoretic Separation of Cellular Materials Under Microgravity	Teruhiko Akiba, The Institute of Physical and Chemical Research
Endocrine and Metabolic Changes in Payload Specialist During Spacelab J	Hisao Seo, Nagoya University Research Institute of Environmental Medicine

Investigation	Principal Investigator
Genetic Effects of HZE and Cosmic Radiation	Mituo Ikenaga, Radiation Biology Center, Kyoto University
Health Monitoring of Japanese Payload Specialist Autonomic Nervous and Cardiovascular Responses Under Reduced Gravity	Chiharu Sekiguchi, NASDA
Manual Control in Space Research on Perceptual Motor Functions Under Microgravity Condition	Akira Tada, National Aerospace Laboratory
Neurophysiological Study of Visuo-Vestibular Control of Posture and Movement in Fish During Adaptation to Weightlessness	Shigeo Mori, Nagoya University Research Institute of Environmental Medicine
Organ Differentiation from Cultured Plant Cells Under Microgravity	Atsushige Sato, Tokyo Medical and Dental University
Separation of Biogenic Materials by Electrophoresis Under Zero Gravity	Masao Kuroda, Osaka University Medical School
Studies on the Effects of Microgravity on the Ultrastructure and Function of Cultured Mammalian Cells	Atsushige Sato, Faculty of Dentistry, Tokyo Medical and Dental University
Study on the Biological Effects of Cosmic Radiation and Development of Radiation Protection Technology	Shunji Nagaoka, Space Experiment Group, NASDA
Study on the Effects of Microgravity on Cell Growth of Human Antibody-Producing Cells and Their Secretions	Toshio Suganuma, Laboratory of Biological Science, Mitsui Pharmaceuticals, Inc.

Source: *Final Science Results, Spacelab J* (Washington, DC: Office of Life and Microgravity Sciences and Applications, NASA Headquarters, 1995), pp. 3–77. Also “Spacelab J Prelaunch Mission Operation Report,” Report No. S-420-47-92-01, Office of Space Science and Applications, Appendix A-1 (NASA History Division electronic record 8650, Historical Reference Collection, NASA Headquarters, Washington, DC).

Table 2-102. USMP-1 Investigations

Investigation	Objective	Principal Investigator
Lambda-Point Experiment (LPE)	To perform a new test of the theory of cooperative phase transitions by making use of the microgravity environment of Earth orbit	John Lipa, Stanford University, Palo Alto, CA
Matériel pour l'Étude des Phénomènes Intéressant la Solidification sur Terre et en Orbite (MEPHISTO)	To perform fundamental studies on the growth mechanisms during directional solidification of the metallic system tin-bismuth in a microgravity environment	Jean Jacques Favier, Commissariat à l'Énergie Atomique, Grenoble, France
Space Acceleration Measurement System (SAMS)	To provide acceleration data in support of LPE and MEPHISTO	Charles Baugher, Project Scientist, MSFC

Source: "United States Microgravity Payload-1 Mission Operation Report," Office of Space Science and Applications Report No. S-420-52-92-01, NASA History Division folder 11035, Historical Reference Collection, NASA Headquarters, Washington, DC.

Table 2-103. USMP-2 Investigations

Investigation	Objective	Principal Investigator
Advanced Automated Directional Solidification Furnace (AADSF)	To study the directional solidification of semiconductor materials in microgravity	S. Lehoczky, Space Science Laboratory, MSFC
Critical Fluid Light Scattering Experiment (ZENO)	To measure properties of xenon 100 times closer to the critical point than would be possible on Earth	R. Gammon, University of Maryland, College Park, MD
Isothermal Dendritic Growth Experiment (IDGE)	To study dendritic solidification of molten materials in the absence of gravity-driven fluid flows	M. Glocksman, Rensselaer Polytechnic Institute, Troy, NY
MEPHISTO	To explore the effect of directional solidification in microgravity on the temperature, velocity, and shape of the solidification front	R. Abbaschian, University of Florida, Gainesville, FL Jean Jacques Favier, Centre d'Études Nucleaires de Grenoble, Grenoble, France
SAMS	To make accurate measurements of residual accelerations and vibrations that can affect sensitive microgravity investigations in support of USMP-2 experiments	M. Wargo, Project Scientist, NASA Headquarters

Source: "United States Microgravity Payload 2," NASA History Division folder 11035, Historical Reference Collection, NASA Headquarters, Washington, DC.

Table 2-104. USMP-3 Investigations

Investigation	Objective	Principal Investigator
Cargo Bay MPESS Experiments		
AADSF	To study the directional solidification of semiconductor materials in microgravity to better understand how solidification influences the properties of semiconductors	Archibald L. Fripp, LRC
ZENO	To measure properties of xenon 100 times closer to the critical point than would be possible on Earth[312]	Robert Gammon, University of Maryland, College Park, MD
IDGE	To study dendritic solidification of molten materials in the absence of gravity-driven fluid flows[313]	Martin Glicksman, Rensselaer Polytechnic Institute, Troy, NY
MEPHISTO	To study the role of gravity-driven convection during the solidification of materials and explore the effect of directional solidification in microgravity on the temperature, velocity, and shape of the solidification front	J. J. Favier, Centre d'Études Nucleaires de Grenoble, Grenoble, France
Orbital Acceleration Research Experiment (OARE)	To accurately measure low-frequency nanogravity on-orbit acceleration disturbances caused by atmospheric leaks, gravity gradients, converging orbital accelerations, out-of-orbital-plane movements, angular velocity, and other emissions[314]	Richard DeLombard, Project Scientist, Lewis Research Center, Cleveland, OH
SAMS	To accurately measure residual accelerations and vibrations that could affect sensitive microgravity investigations[315]	Richard DeLombard, Project Scientist, Lewis Research Center
Middeck Glovebox Experiments		
Comparative Soot Diagnostics (CSD)	To examine the particulate formation from a variety of	David L. Urban, Lewis Research Center

[312] "Critical Fluid Light Scattering Experiment (ZENO)," *http://liftoff.msfc.nasa.gov/shuttle/sts-75/usmp-3/exp/Zeno.html* (accessed January 31, 2006).
[313] Isothermal Dendritic Growth Experiment (IDGE)," *http://liftoff.msfc.nasa.gov/shuttle/sts-75/usmp-3/exp/IDGE.html* (accessed January 31, 2006).
[314] "Orbital Acceleration Research Experiment (OARE)," *http://liftoff.msfc.nasa.gov/shuttle/sts-75/usmp-3/exp/OARE.html* (accessed January 31, 2006).
[315] "Space Acceleration Measurement System (SAMS)," *http://liftoff.msfc.nasa.gov/shuttle/sts-75/usmp-3/exp/SAMS.html* (accessed January 31, 2006).

Investigation	Objective	Principal Investigator
	particulate sources and to quantify the performance of several diagnostic techniques[316]	
Flow Flamespreading Test (FFT)	To identify the effect of low-speed flows and bulk fuel temperature on the flammability, ignition, flame growth, and flame-spreading behavior of solid fuels in a microgravity environment[317]	Kurt R. Sacksteder, Lewis Research Center, Cleveland, OH
Radiative Ignition and Transition to Spread Investigation (RITSI)	To conduct an experimental study of the radiative ignition and subsequent transition to flame spread in low gravity in the presence of very low-speed air flows in two-dimensional and three-dimensional configurations[318]	Takashi Kashiwagi, National Institute for Standards and Testing, Gaithersburg, MD

Source: "United States Microgravity Payload-3 (USMP-3)," *http://liftoff.msfc.nasa.gov/Shuttle/STS-75/usmp-3/usmp-3.html* (accessed January 31, 2006).

[316] "Comparative Soot Diagnostics (CSD)," *http://liftoff.msfc.nasa.gov/shuttle/sts-75/usmp-3/exp/CSD.html* (accessed January 31, 2006).
[317] "Forced Flow Flamespreading Test (FFFT)," *http://liftoff.msfc.nasa.gov/shuttle/sts-75/usmp-3/exp/FFFT.html* (accessed January 31, 2006).
[318] "Radiative Ignition and Transition to Spread Investigation (RITSI)," *http://liftoff.msfc.nasa.gov/shuttle/sts-75/usmp-3/exp/RITSI.html* (accessed January 31, 2006).

Table 2-105. USMP-4 Investigations

Investigation	Objective	Principal Investigator
Cargo Bay MPESS Experiments		
AADSF 1) Compound Semiconductor Growth in a Low-g Environment 2) Growth of Solid Solution Single Crystals	To determine how gravity-driven convection affects the composition and properties of alloys	Archibald Fripp, Jr., LRC Sandor Lehoczky, MSFC
Confined Helium Experiment (CHeX)	To study one of the basic influences on the behavior and properties of materials by using liquid helium, confined between solid surfaces, and the microgravity environment of space	John Lipa, Stanford University, Stanford, CA
IDGE	To study the dendritic solidification of molten materials in the microgravity environment	Martin E. Glicksman, Rensselaer Polytechnic Institute, Troy, NY
MEPHISTO In Situ Monitoring of Crystal Growth Using MEPHISTO	To explore the effect of directional solidification in microgravity on the temperature, velocity, and shape of the solidification front of samples growing under identical conditions	Reza Abbashian, University of Florida, Gainesville, FL
OARE	To accurately measure quasi-steady accelerations aboard the Space Shuttle and sense disturbances caused by mass emissions from the orbiter and by payload bay activities	Melissa J. B. Rogers, Project Scientist, Tal-Cut Company, Lewis Research Center
SAMS	To sense and record vibrations at several locations during a Space Shuttle mission	Melissa J. B. Rogers, Project Scientist, Tal-Cut Company, Lewis Research Center
Microgravity Glovebox Facility (MGBX) Experiments		
Enclosed Laminar Flames (ELF)	To improve our fundamental understanding of the effects of the flow environment on flame stability[319]	Lea-Der Chen, University of Iowa, Iowa City, IA Dennis Stocker, Lewis Research Center
Particle Engulfment and Pushing by a Solid/Liquid Interface (PEP)	To obtain a fundamental understanding of the interaction between the interface and the particles and thereby propose methods and techniques for	Doru Stefanescu, University of Alabama, Tuscaloosa, AL Subhayu Sen and Brij Dhindaw, USRA, MSFC

[319] "Enclosed Laminar Flames (ELF), *http://liftoff.msfc.nasa.gov/shuttle/usmp4/science/elf_obj.html* (accessed February 1, 2006).

Investigation	Objective	Principal Investigator
	processing superior composite materials[320]	
Wetting Characteristics of Immiscibles (WCI)	To use transparent materials to simulate a molten metal so scientists can see how the liquids interact with each other and with their container[321]	Barry Andrews, University of Alabama at Birmingham, Birmingham, AL

Source: "The Fourth United States Microgravity Payload," *http://liftoff.msfc.nasa.gov/shuttle/usmp4/brochure.pdf* (accessed February 1, 2006).

[320] "Particle Engulfment & Pushing by a Solid/Liquid Interface (PEP)," *http://liftoff.msfc.nasa.gov/shuttle/usmp4/science/pep_obj.html* (accessed February 1, 2006).
[321] Wetting Characteristics of Immiscibles (WCI)," *http://liftoff.msfc.nasa.gov/shuttle/usmp4/science/wci_obj.html* (accessed February 1, 2006).

Table 2-106. Spacelab D-2 Investigations

Materials Science Experiment Double Rack for Experiment Modules and Apparatus (MEDEA)
Cellular-Dendritic Solidification with Quenching of Aluminum-Lithium Alloys
Diffusion of Nickel in Liquid Copper-Aluminum and Cooper-Gold Alloys
Directional Solidification of Ge/GaAs Eutectic Composites
Floating-Zone Crystal Growth of Gallium-Doped Germanium
Floating-Zone Growth of GaAs
Growth of GaAs from Gallium Solutions
Hysteresis of the Specific Heat CV During Heating and Cooling Through the Critical Point
Thermoconvection at Dendritic-Eutectic Solidification of an Al-Si Alloy
Werkstofflabor (WL) Material Sciences Laboratory
Cellular-Dendritic Solidification at Low Rate of Aluminum-Lithium Alloys
Convective Effects on the Growth of GaInSb Crystals
Crystallization of Nucleic Acids and Nucleic Acid-Protein Complexes
Crystallization of Ribosomal Particles
Directional Solidification of the LiF-LiBaF3-Eutectic
Heating and Remelting of an Allotropic Fe-C-Si Alloy in a Ceramic Skin and the Effect of the Volume Change on the Mold’s Stability
Higher Modes and Their Instabilities of Oscillating Marangoni Convection in a Large Cylindrical Liquid Column
Immiscible Liquid Metal Systems
Impurity Transport and Diffusion in InSb Melt Under Microgravity Environment
Liquid Columns’ Resonances
Marangoni Convection in a Rectangular Cavity
Marangoni-Benard Instability
Nucleation and Phase Selection During Solidification of Undercooled Alloys
Onset of Oscillatory Marangoni Flows
OSIRIS: Oxide Dispersion Strengthened Single Crystalline Alloys Improved by Resolidification in Space
Separation Behavior of Monotectic Alloys
Solution Growth of GaAs Crystals Under Microgravity
Stability of Long Liquid Columns
Stationary Interdiffusion in a Non-Isothermal Molten Salt Mixture
Transport Kinetics and Structure of Metallic Melts
Vapor Growth of InP-Crystal with Halogen Transport in a Closed Ampoule
Holographic Optics Laboratory (HOLOP)
IDILE: Measurements of Diffusion Coefficients in Aqueous Solution
Interferometric Determination of the Differential Interdiffusion Coefficient of Binary Molten Salts
Marangoni Convection in a Rectangular Cavity
NUGRO: Phase Separation in Liquid Mixtures with Miscibility Gap

Baroreflex (BA)
Residual Acceleration in Spacelab D2
Transfer Function Experiment
Robotics Experiment (ROTEX)
Anthrorack (AR)
Adaptation to Microgravity and Readaptation to Terrestrial Conditions
Cardiovascular Regulation at Microgravity
Cardiovascular Regulation in Microgravity
Central Venous Pressure During Microgravity
Changes in the Rate of Whole-Body Nitrogen Turnover, Protein Synthesis, and Protein Breakdown Under Conditions of Microgravity
Determination of Segmental Fluid Content and Perfusion
Effects of Microgravity on Glucose Tolerance
Effects of Microgravity on the Dynamics of Gas Exchange, Ventilation, and Heart Rate in Submaximal Dynamic Exercise
Effects of Spaceflight on Pituitary-Gonad-Adrenal Function in the Humans
Left Ventricular Function at Rest and Under Stimulation
Leg Fluid Distribution at Rest and Under Lower-Body Negative Pressure
Peripheral and Central Hemodynamic Adaptation to Microgravity During Rest, Exercise, and Lower-Body Negative Pressure in Humans
Pulmonary Perfusion and Ventilation in Microgravity Rest and Exercise
Regulation of Volume Homeostasis in Reduced Gravity, Possible Involvement of Atrial Natriuretic Factor Urodilatin and Cyclic GMP
Tissue Thickness and Tissue Compliance Along Body Axis Under Microgravity Conditions
Tonometry–Intraocular Pressure in Microgravity
Ventilation Distribution in Microgravity
Biolabor (BB)
Antigen-Specific Activation of Regulatory T-Lymphocytes to Lymphokine Production
Comparative Investigations of Microgravity Effects on Structural Development and Function of the Gravity-Perceiving Organ of Two Water-Living Vertebrates
Connective Tissue Biosynthesis in Space: Gravity Effects on Collagen Synthesis and Cell Proliferation of Cultured Mesenchymal Cells
Culture and Electrofusion of Plant Cell Protoplasts Under Microgravity: Morphological/Biochemical Characterization
Development of Vestibulocular Reflexes in Amphibians and Fishes with Microgravity Experience
Enhanced Hybridoma Production Under Microgravity
Fluctuation Test on Bacterial Cultures
Gravisensitivity of Cress Roots
Growth of Lymphocytes Under Microgravity Conditions
Immunoelectron Microscopic Investigation of Cerebellar Development at Microgravity
Influence of Conditions in Low-Earth Orbit on Expression and Stability of Genetic Information in

Bacteria
Influence of Gravity on Fruiting Body Development of Fungi
Productivity of Bacteria
Significance of Gravity and Calcium Ions on the Production of Secondary Metabolites in Cell Suspensions
Structure and Function-Related Neuronal Plasticity of the Central Nervous System of Aquatic Vertebrates During Early Ontogenetic Development Under Microgravity Conditions
Yeast Experiment HB-L29/Yeast: Investigations on Metabolism
Cosmic Radiation Experiments
Biological Hze-Particle Dosimetry with Biostack
Biological Response to Extraterrestrial Solar UV Radiation and Space Vacuum
Chromosome Aberration
Measurement of the Radiation Environment Inside Spacelab at Locations Which Differ in Shielding Against Cosmic Radiation
Personal Dosimetry: Measurement of the Astronaut’s Ionizing Radiation Exposure
User Support Structure Payloads
Atomic Oxygen Exposure Tray (AOET)
Galactic Ultrawide-Angle Schmidt System (GAUSS)
Gas Bubbles in Glass Melts
Material Science Autonomous Payload (MAUS)
Module Optoelectronic Multispectral Stereo Scanner (MOMS)
Pool Boiling
Reaction Kinetics in Glass Melts Payload (RKGM)

Source: “Space Shuttle Mission STS-55 Press Kit,” February 1993, pp. 15–38, *http://www.jsc.nasa.gov/history/shuttle_pk/pk/Flight_055_STS-055_Press_Kit.pdf* (accessed February 1, 2006).

Table 2-107. Spacelab D-2 Payload

Facility	Contributor
Materials Sciences	
Holographic Optics Laboratory (HOLOP)	RWTH Aachen
Materialwissenschaftliche Autonome Experimente unter Schwerelosigkeit (MAUS)	University of Clausthal-Zellerfeld
Materials Sciences Experiment Double-Rack for Experiment Modules and Apparatus (MEDEA)	DLR, Cologne, Germany
Parabolic-Ellipsoid Heating Facility (ELI)	University of Freiburg
Gradient Furnace with Quenching Device (GFQ)	University of Hamburg/ACCESS
High Precision Thermostat (HPT)	Technical University of Munich
Werkstofflabor (WL)	DLR, Cologne, Germany
Advanced Fluid Physics Module (AFPM)	ESA
Cryostat (CRY)	Free University of Berlin
Gradient Heating Facility (GHF)	CNES
Heating Facility for Turbine Blade-Line Technology (HFT)	University of Hamburg/DLR, Cologne, Germany
High Temperature Thermostat (HTT)	Technical University of Berlin
Isothermal Heating Facility (IHF)	University of Hamburg/DLR, Cologne, Germany
Life Sciences	
Anthrorack	ESA
Baroreflex	NASA
Biolab	DLR, Cologne, Germany
Radiation Complex	DLR, Cologne, Germany
Technology Experiments	
Crew Telesupport Experiment (CTE)	ESA
Microgravity Measurement Assembly (MMA)	ESA
Robotic Technology Experiment (ROTEX)	DLR, Cologne, Germany
Astronomy/Earth Observations	
Galaktisches Ultraweitwinkel Schmidt System (GAUSS)	University of Bochum
Modular Opto-electronic Multispectral Scanner (MOMS)	DLR, Cologne, Germany
Outside Experiments	
Atomic Oxygen Exposure Tray (AOET)	DLR, Cologne, Germany
Bremen Universität Satellite (BREMSAT)	ZARM Technik AG

Source: "ESA-D-2: The European Space Agency's Role in the German D-2 Spacelab Mission," ESA Public Relations, NASA History Division folder 008888, Historical Reference Collection, NASA Headquarters, Washington, DC.

Table 2-108. SIR-C/X-SAR System Characteristics

Parameter	L-Band	C-Band	X-Band
Wavelength	0.235 m (0.77 ft)	0.058 m (0.19 ft)	0.031 m (0.10 ft)
Swath Width	15–90 km (9–56 mi)	15–90 km (9–56 mi)	15–40 km (9–25 mi)
Pulse Length	33.8, 16.9, 8.5	33.8, 16.8, 8.5	40
Data Rate	90 Mbits/sec	90 Mbits/sec	45 Mbits/sec
Data Format	8,4 bits/word (8,4) BFPQ[322]	8,4 bits/word (8,4) BFPQ	8,4 bits/word (8,4) BFPQ

Source: "What Is SIR-C/X-SAR?" *http://southport.jpl.nasa.gov/desc/SIRCdesc.html* (accessed February 2, 2006).

[322] BFPQ—Block Floating Point Quantization—is a form of data compression from 8 bits per sample to 4 bits per sample.

Table 2-109. SIR-C/X-SAR Discipline Areas and Supersites

Discipline	Supersites	Backup Supersites
Calibration	Flevoland, the Netherlands; Kerang, Australia; Oberpfaffenhofen, Germany; Western Pacific (rain experiment)	Matera, Italy; Sarobetsu, Japan; Palm Valley, Australia; Eastern Pacific
Ecology	Manaus, Brazil; Raco, MI; Duke Forest, NC	Amazon Survey, Brazil; Prince Albert, Saskatchewan, Canada; Howland, ME; Altona, Manitoba, Canada
Electromagnetic Theory	Safsaf, Sudan	
Geology	Galapagos Islands, Sahara; Death Valley, CA; Andes Mountains, Chile	Hawai'i; Saudi Arabia; Hotien East, China
Hydrology	Chickasha, OK; Ötztal, Austria; Bebedouro, Brazil; Montespertoli, Italy	Mahantango, PA; Mammoth Mountain, CA
Oceanography	East-North Atlantic Gulf Stream, Southern Ocean	Equatorial Pacific, North Sea

Source: "SIR-C/X Supersites," *http://southport.jpl.nasa.gov/cdrom/sirced03/cdrom/DOCUMENT/HTML/SLIDES/MODULE03/SUPERSIT.HTM* (accessed January 17, 2007).

Table 2-110. LITE Geophysical Parameters

Tropospheric Aerosols	Stratospheric Aerosols	Clouds	Surface Reflectance
Aerosol scattering ratio and wavelength dependence	Aerosol scattering ratio and wavelength dependence	Vertical distribution, multilayer structure	Albedo
PBL height and structure	Averaged integrated backscatter	Fractional cloud cover	Multiangle backscatter (+/–30 degrees)
PBL optical depth	Stratospheric density and temperature	Optical depth	—

Source: "LITE Overview," *http://www-lite.larc.nasa.gov/n_overview.html* (accessed January 24, 2007).

Table 2-111. Spacelab-Mir Science Investigations

Investigation	Investigators[323]
Metabolic Research	
Dynamics of Calcium Metabolism and Bone Tissue	Helen Lane, V. Ogonov, Irina Popova
Fluid and Electrolyte Homeostasis and Its Regulation	Helen Lane, Anatoly Grigoriev
Humoral Immunity	Clarence Sams, Irina Konstantinova
Metabolic Response to Exercise	Helen Lane, Irina Popova
Metabolism of Blood Cells	Helen Lane, Svetlana Ivanova
Peripheral Mononuclear Cells	Clarence Sams, Irina Konstantinova
Physiologic Alterations and Pharmacokinetic Changes During Space Flight	Lakshmi Putcha, I. Goncharov
Red Blood Cell Mass and Survival	Helen Lane, Svetlana Ivanova
Renal Stone Assessment	Peggy Whitson, German Arzamozov, Sergey Kreavoy
Viral Reactivation	Duane Pierson, Irina Konstantinova
Cardiovascular and Pulmonary Research	
Evaluation of Thermoregulation During Spaceflight	Suzanne Fortney, Valeriy Mikhaylov
Maximal Aerobic Capacity Using Graded Bicycle Ergometry	Steven Siconolfi, Suzanne Fortney, Valeriy Mikhaylov, Alexander Kotov
Physiological Responses During Descent of Space Shuttle	John Charles, Valeriy Mikhaylov
Studies of Mechanisms Underlying Orthostatic Intolerance Using Ambulatory Monitoring Baraflex Testing and Valsalva Maneuver	Janice Yelle, John Charles, Valeriy Mikhaylov
Studies on Orthostatic Tolerance With the Use of Lower Body Negative Pressure	John Charles, Valeriy Mikhaylov
Sensory-Motor and Neuromuscular Function and Exercise Research	
Evaluation of Skeletal Muscle Performance and Characteristics	Steven Siconolfi, John McCarthy, Inessa Kozlovskaya, Yury Koryak, N. M. Kharitonov
Eye-Head Coordination During Target Acquisition	M. Reschke, J. Bloomberg, W. Paloski, Boris Shenkman, Inessa Kozlovskaya, L. Kornilova, V. Barmin, A. Sokolov, B. Babayev
Morphological, Histochemical, and Ultrastructural Characteristics of Skeletal Muscle	Daniel Feeback, Boris Shenkman
Posture and Locomotion	J. Bloomberg, W. Paloski, M. Reschke, D. Harm, Inessa Kozlovskaya, A. Voronov, I. Tchekirda, M. Borisov
Hygiene, Sanitation, and Radiation Research	
Inflight Radiation Measurements	G. D. Badwhar, Vladislav Petrov
Measurements of Cytogenetic Effects of Space	T. C. Yang, B. Fedorenko

[323] No institutional affiliations were provided in source material.

Investigation	Investigators[323]
Radiation	
Microbiology	Duanne L. Pierson, Richard Sauer, Natalia Novokova, Vladimir Skuratov
Trace Chemical Contamination	John James, Richard Sauer, L. Mukhamedieva, Yuri Sinyak
Microgravity Research	
Protein Crystallization Methods	Stan Koszelac, Alexander Malkin, O. Mitichkin
Space Acceleration Measurement System	Richard DeLombard, S. Tyaboukha
Behavior and Performance Research	
The Effectiveness of Manual Control During Simulation of Flight Tasks (PILOT)	Deborah L. Harm, V. P. Salnitskiy
Fundamental Biology Research	
Incubator	Biospecimen Sharing Program, T. S. Guryeva, Olga Dadasheva

Source: George C. Nield and Pavel Mikhailovich Vorobiev, eds., “Phase 1 Program Joint Report,” NASA Special Publication-6108 (in English), January 1999, pp. 257–264, *http://spaceflight.nasa.gov/history/shuttle-mir/references/documents/phase1-joint-report.pdf* (accessed February 2, 2006). Also “Spacelab-*Mir*,” brochure, NASA History Division folder 008895, Historical Reference Collection, NASA Headquarters, Washington, DC.

Table 2-112. LMS Investigations

Investigation	Principal Investigator
Microgravity Science–Advanced Gradient Heating Facility (AGHF)	
Coupled Growth in Hypermonotectics	J. Barry Andrews, University of Alabama at Birmingham, Birmingham, AL
Directional Solidification of Refined Al–1.5 wt. % Ni Alloys	Henri Nguyen Thi, Université d'Aix-Marseille III, Marseille, France
Directional Solidification of Refined Al–4 wt. % Cu Alloys	Denis Camel, DEM/SES, Grenoble, France
Effects of Convection on Interface Curvature During Growth of Concentrated Ternary Compounds	Thierry Duffar, DEM/SES, Grenoble, France
Interactive Response of Advancing Phase Boundaries to Particles	Ulrike Hecht, ACCESS, Aachen, Germany
Particle Engulfment and Pushing by Solidifying Interfaces	Doru Stefanescu, University of Alabama, Tuscaloosa, AL
Microgravity Science–Advanced Protein Crystallization Facility	
Analysis of Thaumatin Crystals Grown on Earth and in Microgravity	Alexander McPherson, University of California, Irvine, Irvine, CA
Comparative Analysis of Aspartyl tRA-Synthetase and Thaumatin Crystals Grown on Earth and in Microgravity	Richard Giegé, CNRS, Strasbourg, France
Crystallization and X-Ray Analysis of 5S rRNA and the 5S rRNA Domain A	Volker Erdmann, Free University of Berlin, Berlin, Germany
Crystallization in a Microgravity Environment of CcdB, a Protein Involved in the Control of Cell Death	Lode Wyns, Free University of Brussels, Brussels, Belgium
Crystallization of Apocrustacyanin C1	Naomi Chayen, Imperial College, London, England
Crystallization of EGFR-EGF	Christian Betzel, European Molecular Biology Lab, Hamburg, Germany
Crystallization of Photosystem I	Wolf Schubert, Free University of Berlin, Berlin, Germany
Crystallization of *Sulfolobus solfataricus*	Adriana Zagari, University of Naples, Naples, Italy
Crystallization of the Nucleosome Core Particle	Timothy Richmond, ETH Zürich, Zürich, Switzerland
Growth of Lysozyme Crystals at Low Nucleation Density	Juan Garcia-Ruiz, University of Granada, Granada, Spain
Lysosome Crystal Growth in the Advanced Protein Crystallization Facility Monitored via Mach-Zehnder Interferometry and CCD Video	John Helliwell, University of Manchester, Manchester, England
Mechanism of Membrane Protein Crystal Growth: Bacteriorhodopsin–Mixed Micelle Packing at the Consolution Boundary, Stabilized in Microgravity	Gottfried Wagner, Justus-Liebig Universität, Giessen, Germany

Investigation	Principal Investigator
Microgravity Science: Bubble, Drop, and Particle Unit (BDPU)	
Boiling on Small Plate Heaters Under Microgravity and a Comparison with Earth Gravity	Johannes Straub, Technical University Munich, Munich, Germany
Bubbles and Drop Interaction with Solidification Front	Rodolfo Monti, Università degli Studi di Napoli, Naples, Italy
A Liquid Electrohydrodynamics Experiment	Dudley Saville, Princeton University, Princeton, NJ
Nonlinear Surface Tension Driven Bubble Migration	Antonio Viviani, Seconda Università di Napoli, Naples, Italy
Oscillatory Thermocapillary Instability	Jean-Claude Legros, Université Libre de Bruxelles, Brussels, Belgium
Thermocapillary Convection in Multilayer Systems	Jean-Claude Legros, Université Libre de Bruxelles, Brussels, Belgium
Thermocapillary Migration and Interactions of Bubbles and Drops	Shankar Subramanian, Clarkson University Potsdam, NY
Microgravity Science: Accelerometers–Characterizing the Microgravity Environment	
Microgravity Measurement Assembly (MMA)	Maurizio Nati, Project Manager, ESA European Space Research and Technology Center, Noordwijk, the Netherlands
Orbital Acceleration Research Experiment (OARE)	Roshanak Hakimzadeh, Project Scientist, NASA Lewis Research Center, Cleveland, OH
Space Acceleration Measurement System (SAMS)	Roshanak Hakimzadeh, Project Scientist, NASA Lewis Research Center, Cleveland, OH
Life-Sciences Experiments: Animal Enclosure Module	
Role of Corticosteroids in Bone Loss During Spaceflight	Tom Wronski, University of Florida, Gainesville, FL
Life-Sciences Experiments–Johnson Space Center Human Physiology Experiments: ***Musculoskeletal Investigations***	
An Approach to Counteract Impairment of Musculoskeletal Function in Space (Ground Study)	Dr. Per Tesch, Karolinska Institute, Stockholm, Sweden
Direct Measurement of the Initial Bone Response to Spaceflight in Humans	Christopher Cann, University of California, San Francisco, San Francisco, CA
Effects of Microgravity on Skeletal Muscle Contractile Properties	Paolo Cerretelli, Université de Genève, Geneva, Switzerland
Effects of Microgravity on the Biomechanical and Bioenergetic Characteristics of Human Skeletal Muscle	Pietro di Prampero, Università degli Studi di Udine, Udine, Italy
Effects of Weightlessness on Human Single Muscle Fiber Function	Robert Fitts, Marquette University, Milwaukee, WI
Magnetic Resonance Imaging After Exposure to Microgravity (Ground Study)	Adrian LeBlanc, Methodist Hospital, Houston, TX

Investigation	Principal Investigator
Relationship of Long-Term Electromyographic Activity and Hormonal Function to Muscle Atrophy and Performance	Dr. V. Reggie Edgerton, University of California, Los Angeles, Los Angeles, CA
Life-Sciences Experiments–Johnson Space Center Human Physiology Experiments: Metabolic Investigations	
Measurement of Energy Expenditures During Spaceflight Using the Doubly Labeled Water Method	Peter Stein, University of Medicine and Dentistry of New Jersey, Stratford, NJ
Life-Sciences Experiments–Johnson Space Center Human Physiology Experiments: Pulmonary Investigations	
Extended Studies of Pulmonary Function in Weightlessness	John B. West, University of California, San Diego, La Jolla, CA
Life-Sciences Experiments–Johnson Space Center Human Physiology Experiments: Human Behavior and Performance Investigations	
Human Sleep, Circadian Rhythms and Performance in Space	Timothy Monk, University of Pittsburgh, Pittsburgh, PA
Microgravity Effects on Standardized Cognitive Performance Measures	Sam Schiflett, USAF Armstrong Laboratory, Brooks Air Force Base, TX
Life-Sciences Experiments–Johnson Space Center Human Physiology Experiments: Neuroscience Investigations	
Torso Rotation Experiment	Douglas Watt, McGill University, Montreal, Quebec, Canada
Canal and Otolith Integration Studies (COIS)	Millard Reschke, NASA Johnson Space Center, Houston, TX
Life-Sciences Experiments: Plant Growth Facility (PGF)	
Compression Wood Formation in a Microgravity Environment	Norman Lewis, Washington State University, Pullman, WA
Space Tissue Loss Configuration B (SLB-B)	
Development of the Fish Medaka in Microgravity	Debra Wolgemuth, Columbia College of Physicians and Surgeons, New York, NY

Source: J. P. Downey, compiler, Life and Microgravity Spacelab (LMS) Final Report, NASA Contractor Publication CP-1998-206960, February 1998. Also "Space Shuttle Mission STS-78 Press Kit," June 1996, pp. 15–27, *http://www.jsc.nasa.gov/history/shuttle_pk/pk/Flight_078_STS-078_Press_Kit.pdf* (accessed February 5, 2006).

Table 2-113. MSL-1 Investigations

Investigation	Principal Investigator/Hardware Developer
Large Isothermal Furnace (LIF) Hardware Developer: Toshihiko Oida, NASDA Project Scientists: Shinichi Yoda, NASDA; Thomas Glasgow and Alfonso Velosa, Lewis Research Center	
Diffusion in Liquid Lead-Tin-Telluride	Misako Uchida, Ishikawajima-Harima Heavy Industries, Tokyo, Japan
Diffusion of Liquid Metals	Toshio Itami, Hokkaido University, Sapporo, Japan
Diffusion Processes in Molten Semiconductors	David N. Matthiesen, Case Western Reserve University, Cleveland, OH
Impurity Diffusion in Ionic Metals	Tsutomu Yamamura, Tohoku University, Sendai, Japan
Liquid Phase Sintering II	Randall German, Pennsylvania State University, University Park, PA
Measurement of Diffusion Coefficient by Shear Cell Method	Shinichi Yoda, NASDA, Tsukuba, Japan
Expedite the Processing of Experiments to the Space Station (EXPRESS) Rack Hardware Developer: Annette Sledd, MSFC	
Astro/Plant Generic Bioprocessing Apparatus (AstroPGBA)	Louis Stodieck, University of Colorado, Boulder, CO
Physics of Hard Sphere Experiment	Paul Chaikin, Princeton University, Princeton, NJ
Electromagnetic Containerless Processing Facility (TEMPUS) Hardware Developer: Wolfgang Dreier, DARA Project Scientists: Ivan Egry, DLR; Jan Rogers, MSFC	
AC Calorimetry and Thermophysical Properties of Bulk Glass-Forming Metallic Liquids	W. L. Johnson, California Institute of Technology, Pasadena, CA
Alloy Undercooling Experiments	Merton Flemings, Massachusetts Institute of Technology, Cambridge, MA
Experiments on Nucleation in Different Flow Regimes	Robert Bayuzick, Vanderbilt University, Nashville, TN
Measurement of Surface Tension and Viscosity of Undercooled Liquid Metals	Julian Szekely, Merton Flemings, and Gerardo Trapaga, Massachusetts Institute of Technology, Cambridge, MA
Measurement of the Surface Tension of Liquid and Undercooled Metallic Melts by Oscillating Drop Technique	Martin G. Grohberg, Technical University, Berlin, Germany
Study of the Morphological Stability of Growing Dendrites by Comparative Dendrite Velocity Measurements on Pure Ni and a Dilute Ni-C Alloy in the Earth and Space Laboratory	D. M. Herlach, DLR, Cologne, Germany
Thermal Expansion of Glass Forming Metallic Alloys in the Undercooled State	K. Samwer, Institute for Physics, University of Augsburg, Germany
Thermophysical Properties of Advance	Hans F. Fecht, Technical University, Berlin, Germany

Investigation	Principal Investigator/Hardware Developer
Materials in the Undercooled Liquid State	
Thermophysical Properties of Undercooled Metallic Melts	Ivan Egry, German Aerospace Research Establishment (DLR, Cologne, Germany)
Undercooled Melts of Alloys with Polytetrahedral Short-Range Order	D. M. Herlach, DLR, Cologne, Germany
Combustion Module-1 (CM-1)	
Laminar Soot Processes	Gerard Faeth, University of Michigan, Ann Arbor, MI
Structure of Flame Balls at Low Lewis Number (SOFBALL)	Paul Romney, University of Southern California, Los Angeles, CA
Droplet Combustion Apparatus Hardware Developer: John B. Haggard, Lewis Research Center Project Scientist: Vedha Nayagam, Analex Corporation	
Droplet Combustion Experiment	Forman Williams, University of California, San Diego, San Diego, CA
Fiber-Supported Droplet Combustion	Forman Williams, University of California, San Diego, San Diego, CA
Middeck Glove Box Hardware Developer: David Jex, MSFC Project Scientist: Don Reiss, MSFC	
Bubble and Drop Nonlinear Dynamics	L. G. Leal, University of California, Santa Barbara, Santa Barbara, CA
Coarsening in Solid-Liquid Mixtures	Peter Voorhees, Northwestern University, Chicago, IL
Internal Flows in a Free Drop	S. S. Sadhal, University of Southern California, Los Angeles, CA
A Study of Fundamental Operation of a Capillary-driven Heat Transfer (CHT) Device in Microgravity	Kevin P. Hallinan, University of Dayton, Dayton, OH
Protein Crystallization Apparatus	
Handheld Diffusion Test Cells	Alexander McPherson, University of California, Riverside, Riverside, CA Hardware Developer: Ron King, MSFC Project Scientist: Bill Witherow, MSFC
Protein Crystallization Apparatus for Microgravity	Dan Carter, New Century Pharmaceuticals, Huntsville, AL Hardware Developer: Keith Higginbotham, MSFC Project Scientist: Robert Snyder, MSFC
Second Generation Vapor Diffusion Apparatus	Larry DeLucas, Center for Macromolecular Crystallography, University of Alabama at Birmingham Hardware Developer: John Nordness, Center for Macromolecular Crystallography Project Scientist: Laurel Karr, NASA Marshall Space

Investigation	Principal Investigator/Hardware Developer
	Flight Center
Measuring Microgravity	
Microgravity Measurement Assembly (MMA)	Project Scientist: Hans Hamacher, German Aerospace Research Establishment, DLR, Cologne, Germany Hardware Developer: Maurizio Nati, ESA
Orbital Acceleration Research Experiment (OARE)	Project Scientist: Peter Tschen, Lewis Research Center Hardware Developer: William Wagar, Lewis Research Center
Quasi-Steady Acceleration Measurement (QSAM)	Project Scientist: Hans Hamacher, German Aerospace Research Establishment, DLR, Cologne, Germany Hardware Developer: Hans-Ewald Richter, German Aerospace Research Establishment, DLR, Cologne, Germany
Space Acceleration Measurement System (SAMS)	Project Scientist: Peter Tschen, Lewis Research Center Hardware Developer: Ron Sicker, Lewis Research Center

Source: "Space Shuttle Mission STS-94 Press Kit," pp. 19–30, *http://www.jsc.nasa.gov/history/shuttle_pk/pk/Flight_085_STS-094_Press_Kit.pdf* (accessed February 5, 2006). Also "NASA's Microgravity Science Laboratory: Illuminating the Future," NASA Marshall Space Flight Center Payload Projects Office, NASA History Division folder 17676, Historical Reference Collection, NASA Headquarters, Washington, DC. Also at *http://liftoff.msfc.nasa.gov/shuttle/msl/brochure.pdf* (accessed February 7, 2006).

Table 2-114. Neurolab Investigations

Investigation	Principal Investigator
Blood Pressure Control	
Blood Pooling and Plasma Filtration in the Thigh in Microgravity (Artificial Neural Networks and Cardiovascular Regulation)	Friedhelm J. Baisch, DLR Institute of Aerospace Medicine, Cologne, Germany
The Human Sympathetic Nervous System Response to Spaceflight (Autonomic Neurophysiology in Microgravity)	David Robertson, Vanderbilt University, Nashville, TN
The Influence of Microgravity on Arterial Baroreflex Responses Triggered by Valsalva's Maneuver (Autonomic Neuroplasticity in Weightlessness)	Dwain L. Eckberg, Virginia Commonwealth University, Richmond, VA
Neural Control of the Cardiovascular System in Space (Integration of Neural Cardiovascular Control in Space)	C. Gunnar Blomqvist, University of Texas Southwestern Medical Center, Dallas, TX
Sensory Integration and Navigation	
The Brain as a Predictor: On Catching Flying Balls in Zero-g (Frames of Reference and Internal Models)	Alain Berthoz, CNRS/College de France, Paris, France
Ensemble Neural Coding of Place in Zero-g	Bruce L. McNaughton, University of Arizona, Tucson, AZ
The Role of Visual Cues in Microgravity Spatial Orientation	Charles M. Oman, Massachusetts Institute of Technology, Cambridge, MA
Visual-Motor Coordination During Spaceflight	Otmar Bock, German Sport University, Köln, Germany
The Balance System	
The Effect of Spaceflight on the Ultrastructure of the Cerebellum (Anatomical Studies of Central Vestibular Adaptation)	Gay R. Holstein, Mount Sinai School of Medicine, New York, NY
Gene Expression in the Rat Brain During Spaceflight	Ottavio Pompeiano, Università di Pisa, Pisa, Italy
Neural Re-adaptation to Earth's Gravity Following Return from Space (Chronic Recording of Otolith Nerves in Microgravity)	Stephen M. Highstein, Washington University School of Medicine, St. Louis, MO
Ocular Counter-Rolling During Centrifugation and Static Tilt (Spatial Orientation of the Vestibulo-Ocular Reflex)	B. Cohen, Mount Sinai School of Medicine, New York, NY
Perception of the Spatial Vertical During Centrifugation and Static Tilt (Visual-Otolithic Interactions in Microgravity)	G. R. Clement, Centre National de la Recherche Scientifique/College de France, Paris, France
Ribbon Synaptic Plasticity in Gravity Sensors of Rats Flown on Neurolab (Multidisciplinary Studies of Neural Plasticity in Space)	Muriel D. Ross, ARC
Circadian Rhythms, Sleep, and Respiration	
The Effects of Spaceflight on the Rat Circadian	Charles Fuller, University of California at Davis,

Investigation	Principal Investigator
Timing System (Central Nervous System Control of Rhythms and Homeostasis During Spaceflight)	Davis, CA
Sleep and Respiration in Microgravity	John B. West, University of California, San Diego, La Jolla, CA
Sleep, Circadian Rhythms, and Performance During Space Shuttle Missions (Clinical Trial of Melatonin as Hypnotic for Neurolab Crew)	C. Czeisler, Brigham and Women's Hospital, Harvard Medical School, Boston, MA
Nervous System Development in Weightlessness	
Development of an Insect Gravity Sensory System in Space; Crickets in Space (CRISP)	Eberhard R. Horn, University of Ulm, Ulm, Germany
Development of the Aortic Baroreflex in Microgravity (Postnatal Development of Aortic Nerves in Space)	Tsuyoshi Shimizu, Fukushima Medical University School of Medicine, Fukushima, Japan
Development of the Vestibular System in Microgravity (Microgravity and Development of Vestibular Circuits)	Jacqueline Raymond, Université Montpellier II, Montpellier, France
Early Development of Gravity-Sensing Organs in Microgravity (Development of Vestibular Organs in Microgravity)	Michael L. Wiederhold, University of Texas Health Science Center at San Antonio, San Antonio, TX
Effect of Weightlessness on the Developing Nervous System (Reduced Gravity: Effects in the Developing Nervous System)	Richard S. Nowakowski, University of Medicine and Dentistry of New Jersey; Robert Wood Johnson Medical School, Piscataway, NJ
Gravity Plays an Important Role in Muscle Development and the Differentiation of Contractile Protein Phenotype (Neuro-Thyroid Interaction on Skeletal Isomyosin Expression in Zero Gravity)	Kenneth Baldwin, College of Medicine, University of California, Irvine, Irvine, CA
Motor System Development Depends on Experience: A Microgravity Study of Rats (Effects of Gravity on Postnatal Motor Development)	Kerry D. Walton and Rodolfo R. Llinás, New York University School of Medicine, New York, NY
Neural Development Under Conditions of Spaceflight	Kenneth S. Kosik, Brigham and Women's Hospital, Harvard Medical School, Boston, MA
Neuromuscular Development Is Altered by Spaceflight (Effects of Microgravity on Neuromuscular Development)	Danny A. Riley, Medical College of Wisconsin, Milwaukee, WI

Source: Jay C. Buckey, Jr., and Jerry L. Homick, eds., *The Neurolab Spacelab Mission: Neuroscience Research in Space: Results from the STS-90 Neurolab Spacelab Mission* (Washington, DC: NASA SP-535, 2003). Also "Space Shuttle Mission STS-90 Press Kit," April 1998, pp. 16–29, *http://www.jsc.nasa.gov/history/shuttle_pk/pk/Flight_090_STS-090_Press_Kit.pdf* (accessed February 7, 2006). Several investigation titles listed in the press kit, which was published before the mission, differed from those used in the *Neurolab Spacelab Mission*. The titles from the press kit are shown in parentheses in the table. Also "Benefits of Neurolab Science" (Archived Site), *http://web.archive.org/web/20021218070259/http://neurolab.jsc.nasa.gov/benefits.htm* (accessed May 23, 2007).

Chapter 3

Table 3-1. Programmed Budget (FY 1989–1998) (thousands of dollars)

	1989	**1990**	**1991**	**1992**	**1993**	**1994**	**1995**	**1996**	**1997**	**1998**
Aeronautical R&T	309,200	442,598	512,000	788,192	769,362	844,200	823,500	853,900	*844,200*	*920,100*
Transatmospheric R&T	69,400	59,027	95,000	4,100	—	20,000	—	—	—	—
Space R&T	285,900	284,029	286,900	309,172	—	—	—	—	—	—
Advanced Space Transportation[324]	—	—	—	—	114,600	109,100	162,100	234,000	336,700	417,100
Spacecraft and Remote Sensing	—	—	—	—	140,800	183,300	174,900	—	—	—
Flight Programs	—	—	—	—	115,000	140,900	3,500	—	—	—
Space Communications					33,100	—	—	—	—	—
Space Processing	—	—	—	—	31,900	19,500	33,300	—	—	—
Advanced Smallsat Technology	—	—	—	—	—	12,500	61,900	—	—	—
Launch Vehicles Support	—	—	—	—	—	37,100	—[325]	—	—	—
Total Space R&T	285,900	284,029	286,900	309,172	435,400	69,100	95,200	234,000[326]	336,700	417,100

[324] Beginning in FY 1993, space R&T activities were funded by different organizations: the Office of Advanced Concepts and Technology (OACT) until FY 1995, the Office of Space Access and Technology (OSAT) until FY 1997, and the Office of Aeronautics and Space Transportation Technology beginning in FY 1997. These organizations included activities not directly related to space R&T, such as commercial programs and technology transfer. In addition, in some years, all space R&T activities were included in the category of advanced space transportation. In other years, they were several categories shown in addition to advanced space transportation. Whenever possible, this is indicated in the table.
[325] Discontinued as separate budget category. Included with Expendable Launch Vehicles and Services.

	1989	**1990**	**1991**	**1992**	**1993**	**1994**	**1995**	**1996**	**1997**	**1998**
Aeronautics and Space R&T	664,500	785,654	893,900	1,101,464	1,204,762	1,366,600	1,259,200	1,087,900	1,180,900	1,337,200
Change		121,154	108,246	207,564	103,298	161,838	–107,400	–171,300	93,000	156,300
Percent Change	—	15.4	12.1	18.8	8.6	11.8	–8.5	–15.7	*7.9*	*11.7*

[326] Included funding only for Delta Clipper, X-33, X-34, and Advanced Space Transportation programs. Other programs relating to space R&T were redistributed into the Space Science, Mission to Planet Earth, Aeronautics, and Life and Microgravity Sciences programs. This reallocation reflected the distribution of technology into the benefiting programs.

Table 3-2. Aeronautics R&T Funding History (in thousands of dollars)

Year (Fiscal)	Submission	Programmed
1989	414,200/404,200[327]	309,200
1990	462,800/449,756[328]	442,598
1991	512,000/512,000	512,000
1992	591,200/774,600[329]	788,192
1993	890,200/865,587	769,362
1994	1,020,700/1,082,200	844,200
1995	898,500/860,000	823,500
1996	911,900/845,900	865,900
1997	857,800/844,200	844,200
1998	920,100/907,100	920,100

[327] The reduction of $10.0 million resulted from congressional action on the FY 1989 budget request. This reduction was reflected in the advanced composites program under materials and structures systems technology.
[328] The decrease of $13.1 million reflected a $7.3 million general reduction and $5.8 million sequestration.
[329] The net increase of $183.4 million resulted from a reduction of $26.7 million. This included a general reduction of $17.0 million directed by Congress, a reallocation of $9.7 million to transatmospheric R&T, and an increase of $210.0 million for the transfer of research operations support previously funded as operation of installation in the Research and Program Management (R&PM) appropriation.

Table 3-3. R&T Base (Aeronautics) Funding History (in thousands of dollars)

Year (Fiscal)	Submission	Programmed
1989	314,200[330]/315,563[331]	309,563
1990	335,700/326,122	321,764
1991	353,400/336,400[332]	336,400
1992	375,600/360,700	343,297
1993	394,000/436,478[333]	451,547
1994	448,300/418,300	420,300
1995	342,800[334]/366,300[335]	354,300
1996	354,700/350,300	430,600
1997	354,400/404,200	404,200
1998	418,300/428,300	428,300

[330] Included funding for fluid and thermal physics, applied aerodynamics, propulsion and power research, information sciences, controls and guidance, human factors, flight systems R&T, and systems analysis. The increase from the estimate for FY 1988 of $251.6 million to $314.2 million was due to increases in all categories except human factors, which decreased slightly.

[331] In the R&T base, a number of realignments were made as a result of implementing new charging algorithms for program support requirements in the scientific and technical automatic data processing and facilities areas. This change, which allocated costs to benefiting programs, was an outgrowth of the appropriation realignment activity of the previous year. The increase of $1.4 million in the R&T base program reflected the realignment of funding from the numerical aerodynamic simulation program in the systems technology area for priority program requirements in the R&T base.

[332] The R&T base was reduced by $17.0 million, which was reallocated to the systems technology area to support the high-performance computing program.

[333] A new discipline research program for hypersonic research was established to consolidate total funding for these activities and give visibility to the program. The space R&T portion of hypersonic funding ($5.1 million) was reallocated to the aeronautics R&T base.

[334] For FY 1995, the 18 percent reduction in the R&T base resulted from reductions ($47.5 million) to facilities and operations support and technical services along with reductions in the R&T base research activities, discontinuing the one-time adjustment for aeronautics facilities research and development included in FY 1994 into FY 1995 ($19.0 million), and consolidating the Small Business Innovative Research activities ($9.0 million) into the Advanced Concepts and Technology budget.

[335] The rotorcraft industry technology program was eliminated from the R&T base following a review of the program. The hypersonics program was added to the R&T base.

Table 3-4. Systems Technology/Focused Programs (Aeronautics) Funding History (in thousands of dollars)

Year (Fiscal)	Submission	Programmed
1989	100,000[336]/88,637[337]	88,637
1990	127,100/123,634[338]	120,834
1991	158,600/175,600[339]	175,600
1992	215,600/203,800	212,122
1993	253,000/280,284	265,215
1994	428,900[340]/451,900[341]	423,900
1995	533,700/493,700	469,200
1996	557,200/495,600[342]	435,300
1997	503,400/440,000[343]	440,000
1998	501,800/491,800	491,800

[336] This amount included funding for materials and structures systems technology, rotorcraft systems technology, high-performance aircraft systems technology, advanced propulsion systems technology, and numerical aerodynamic simulation. The increase from FY 1998 funding of $83.2 million was due largely to the establishment of a new budget category—advanced composite materials technology in the broader materials and structures systems technology area—and the accompanying funding of $20 million.

[337] The decrease was due to congressional action on the FY 1989 budget request. The decrease was reflected in the advanced composites program under materials and structures systems technology.

[338] A new budget line was established for the high-speed research program (previously included under high-performance aircraft systems technology), reflecting its importance and increased research emphasis. Funding was realigned from the high-performance aircraft systems technology program.

[339] As a result of congressional action on the FY 1991 budget request, NASA was directed to absorb $15.0 million in aeronautics for application to high-performance computing. This $15.0 million, when combined with $2.0 million previously identified by NASA within the aeronautics R&T base for precursor work in high-performance computing, resulted in a total of $17.0 million in FY 1991. The funding was reallocated from the R&T base, and a new program within systems technology was created for high-performance computing.

[340] The increased submission in FY 1994 reflected restructuring to include $10,523,000 transferred from advanced high-temperature engine materials (materials and structures systems technology) into the materials and structures portion of the R&T base, $5.28 million transferred from advanced rotorcraft (rotorcraft systems technology) into the aerodynamics portion of the R&T base, and $9.57 million transferred from high-performance flight research (high-performance aircraft systems technology) transferred into the flight systems portion of the R&T base. Also in the advanced propulsion systems technology program, $15,246,000 was transferred from advanced turboprop systems into advanced subsonic technology and $3,085,000 was transferred from general aviation/commuter engine technology into the materials and structures portion of the R&T base.

[341] The hypersonic technology component of the system technology program moved to the R&T base. Materials and structures systems technology was renamed “advanced composite technology.” This category also included high-performance computing and communications, advanced composite technology, numerical aerodynamic simulation, high-speed research, and advanced subsonic technology programs.

[342] The budget category was renamed “focused programs.” Individual programs remained unchanged, with the exception of advanced composites technology, which was transferred to the composites element of the advanced subsonic technology program. Technology efforts related to the fuselage were transferred into the materials and structures R&T base element. The advanced composite technology program concluded at the end of FY 1995.

[343] This did not include the numerical aerodynamic simulation program, which was included in the information technology segment of the R&T base program.

Table 3-5. Research Operations Support Funding History (in thousands of dollars)[344]

Year (Fiscal)	Submission	Programmed
1992	(281,812)[345]/210,100[346]	232,773
1993	243,200/148,825	—
1994	143,500/—[347]	—

[344] Research Operations Support (ROS) provided support to the civil service workforce and the physical plant at the Centers and NASA Headquarters.
[345] Previously funded in the R&PM appropriation. Reflected congressional reduction in R&PM funds and increase in R&D funds.
[346] Reflected the change from R&PM/Operation of Installation appropriation to Research and Development (R&D) appropriation. FY 1992 congressional action sharply reduced the requested funding for these activities and authorized their transfer into the R&D and SFC&DC appropriations. That transfer allowed the reduction to be accommodated with minimal impact by allowing the programs to fund some of the activities previously covered by R&PM funds.
[347] No submission.

Table 3-6. Construction of Facilities (Aeronautics) Funding History (in thousands of dollars)[348]

Year (Fiscal)	Submission	Programmed
1993	—	52,600
1994	—/212,000	203,000[349]
1995	22,000[350]	22,000[351]

[348] Included National Aeronautical Facilities and Aeronautical Facilities Revitalization.
[349] Included National Aeronautical Facilities ($172 million) and Aeronautical Facilities Revitalization ($25 million).
[350] Aeronautics Facilities Revitalization. Funding for modernization of the Unitary Plan Wind Tunnel Complex at NASA Ames Research Center. National Aeronautical Facilities was made into a separate budget category.
[351] Included Aeronautical Facilities Revitalization, specifically modernization of the Unitary Plan Wind Tunnel Complex at Ames Research Center.

Table 3-7. Transatmospheric R&T (Aeronautics) Funding History (in thousands of dollars)[352]

Year (Fiscal)	Submission	Programmed
1989	84,400/69,400	69,400
1990	127,000/59,027	59,027
1991	119,000/95,000	95,000
1992	72,000/20,000	4,100
1993	80,000/—[353]	—
1994	80,000/20,000[354]	20,000[355]

[352] NASP program.
[353] No revised estimate submitted.
[354] The transatmospheric R&T program concluded in FY 1994. A restructured hypersonic technology program began in FY 1995.
[355] In 1994, Congress directed the conclusion of the NASP program while it was in the technology-development phase.

Table 3-8. National Aeronautical Facilities (Aeronautics) Funding History (in thousands of dollars)

Year (Fiscal)	Submission	Programmed
1995	—/400,000[356]	35,000[357]

[356] Removed from Construction of Facilities and included in a separate budget line item.
[357] The administration decided not to pursue development of the National Wind Tunnel Complex, given anticipated budget constraints. The National Wind Tunnel Project Office at Lewis Research Center completed a Systems Design Review followed by archiving of the collected data and a phase-down of the program.

Table 3-9. Space R&T Funding History (in thousands of dollars)

Year (Fiscal)	Submission	Programmed
1989	390,900[358]/295,900[359]	285,900
1990	338,100/285,871[360]	284,029
1991	532,900[361]/290,400	286,900
1992	421,800[362]/309,000	309,172
1993	332,000/272,729[363]	—
1994	298,200[364]/—[365]	—

[358] The increase from FY 1988 of $167.3 million reflected greater emphasis on focused technology (CSTI and Pathfinder) and university space research programs. See the tables below for further details.
[359] The decrease of $95.0 million reflected congressional action on the FY 1989 budget request.
[360] The reduction reflected congressionally directed decreases in the IN-STEP, CSTI, and exploration technology programs; general budget reduction; and sequestration of funds. See the individual tables below for details.
[361] The funding request reflected the addition of $37.0 million for Exploration Mission Studies to the Space R&T program for consolidation in a single budget element. See the Exploration and Mission Studies funding table below. The increase from the FY 1990 budget request reflected larger amounts for the Exploration Technology and CSTI programs. See the individual funding tables below.
[362] The amount reflected $82.9 million to fund a new budget category of space automation and telerobotics, which was previously part of the CSTI program.
[363] In 1993, the Office of Commercial Programs and the space R&T program merged to create the new OACT. The reduction of $59.3 million was the result of a congressional general reduction of $65.0 million, a reallocation of $5.1 million of hypersonic funding to the aeronautical R&T base, and a reallocation of $0.1 million to research operations support in the aeronautics R&T budget. This was offset by the transfer of $10.9 million due to the redistribution of the research operations support funding program.
[364] This included the R&T base program and CSTI program, which included research in five categories: 1) space science technology thrust, 2) planetary surface technology thrust, 3) transportation technology thrust, 4) space platforms technology thrust, and 5) operations technology thrust.
[365] The space R&T budget category was eliminated. Individual program categories became part of Advanced Concepts and Technology.

Table 3-10. R&T Base (Space) Funding History (in thousands of dollars)

Year (Fiscal)	Submission	Programmed
1989	134,100[366]/134,100	124,100
1990	130,100/124,961	125,033
1991	125,700/125,700[367]	125,688
1992	141,600/141,800[368]	140,850
1993	173,800[369]/158,113[370]	—
1994	160,800/—[371]	—

[366] The R&T base funding category included 1) aerothermodynamics, 2) space energy conversion, 3) propulsion, 4) materials and structures, 5) space data and communications, 6) information sciences, 7) controls and guidance, 8) space human factors, 9) spaceflight, 10) systems analysis, and 11) university space research programs.
[367] Budget categories were realigned as programs in space data and communications R&T, and information sciences R&T. Controls and guidance were combined into one program: information and controls. Human factors R&T was combined with life-support work, previously carried in the space energy conversion R&T program, and renamed human support R&T.
[368] The R&T base programs included 1) aerothermodynamics, 2) space energy conversion, 3) propulsion, 4) materials and structures, 5) spaceflight, 6) in-space technology experiments, 7) systems analysis, 8) university space research, 9) information and controls technology, 10) human support technology, and 11) space communications.
[369] The increase reflected the addition of IN-STEP, formerly a separate budget category.
[370] The decrease of $15.7 million was the net result of the distribution of the appropriations general reduction of $18.5 million, reallocation of $5.1 million of hypersonic research funding to the aeronautics R&T base, and reallocation of $0.1 million to ROS in the Aeronautical R&T budget offset by the transfer of $8.0 million due to the redistribution of ROS funding. The reduction directed by Congress affected planned activities within the NASA Field Centers as well as universities and industry.
[371] The budget category was eliminated.

Table 3-11. IN-STEP Funding History (in thousands of dollars)

Year (Fiscal)	Submission	Programmed
1989	—[372]	19,800
1990	16,200[373]/10,200	10,155
1991	19,800/11,200[374]	11,200
1992	16,000/15,500	15,074
1993	—[375]	—

[372] No budget submission for this category.
[373] New program.
[374] This program was reduced by $8.6 million as a result of congressional action on the FY 1991 budget request, resulting in the delay and/or cancellation of several NASA and industry/university experiments.
[375] Transferred into the R&T base funding category, focused on supporting technology flight experiments selected from announcements of opportunity, and later funded by the flight programs budget.

Table 3-12. CSTI Program Funding History (in thousands of dollars)

Year (Fiscal)	Submission	Programmed
1989	156,800[376]/121,800	121,800
1990	144,500/123,810[377]	121,373
1991	171,00/119,000[378]	119,000
1992	114,300/79,800[379]	82,948
1993	158,200[380]/114,616[381]	—
1994	137,400/—[382]	—

[376] CSTI research focused on technologies to enable reliable and lower-cost access to space and to support space operations and science missions. The funding category included automation and robotics, propulsion, vehicle, information technology, large structures and control, and high-capacity power.
[377] The decrease reflected congressional action on the FY 1990 budget request: a reduction of $17.5 million spread across Earth-to-orbit technology ($8.5 million), telerobotics ($1.0 million), artificial intelligence ($1.0 million), and control of flexible structures ($1.0 million), as well as the deletion of the total effort in booster technology ($6.0 million). In addition, the sequestration resulted in a further reduction of $3.2 million, which included a reduction of $0.7 million in telerobotics, $0.3 million in artificial intelligence, $1.3 million in control of flexible structures, $0.4 million in science sensor technology, and $0.5 million in high rate/capacity data.
[378] CSTI funding was reduced by $52.0 million, which included a decrease of $49.5 million as a result of congressional action on the FY 1991 budget request and a reallocation of $2.5 million to support exploration mission studies. The reduction was accommodated by decreasing the operations area by $5.7 million and the transportation area by $43.8 million. The reallocation of $2.5 million to support exploration mission studies resulted in reductions of $1.5 million from the operations area, $0.8 million from transportation, and $0.2 million from sensor technology in the science area.
[379] The reduction reflected an increase of $1.0 million in CSTI operations and a decrease of $35.5 million in the CSTI transportation area, reflecting the termination of the aeroassist flight experiment in accordance with congressional direction and a reduction of $0.7 million in the Earth-to-orbit propulsion program for reallocation to transatmospheric R&T.
[380] In FY 1993, the CSTI program was restructured to include all elements of the ongoing CSTI, exploration technology, and space automation and telerobotics programs. It focused on research in five thrust areas: 1) space science, 2) planetary surface, 3) transportation, 4) space platforms, and 5) operations. It incorporated elements of the previous exploration technology program and the space automation and telerobotics program.
[381] The reduction of $43.6 million in the CSTI budget was the net result of a congressional reduction of $46.5 million partially offset by a transfer of $2.9 million due to the redistribution of research operations support funding.
[382] The budget category was eliminated.

Table 3-13. Exploration Technology (Pathfinder) Program Funding History (in thousands of dollars)

Year (Fiscal)	Submission	Programmed
1989	100,000[383]/40,000[384]	40,000
1990	47,300[385]/26,900[386]	27,468[387]
1991	179,400[388]/27,500[389]	27,500
1992	52,000/29,000[390]	28,900
1993	—[391]	—

[383] First year of the Pathfinder program. The budget category included programs in exploration technology, operations technology, humans-in-space technology, transfer vehicle technology, and mission studies.
[384] The Pathfinder program was reduced by $60.0 million as a result of congressional action on the FY 1989 budget. This resulted in a change in scope or deferred start-up of essentially all Pathfinder activities.
[385] Added programs in surface exploration and in-space operations, replacing exploration technology and operations technology.
[386] Pathfinder (Exploration Technology) funding was reduced by a total of $20.4 million as a result of congressional action on the FY 1990 budget request. This necessitated reductions in all areas of this program.
[387] The program name changed to Exploration Technology.
[388] This focused technology program was organized into the technology areas of space transportation, in-space operations, surface operations, human support, lunar and Mars science, information systems and automation, nuclear propulsion, and innovative technologies and systems analysis. The increase reflected the initiation of a number of new programs.
[389] The decrease reflected a $151.9 million reduction directed by Congress. This included reductions of $32.0 million in space transportation, $21.0 million in in-space operations, $48.2 million in surface operations, $21.9 million in human support, $3.8 million in lunar and Mars science, $10.5 million in information systems and automation, $10.5 million in nuclear propulsion, and $4.0 million in innovative technologies and exploration technology analysis.
[390] The Exploration Technology program was reduced as a result of congressional action that reduced the program by $25.0 million and provided an additional $2.0 million for laser power beaming research.
[391] In FY 1993, the Exploration Technology program was transferred into two thrusts of the restructured CSTI program, specifically planetary surface technology and transportation technology. The Exploration Technology budget category was eliminated.

Table 3-14. Space Automation and Telerobotics Funding History (in thousands of dollars)

Year (Fiscal)	Submission	Programmed
1991	—[392]	(128,534)
1992	82,900[393]/37,900[394]	37,900
1993	—[395]	—

[392] No submission in this category. Included in the CSTI program.
[393] This budget category included the technology demonstration elements of the flight telerobotics servicer program (previously conducted as part of the Space Station Freedom program) and the telerobotics and artificial intelligence programs (previously conducted as part of the CSTI program).
[394] In FY 1993, the majority of budget items in the space automation and telerobotics funding category, specifically the telerobotics and artificial intelligence categories, transferred into the CSTI operations technology thrust. Funding for the program was reduced by $45.0 million, which reflected the termination of the flight telerobotic servicer program ($55.0) planned for Space Station Freedom, as directed by Congress, with $10.0 million redirected to the telerobotics program for advanced competitive robotics efforts.
[395] The budget category was eliminated.

Table 3-15. Exploration Mission Studies Funding History (in thousands of dollars)

Year (Fiscal)	Submission	Programmed
1991	37,000[396]/7,000[397]	—[398]
1992	15,000[399]/5,000[400]	3,500
1993	31,800[401]/—[402]	—

[396] FY 1991 was the first year of direct funding for exploration study activities in a consolidated budget line item. Prior year funding for exploration mission studies was contained within the space R&T, space science and applications, and space transportation budgets.
[397] Although funds were authorized in FY 1991 for exploration mission studies, no funds were appropriated. In accordance with the language contained in the October 18, 1990, Conference Report, a subsequent reprogramming request of $7.0 million was submitted to continue preliminary SEI conceptual design studies.
[398] No amount indicated in budget documents.
[399] Focused on providing the technical, programmatic, and cost analyses required to select an SEI architecture.
[400] Budgeted under space R&T.
[401] The Office of Exploration acquired management responsibility for FY 1991 and FY 1992 exploration mission studies requirements, which were formerly budgeted under space R&T. This amount included a new budget element to develop and conduct several small-scale, robotic/automated precursor missions.
[402] The budget category was eliminated.

Table 3-16. Space Access and Technology Funding History (in thousands of dollars)

Year (Fiscal)	Submission	Programmed
1994	—	109,100
1995	—[403]/162,100	605,400
1996	193,000/641,300	—
1997	725,000/—[404]	—

[403] The program was not established at the time of the initial budget submission.
[404] Funds for activities budgeted in the Space Access and Technology program were redistributed into the Space Science, Mission to Planet Earth, Aeronautics, and Life and Microgravity Sciences programs. A reallocation of $487.3 million was made from space access and technology to the new aeronautics and space transportation technology program.

Table 3-17. Advanced Space Transportation Funding History (in thousands of dollars)

Year (Fiscal)	Submission	Programmed
1993	—[405]	114,600[406]
1994	—[407]/121,900[408]	109,100
1995	103,100/162,100[409]	162,100
1996	193,300/188,500	234,000
1997	324,700[410]/336,700[411]	336,700[412]
1998	396,600[413]/417,100	417,100[414]

[405] The budget category was not established at the time of the budget submission.
[406] Included as part of the OACT budget.
[407] The budget category was not established at the time of the initial submission.
[408] Advanced space transportation included funds for technology assessment and development, advanced technology maturation, in-space transportation, new launch system, and a single-engine Centaur. The advanced space transportation program combined space transportation technology efforts that previously were distributed among several programs: advanced concepts and technology (space transportation), space systems development (advanced programs, specifically advanced transportation, the Solid Propulsion Integrity Program [SPIP], advanced launch technology, and the single-engine Centaur).
[409] The budget category moved from OACT with the merger of OACT into the new OSAT.
[410] The increase in the budget submission reflected an increase in the budget request for the reusable launch vehicle–initial flight demonstration program from $109 million to $266.1 million and the initiation of the advanced space transportation technology program ($42.0 million). Other changes were decreases due to the elimination of the reusable launch vehicle–systems engineering and analysis program (–$0.5 million) and reusable launch vehicle–technology program (–$49.5 million) and a decrease in the transportation technology support program from $29.5 million to $16.6 million.
[411] The program was now part of the new aeronautics and space transportation technology program. Of the $336.7 million, $324.7 million was reallocated from the former OSAT and $12.0 million was added to augment funding for the low-cost booster technology program, as directed in House Report 104-812.
[412] Aeronautics and space transportation technology funding.
[413] The program was restructured to include the Delta Clipper, X-33 Advanced Technology Demonstrator, and Advanced Space Transportation programs.
[414] The program included the reusable launch vehicle flight demonstration program ($345.0 million), future launch studies ($10.0 million), and advanced space transportation technology ($62.1 million).

Table 3-18. Spacecraft and Remote Sensing Funding History (in thousands of dollars)

Year (Fiscal)	Submission	Programmed
1993	—	140,800
1994	—[415]/156,000[416]	183,300
1995	143,300[417]/144,300[418]	174,900
1996	177,500/174,100[419]	—
1997	151,000/—[420]	—

[415] The budget category was not established at the time of the initial submission.
[416] Included in the Advanced Concepts and Technology program.
[417] Included Earth applications systems, space and planetary systems, and space platforms systems.
[418] Added the partnership for next generation vehicle and communications systems line items to the budget category. The separate communications systems budget category was eliminated. Part of the new Space Access and Technology program.
[419] The budget category was restructured to include spacecraft systems technology, instrument/sensing technology, autonomy and operations, telerobotics, communications, and the SBIR funding allocation. The IN-STEP program moved to spacecraft and remote sensing from the flight programs category ($30.1 million), and on-board propulsion moved to spacecraft and remote sensing from the advanced space transportation budget category ($4.5 million). The net reduction of $3.4 million reflected a reduction of $28.3 million consistent with congressional direction and a reduction of $5.2 million to cover increases in the cost of the Lewis spacecraft in the advanced Smallsat technology budget element. These reductions were offset by an increase of $30.1 million due to budget restructuring. The reduction of $28.3 million was accommodated by a reduction in funding for the Partnership for a Next Generation Vehicle of $7.0 million and a reduction of $21.3 million to the remainder of spacecraft and remote sensing, reflecting congressional direction.
[420] In accordance with the realignment of funding, $133.6 million of spacecraft and remote sensing funding was redistributed to the space science budget in order to integrate the science goals and technology requirements of the space science programs. The exact reallocation of the remaining $17.4 million was unspecified, but budget documents indicate that it went to Mission to Planet Earth.

Table 3-19. Flight Programs (Advanced Concepts and Technology) Funding History (in thousands of dollars)

Year (Fiscal)	Submission	Programmed
1993	—	115,000
1994	—[421]/117,400[422]	140,900
1995	91,600/49,100	3,500
1996	76,000/8,800[423]	—

[421] The budget category was not established at the time of the initial submission.
[422] Included program definition; flight experiments; space station utilization; experiment carriers, transporters, and preparation; integration; and mission management.
[423] The reduction reflected the transfer of IN-STEP program funds to spacecraft and remote sensing, as well as the transfer of space station utilization funding to space processing budget categories in FY 1996. Remaining activities funded in the flight programs budget line were completed in FY 1996.

Table 3-20. Space Communications (Advanced Concepts and Technology) Funding History (in thousands of dollars)

Year (Fiscal)	Submission	Programmed
1993	—	33,100
1994	—[424]/31,000[425]	—
1995	23,700[426]/—[427]	—

[424] The budget category was not established at the time of the initial submission.
[425] Included near-Earth communication systems, deep space communication systems, space terrestrial hybrid systems, and application experiments.
[426] The decrease in funding reflected the reduction in the near-Earth communications systems program and applications experiments program due to the completion of the development of the high data rate and T1-VSAT terminals for the Advanced Communications Technology Satellite (ACTS) experiments.
[427] Space communications added to spacecraft and remote sensing budget category.

Table 3-21. Space Processing Funding History (in thousands of dollars)

Year (Fiscal)	Submission	Programmed
1993	—	31,900
1994	—[428]/16,500[429]	19,500
1995	19,200/18,300	33,300[430]
1996	18,100/54,000[431]	—
1997	41,800/—[432]	—

[428] The budget category was not established at the time of the initial submission.
[429] Included materials processing and biotechnology programs. Part of the advanced concepts and technology program.
[430] Reflected the addition of funds for space station utilization.
[431] The increase reflected the addition of funds for space station utilization.
[432] Funding was reallocated due to the dissolution of the space access and technology program.

Table 3-22. NASA Technology Transfer/Commercial Technology Programs Funding History (in thousands of dollars)

Year (Fiscal)	Submission	Programmed
1993	—	29,500
1994	—[433]/27,800[434]	27,800
1995	36,800[435]/45,800	33,800
1996	40,400/27,400[436]	27,400
1997	24,200/25,800	25,800
1998	20,000/20,000	25,200

[433] The budget category was not established at the time of the initial budget submission.
[434] New initiative in FY 1994. Included in the advanced concepts and technology programs.
[435] Approximately 50 percent of the total program funding required to meet the schedule of contract-to-launch in 24 and 36 months, respectively, for two technology-demonstration missions.
[436] The reduction reflected the transfer of AdaNET, the Rural State Technology Transfer Center, and the National Technology Transfer Center to a new budget category: technology transfer agents.

Table 3-23. Advanced Smallsat Technology (Advanced Concepts and Technology) Funding History (in thousands of dollars)

Year (Fiscal)	Submission	Programmed
1994	—[437]	12,500
1995	—[438]/61,900	61,900
1996	33,900[439]/39,100	—
1997	30,000/—[440]	—

[437] The budget category was not established at the time of the budget submission.
[438] The budget category was not established at the time of the initial submission.
[439] The decrease in funding reflected the completion of the detailed design of the Lewis and Clark spacecraft.
[440] Funding was reallocated due to the dissolution of the space access and technology program.

Table 3-24. Industry Technology Program (Advanced Concepts and Technology) Funding History (in thousands of dollars)

Year (Fiscal)	Submission	Programmed
1993	—	—
1994	—[441]/19,700	19,700
1995	18,900/(18,900)[442]	—

[441] The budget category was not established at the time of the budget submission.
[442] The budget category was eliminated.

Table 3-25. Construction of Facilities Funding History (in thousands of dollars)

Year (Fiscal)	Submission	Programmed
1993	—	—
1994	—/12,500[443]	12,500[444]
1995	47,900[445]/—	—

[443] Funds for the rehabilitation of the rocket engine test facility at Lewis Research Center.
[444] Included in the Advanced Concepts and Technology budget.
[445] Funds for the rehabilitation of the rocket engine test facility at Lewis Research Center.

Table 3-26. Small-Business Innovation Research and Small-Business Technology Transfer (Advanced Concepts and Technology) Funding History (in thousands of dollars)

Year (Fiscal)	Submission	Programmed
1993	—	(98,825)[446]
1994	—/(111,511)[447]	(110,900)
1995	123,900[448]/123,900	123,900
1996	129,100/125,700	125,000
1997	142,200/125,000	125,00
1998	100,000/100,000	101,500

[446] Funding was included in the Office of Commercial Programs budget.
[447] Funding was included in the Office of Commercial Programs budget.
[448] Moved from the disbanded Office of Commercial Programs.

Table 3-27. Technology Transfer Agents Funding History (in thousands of dollars)

Year (Fiscal)	Submission	Programmed
1995	—[449]	12,000
1996	—/17,100[450]	17,100
1997	7,300/7,800	7,800
1998	7,800/7,800	20,000

[449] No budget submission in this category indicated in budget documents.
[450] New budget category included funds for AdaNET, the Rural State Technology Transfer Center, and the National Technology Transfer Center, previously included with the Commercial Technology Programs budget line.

Table 3-28. Launch Vehicles Support (Advanced Concepts and Technology) Funding History (in thousands of dollars)

Year (Fiscal)	Submission	Programmed
1994	—	37,100
1995	—/37,000	—
1996	37,600/—[451]	—

[451] Discontinued as a separate budget category. Included with Expendable Launch Vehicles and Services.

Table 3-29. Advanced Concepts Funding History (in thousands of dollars)

Year (Fiscal)	Submission	Programmed
1995		(3,000)
1996	—/6,600[452]	—
1997	3,800/—[453]	—

[452] Provided start-up funding to pay for the initiation of early concept/technology-driven and challenge-driven projects while the process for outside input was being definitized.
[453] Funding was reallocated due to the dissolution of the Space Access and Technology program. The program was managed by the NASA Chief Technologist.

Table 3-30. Tu-144LL Flight Experiments

Surface/Structure Equilibrium Temperature Verification (Experiment 1.2). This experiment identified areas of temperature increase to help researchers determine what materials to use on a future supersonic passenger transport and how to manage the heat that builds on it.
Engine Airflow and Heat (Experiment 1.5). This experiment provided data on the temperatures within an engine compartment at both subsonic and supersonic speeds. Engines built for supersonic flight must be durable enough to stand up to the tremendous heat generated when flying for long periods.
Slender Wing Ground Effects (Experiment 1.6). When an airplane is landing, air pressure builds up between the plane and the ground. This "ground effect" pushes back at the plane and is a factor in a pilot's handling of the aircraft. This experiment helped researchers understand more about how ground effects would affect supersonic aircraft because the shape of the wings on the Tu-144LL resembled the shape envisioned for future supersonic aircraft. Additionally, data from wind tunnel ground effect tests matched data taken on the Tu-144LL flight, indicating that the wind tunnel tests were a valid way to generate accurate supersonic transport ground effects data.
Structure/Cabin Noise (Experiment 2.1). Researchers conducted noise-measurement experiments to learn how airflow over the surface of the fuselage generated noise inside the passenger cabin and how to design an efficient way to reduce the noise level.
Handling Quality Assessment (Experiment 2.4). Researchers studied the flight controls of the Tu-144LL to make future supersonic aircraft as easy to fly as possible.
Coefficient of Friction and Pressure—Boundary Layer Measurement (Experiment 3.3). This experiment measured pressures, skin friction, and other aerodynamic characteristics on the wing of the Tu-144LL to enable researchers to calibrate their computational tools to better predict and improve the performance of future supersonic passenger aircraft with the aim of reducing aerodynamic drag.

Source: "High-Speed Research—The Tu-144LL, A Supersonic Flying Laboratory," FS-1996-09-18-LaRC, September 1996, *http://www.nasa.gov/centers/langley/news/factsheets/TU-144.html* (accessed July 10, 2006).

Table 3-31. Perseus A Characteristics

Owner	NASA
Manufacturer	Aurora Flight Sciences Corp.
Fuselage length	26.2 ft (8 m)
Wingspan	58.7 ft (18 m)
Wing area	172 ft (52.4 m)
Aspect ratio	20
Takeoff weight	1,400–1,825 lb (635–828 kg)
Payload	110 lb (50 kg)
Altitude	Maximum altitude attained: 50,125 ft (15,278 m) on August 13, 1994
Mission duration	6 hr
Structure	Graphite epoxy, Nomex honeycomb, and Kevlar aero surfaces; tubular steel frame fuselage
Engine	Rotax 912 horizontally opposed four-cylinder core modified to operate closed-cycle using liquid oxygen
Engine horsepower	80

Source: "Past Projects–ERAST, Perseus A," Dryden Flight Research Center, *http://www.nasa.gov/centers/dryden/history/pastprojects/Erast/perseusa.html* (accessed June 8, 2006).

Table 3-32. Perseus B Characteristics

Owner	Aurora Flight Sciences
Designer/manufacturer	Aurora Flight Sciences
Fuselage length	25 ft (7.6 m)
Height	12 ft (3.6 m)
Wingspan	71.5 ft (21.8 m)
Wing area	194 ft^2 (18 m^2)
Wing aspect ratio	26.4
Gross takeoff weight	2,200 lb (998 kg) with full internal fuel
Fuel capacity	100 gal (378.5 L), including 40 gal internal (151.4 L) and 60 gal (227.1 L) in underwing auxiliary tanks, standard aviation gasoline
Payload	Up to 264 lb (119.7 kg) of sensors and instruments in nose compartment; typical payload approximately 175 lb (79.3 kg)
Maximum altitude	Approx. 62,000 ft (19,000 m)
Mission duration	8–24 hr depending on payload and altitude
Airspeed	Approx. 60 mph (96.5 km/hr) cruise, 70 mph (112.7 km/hr) never-exceed speed
Structure	Primarily composite materials such as graphite epoxy, Nomex honeycomb, and Kevlar aero surfaces; tubular steel frame fuselage
Engine	Rotax 914 horizontally opposed four-cylinder piston engine modified to operate with a three-stage turbocharger capable of providing sea-level air pressure at 60,000 ft (18,288 m). Was integrated with an Aurora-designed three-stage turbocharger driving a tail-mounted, lightweight, two-blade pusher propeller via an 8-ft (2.4-m) driveshaft.
Engine horsepower	Flat-rated at 105 hp to 60,000 ft (18,288 m) altitude
Propeller	Two-blade constant-speed propeller designed for high-altitude operation, 8.9-ft (2.7-m) diameter

Source: "Past Projects–ERAST, Perseus B," Dryden Flight Research Center, *http://www.nasa.gov/centers/dryden/history/pastprojects/Erast/perseusb.html* (accessed June 8, 2006). Also "Perseus B," Fact Sheet, *http://www.nasa.gov/centers/dryden/news/FactSheets/FS-059-DFRC.html* (accessed June 8, 2006).

Table 3-33. Pathfinder and Pathfinder-Plus Characteristics

	Pathfinder	**Pathfinder-Plus**
Wingspan	98.4 ft (29.5 m)	121 ft (36.3 m)
Length	12 ft (3.6 m)	
Wing chord	8 ft (2.4 m)	8 ft (2.4 m)
Wing aspect ratio	12 to 1	15 to 1
Gross weight	Approx. 560 lb (252 kg)	Approx. 700 lb (315 kg)
Payload	Up to 100 lb (45 kg)	Up to 150 lb (67.5 kg)
Airspeed	Approx. 17–20 mph (27.4–32.2 km/hr) cruise	
Power (arrays of solar cells)	Maximum output approx. 7,500 W	Maximum output approx. 12,500 W
Motors	Six electric motors, 1.5 kW maximum each	Eight electric motors, 1.5 kW maximum each
Endurance	Approx. 14–15 hr, daylight limited with 2–5 hr on backup batteries	
Glide ratio (power off)	18 to 1	21 to 1
Manufacturer	AeroVironment, Inc.	
Primary materials	Carbon fiber, Nomex, Kevlar, plastic sheeting, plastic foam	

Source: "Pathfinder Solar-Powered Aircraft," Fact Sheet, *http://www.nasa.gov/centers/dryden/news/FactSheets/FS-034-DFRC.html* (accessed June 8, 2006).

Table 3-34. Altus Characteristics

Owner	General Atomics Aeronautical Systems, Inc., and NASA
Manufacturer	General Atomics Aeronautical Systems, Inc.
Fuselage length	23.6 ft (7.2 m)
Wingspan	55.3 ft (16.8 m)
Wing area	132 ft^2 (12.3 m^2)
Aspect ratio	22.2
Maximum takeoff weight	2,150 lb (980 kg)
Wing loading at gross weight	16.3 lb/ft^2 (80 kg/m^2)
Payload	330 lb (150 kg) in nose compartment
Fuel capacity	92 gal (348 L)
Airspeed	100 knots (115 mph) maximum; 70 knots (80 mph) cruise; speed varied with altitude
Maximum altitude	68,000 ft (20,736 m)
Mission duration	30 hr
Structure	Composite construction
Engine	Rear-mounted Rotax 912-2T four-cylinder piston engine integrated with a thermo-mechanical systems turbocharger
Engine horsepower	100 hp at 52,000 ft (15,850 m)
Propeller	A two-blade pusher 84-in (213-cm)-diameter propeller was used for flights up to about 53,000 ft (16,154 m) altitude; a larger 100-in (254-cm)-diameter lightweight carbon-fiber propeller was installed for flights above that altitude.

Source: Past Projects–ERAST: Altus," *http://www.nasa.gov/centers/dryden/history/pastprojects/Erast/altus.html* (accessed July 11, 2006). Also "Altus II," *http://www.nasa.gov/centers/dryden/news/FactSheets/FS-058-DFRC.html* (accessed July 11, 2006).

Table 3-35. Raptor D-2 Demonstrator Characteristics

Owner	BMDO/DOE transferring to NASA
Manufacturer	Scaled Composites Inc.
Fuselage length	25 ft (7.6 m)
Wingspan	66 ft (20.1 m)
Wing area	187.9 ft^2 (17.5 m^2)
Aspect ratio	20
Takeoff weight	1,880 lb (852.8 kg)
Wing loading	10.0 lb/ft^2 (48.8 kg/m^2)
Payload	75 lb (34 kg)
Altitude	65,000 ft (19,812 m)
Mission duration	4–8 hr
Structure	Carbon over Nomex honeycomb and foam
Propulsion	Rotax 912 horizontally opposed four-cylinder engine modified to operate with twin turbocharging in series with intercooler
Power	100 hp
Propeller	4.27-m (14-ft) diameter

Source: “D-2 Demonstrator,” Past Projects–ERAST, Dryden History, *http://www.nasa.gov/centers/dryden/history/pastprojects/Erast/d2.html* (accessed June 8, 2006).

Table 3-36. X-29 Characteristics

Length	48.1 ft (14.7 m)
Wingspan	27.2 ft (8.3 m)
Propulsion	General Electric F404-GE-400 engine
Thrust	16,000 lb (7,257 kg)
Weight (empty)	13,600 lb (6,169 kg)
Takeoff weight	17,600 lb (7,983 kg)
Maximum operating altitude	50,000 ft (15,240 m)
Maximum speed	Mach 1.6
Flight endurance time	Approx. 1 hr
Materials	External wing structure: composite materials Wing substructure and basic airframe: aluminum and titanium
Manufacturer	Grumman Aircraft Corp.

Source: “X-29,” Fact Sheet, Dryden Flight Research Center, *http://www.nasa.gov/centers/dryden/news/FactSheets/FS-008-DFRC.html* (accessed August 3, 2006).

Table 3-37. X-31 Characteristics

Wingspan	23.83 ft (7.26 m)
Fuselage length	43.33 ft (13.2 m)
Power source	GE F404-GE-400 turbofan engine
Thrust	16,000 lb (71.2 kN)
Takeoff weight	16,100 lb (7,303 kg) including 4,100 lb (1,860 kg) of fuel
Design speed	Mach 0.9
Maximum speed reached	Mach 1.28 at 35,000 ft (10,668 m)
Altitude capability	40,000 ft (12,192 m)
Manufacturers	Rockwell International and Deutsche Aerospace

Table 3-38. F-18 HARV Characteristics

Overall length	56 ft (17.1 m)
Wingspan	37.4 ft (11.4 m)
Weight	31,980 lb (14,506 kg), modified to 36,099 lb (16,374 kg) for Phase 2
Wing area	400 ft^2 (37.2 m^2)
Wing aspect ratio	3.5
Propulsion	Two modified General Electric F404-GE-400 afterburning turbofan engines
Thrust	Each engine rated at approx. 16,000 lb (71.2 kN) at sea level
Materials	Advanced composite materials (largely graphite/epoxy), aluminum, steel, and titanium
Manufacturer	McDonnell Douglas Corp. and Northrop Corp.

Table 3-39. SR-71 Blackbird Characteristics

Length	107.4 ft (32.73 m)
Wingspan	55.6 ft (16.94 m)
Height	18.5 ft (5.63 m) from the ground to the top of the rudders when parked
Takeoff weight	140,000 lb (52,253 kg), including a fuel weight of 80,000 lb (29,859 kg)
Structure	Titanium and titanium alloys
Maximum speed	In excess of Mach 3.2[454]
Range	2,000 miles (3,218.68 km) unrefueled
Altitude	Over 85,000 ft (25,908 m)[455]
Endurance	More than 1 hr at Mach 3 (as a research platform)
Manufacturer	Lockheed Skunk Works

[454] Exact maximum speed was not provided.
[455] Exact maximum altitude was not provided.

Table 3-40. NASA's Wind and Propulsion Tunnels, 1989–1998

Facility Name	Speed Range	Reynolds Number	Dimensions	Comments
Ames Research Center				
14-Foot (4.3-Meter) Transonic Tunnel	Mach 0.5 to Mach 1.2	2.6 to 4.2 × 10^6/ft	13.5 ft (4.1 m) × 13.71 ft (4.2 m) × 33.75 ft (10.29 m)	Used primarily for performance and stability and control testing of aircraft configurations
7 × 10-Foot (2.1 × 3-Meter) Subsonic Tunnel	Mach 0 to Mach 0.33	0 to 2.1 × 10^6/ft	7 ft (2.1 m) × 10 ft (3 m) × 15 ft (4.6 m)	Used primarily for low-speed aircraft and V/STOL configurations
Unitary Plan Wind Tunnel Complex				
11 × 11-Foot (3.4 × 3.4-Meter) Transonic Tunnel	Mach 0.20 to Mach 1.45	0.30 to 9.6 × 10^6/ft	11 ft (3.4 m) × 11 ft (3.4 m) × 22 ft (6.7 m)	Used primarily for force, moment, and pressure tests of aircraft configurations or specific aircraft components
9 × 7-Foot (2.7 × 2.1-Meter) Supersonic Tunnel	Mach 1.55 to Mach 2.55	0.50 to 5.7 × 10^6/ft	7 ft (2.1 m) × 9 ft (2.7 m) × 18 ft (5.5 m) (effective length: 11 ft [3.4 m])	Used primarily for force, moment, and pressure tests of aircraft configurations or specific aircraft components
8 × 7-Foot (2.4 × 2.1-Meter) Supersonic Tunnel	Mach 2.4 to Mach 3.5	0.6 to 5.0 × 10^6/ft	8 ft (2.4 m) × 7 ft (2.1 m) × 16 ft (4.9 m)	Used primarily for force, moment, and pressure tests of aircraft configurations or specific aircraft components
12-Foot (3.7-Meter) Pressure Tunnel	Mach 0.05 to Mach 0.55	0.1 to 12 × 10^6/ft	11.3 ft (3.4 m) × 28 ft (8.5 m)	Used primarily for high Reynolds number testing
National Full Scale Aerodynamic Complex: 40 × 80 × 120-Foot (12.2 × 24.3 × 36.6-Meter) Subsonic Tunnel	40 × 80 section: Mach 0.45 (504 ft/sec); 80 × 120 section: Mach 0.15 (168 ft/sec)	40 × 80 section: 0 to 30 × 10^6/ft; 80 × 120 section: 0 to 1.1 × 10^6/ft	40 ft (12.2 m) × 80 ft (24.3 m) and 80 ft (24.3 m) × 120 ft (36.6 m) × 190 ft (57.9 m)	The largest known wind tunnel in the world
Langley Research Center				
0.3-Meter (1-Foot) Transonic Cryogenic Tunnel	Mach 0.2 to Mach 0.9	1 to 100 × 10^6/ft	13 in (33 cm) × 13 in (33 cm) × 69 in (175 cm)	Used for testing two-dimensional airfoil sections and other models at high Reynolds numbers

Facility Name	Speed Range	Reynolds Number	Dimensions	Comments
8-Foot (2.4-Meter) Transonic Pressure Tunnel	Mach 0.2 to 1.4	0.1 to 6 × 10^6/ft	7.1 ft (2.2 m) × 7.1 ft (2.2 m)	A continuous-flow, variable-pressure tunnel
14 × 22-Foot (4.3 × 6.7-Meter) Subsonic Tunnel	Mach 0 to Mach 0.3	0 to 2.1 × 10^6/ft	14.5 ft (4.4 m) × 21.75 ft (6.6 m) × 50 ft (15.2 m)	Used for low-speed tests of powered and unpowered models of various fixed- and rotary-wing civil and military aircraft
30 × 60-Foot (9.1 × 18.3-Meter) Full-Scale Tunnel	38 ft/sec (11.5 m/sec) to 132 ft/sec (40.2 m/sec)	0 to 1 × 10^6/ft	30 ft (9.1 m) × 60 ft (18.3 m) × 56 ft (17.1 m)	Designed to test full-scale models and actual airplanes at operational flight speeds
7 × 10-Foot (2.1 × 3-Meter) High Speed Tunnel	Mach 0.2 to 0.9	0.1 to 3.2 × 10^6/ft	6.6 ft × 9.6 ft	A closed-circuit, single-return, continuous-flow tunnel
Low Turbulence Pressure Tunnel	Mach 0.05 to Mach 0.5	0.4 to 15 × 10^6/ft	7.5 ft (2.3 m) × 3 ft (0.9 m) × 7.5 ft (2.3 m)	Provided flight Reynolds number testing capability for two-dimensional airfoils and a low-turbulence environment for laminar flow control and transition studies and the testing of low-drag airfoils
National Transonic Facility	Mach 0.1 to Mach 1.2	4 to 146 × 10^6/ft	8.2 ft (2.5 m) × 8.2 ft (2.5 m) × 25 ft (7.6 m)	Provided the highest-quality flight Reynolds number aeronautical data to the research, industry, and DOD communities
Unitary Plan Wind Tunnel	Two test sections: 1) Mach 1.5 to Mach 2.9; 2) Mach 2.3 to Mach 4.6	Two test sections: 1) 0.5 to 6 × 10^6/ft; 2) 0.5 to 11 × 10^6/ft	Both test sections are 4 ft (1.2 m) × 4 ft (1.2 m) × 7 ft (2.1 m)	Typical tests included force and moment, surface pressure measurements, and flow visualization of on- and off-surface flow patterns. Other tests involved jet effects, dynamic stability, model deformation, global surface and off-body flow measurements, and heat transfer
16-Foot (4.9-Meter) Transonic Dynamics	Mach 0.1 to 1.2	Air: 0.03 to 3 × 10^6/ft	16 ft (4.9 m) × 16 ft (4.9 m) ×	Specially dedicated to investigating flutter

Facility Name	Speed Range	Reynolds Number	Dimensions	Comments
Tunnel		R-134a: 0.2 to 10×10^6/ft	17 ft (5.2 m)	problems of fixed-wing aircraft
16-Foot (4.9-Meter) Transonic Tunnel	Mach 0.2 to 1.25	1 to 4×10^6/ft	15.5 ft (4.7 m) (octagonal) × 22 ft (37.2 m) long	Used for inlet, nozzle, and aerodynamic testing across the transonic speed range at atmospheric conditions
20-Foot (6.1-Meter) Vertical Spin Tunnel	0 to 85 ft/sec (25.9 m/sec)	0 to 0.15×10^6/ft	20 ft (6.1 m) in diameter × 25 ft (7.6 m) high	A closed-throat, annular-return wind tunnel operating in atmospheric conditions; used to investigate spinning, tumbling, and free-fall characteristics of aircraft and spacecraft
12-Foot (3.7-Meter) Low-Speed Tunnel	0 to 77 ft/sec (23.5 m/sec)	0 to 0.5×10^6/ft	12 ft (3.7 m) × 15 ft (4.6 m)	An atmospheric-pressure, open-circuit tunnel enclosed in a 60-ft (18.3-m)-diameter sphere used to investigate static, dynamic, and free-to-roll characteristics of mostly new configuration concepts
20-Inch (50.8-Centimeter) Supersonic Wind Tunnel	Mach 1.6 to 5.0; Mach 0.035 to 0.75 for airfoils	Two-dimensional: 1.0×10^5 to 20×10^6/ft; 0.35×10^5 to 20×10^6/ft	20 in (50.8 cm) × 18 in (45.7 cm)	Located in the Gas Dynamics Facility, this tunnel offered a wide variety of wind tunnel conditions and measurement techniques for basic research by means of conventional configuration testing over the supersonic Mach range of 1.6 to 5.0 at relatively low cost
Supersonic Low Disturbance Tunnel	Mach 3.5	1.7×10^6 to 20×10^6/ft (depending on extent of quiet core flow)	6 in (15.2 cm) × 10 in (25.4 cm) × 15 in (38.1 cm)	Provided a low-disturbance, free-stream environment for high-speed transition research
8-Foot (2.4-Meter) High-Temperature Tunnel	Mach 4, 5, and 7	0.3 to 5.1×10^6/ft	8 ft (2.4 m) in diameter × 12 ft (3.7 m)	Simulated true enthalpy at hypersonic flight conditions to test

Facility Name	Speed Range	Reynolds Number	Dimensions	Comments
				advanced large-scale, flight-weight aerothermal, structural, and propulsion concepts
Arc-Heated Scramjet Test Facility	Mach 4.7 to 8.0	0.4 to 2.2 × 10^6/ft	4 ft (1.2 m) in diameter × 11 ft (3.35 m)	Part of the NASA Langley Scramjet Test Complex, the facility was used to test complete subscale, scramjet component integration models in conditions simulating flight Mach numbers from 4.7 to 8
Combustion-Heated Scramjet Test Facility	Mach 3.5 to 6.0	1.0 to 6.8 × 10^6/ft	42 in (107 cm) × 30 in (76 cm) × 96 in (243.8 cm)	Part of the NASA Langley Scramjet Test Complex, this facility offered the capability to test subscale propulsive flowpaths of hypersonic vehicles at conditions simulating flight Mach numbers from 3.5 to 6.0
Direct Connect Supersonic Combustion Test Facility	Mach 4.0 to 7.5	1.8 to 31.0 × 10^6/ft	Mach 2 nozzle: 1.52 in (3.86 cm) × 3.46 in (8.79 cm); Mach 2.7 nozzle: 1.50 in (3.81 cm) × 6.69 in (16.99 cm)	Part of the NASA Langley Scramjet Test Complex, this facility was used to test ramjet or scramjet combustors at conditions simulating flight Mach numbers from 4 to 7.5
Hypersonic PULSE (HYPULSE)	Mach 5.0 to 21.0	0.50 to 2.5 × 10^6/ft	Chamber: 7 ft (2.1 m) in diameter × 19 ft (5.8 m); nozzle: 18 in (45.7 cm) to 26 in (66 cm)	Located and operated by the GASL Division of Allied Aerospace Industries, Inc., in Ronkonkoma, NY
Langley Aerothermodynamics Laboratory				
15-Inch (38-Centimeter) Mach 6 High Temperature Tunnel	Mach 6	0.5 to 8.0 × 10^6/ft	15-in (38-cm) diameter; test core size: 8- to 10-in (20- to 25-cm) diameter	An open-jet facility with superior optical access and high-temperature capability; ideally suited for developing and applying advanced nonintrusive optical surface and flowfield

Facility Name	Speed Range	Reynolds Number	Dimensions	Comments
				measurement test techniques
20-Inch (50.8-Centimeter) Mach 6 CF4 Tunnel	Mach 6	0.05 to 0.7 × 10^6/ft	20-in (50.8-cm) diameter; test core size: 14-in (35.6-cm) diameter	The only operational, conventional type hypersonic facility in the United States that simulated dissociative real-gas phenomena associated with hypersonic flight. CF4 test media provided a normal shock density ratio of 12 (simulating Mach 13–18 flight) and enabled the determination of real-gas effects on vehicle aerodynamics.
20-Inch (50.8-Centimeter) Mach 6 Tunnel	Mach 6	0.5 to 8.0 × 10^6/ft	20 in (50.8 cm) × 20 in (50.8 cm); test core size: 12 in (30.5 cm) × 12 in (30.5 cm)	A versatile hypersonic facility used for aerodynamic and aeroheating testing of advanced access to space and planetary vehicles, as well as exploring basic fluid dynamic phenomena, including boundary layer transition
31-Inch (78.7-Centimeter) Mach 10 Tunnel	Mach 10	Mach 100.2 to 2.2 × 10^6/ft	31 in (78.7 cm) × 31 in (78.7 cm); test core size: 14 in (35.6 cm) × 14 in (35.6 cm)	A hypersonic facility with a large temperature driver that was ideal for heat-transfer studies. With its extremely uniform flow quality, it was considered to be excellent for CFD code calibration experiments, as well as aerodynamic performance testing.

	General Description
Jet Exit Test Facility	A ground test stand consisting of a dual-flow test apparatus connected to two separate heated-air supply systems
Langley Acoustic Wind Tunnel Facilities	
Anechoic Noise Research Facility	8.4-m (27.6-ft) × 8.2-m (26.9-ft) × 7.3-m (24-ft) anechoic chamber
Flow Impedance Test	Raylometer, normal incidence impedance tube, grazing flow impedance

Facility Name	Speed Range	Reynolds Number	Dimensions	Comments
Facility	tube (Mach 0.5, 160 dB)			
Jet Noise Lab	8-m (26.2-ft) × 30-m (98.4-ft) × 7-m (23-ft) open jet anechoic wind tunnel (Mach 0.32) with dual-stream jet engine simulator (1/10 scale exhaust nozzle)			
Quiet Flow Facility	6.1-m (20-ft) × 7.3-m (24-ft) × 9.2-m (30.2-ft) anechoic open jet wind tunnel			
Structural Acoustics Loads and Transmission Facility	337 m^3 (11,901 ft^3) anechoic chamber, 278 m^3 (9,817 ft^3) reverberation chamber, 1.4-m (4.6-ft) × 1.4-m (4.6-ft) transmission loss window			
Thermal Acoustic Fatigue Apparatus	Progressive wave tube test facility, 40–500 Hz, 172 dB, 360 kW quartz lamp heating system			
Jet Exit Test Facility	An indoor engine/nozzle test stand that combined multiple-flow air propulsion simulation with high-pressure and high-mass flow capabilities			
Lewis Research Center				
Abe Silverstein 10 × 10-Foot (3 × 3-Meter) Supersonic Tunnel	Propulsion cycle: Mach 2.0 to Mach 3.5; aero cycle: 0 to Mach 0.36	Propulsion cycle: 2.1 to 2.7 × 10^6/ft; aero cycle: 0.12 to 3.4 × 10^6/ft	10 ft (3 m) × 10 ft (3 m)	Can be configured in either closed-loop or vented-loop mode
1 × 1-Foot (0.3 × 0.3-Meter) Supersonic Tunnel	Mach 1.3 to Mach 6.0 (10 discrete airspeeds)	0.4 to 16.5 × 10^6/ft	12.2 in (31 cm) × 12 in (30.4 cm) × 8 ft (2.4 m)	Designated an International Historic Mechanical Engineering Landmark by the American Society of Mechanical Engineers
Low-Speed Wind Tunnel Complex				
8 × 6-Foot (2.4 × 1.8-Meter) Supersonic Tunnel	Mach 0.25 to Mach 2.0	3.6 × 4.8 × 10^6/ft	8 ft (2.4 m) × 6 ft (1.8 m)	Air sucked through holes in the walls of the test section prevents shock waves from interfering with test models
9 × 15-Foot (2.7 × 4.6-Meter) Low-Speed Tunnel	Mach 0 to Mach 0.23	0 5 to 1.4 × 10^6/ft	9 ft (2.7 m) × 15 ft (4.6 m)	Built in return leg of 8 × 6-ft tunnel
Hypersonic Tunnel Facility	Mach 5 to Mach 7	0.97 to 2.3 × 10^6/ft	Test section is adjustable from 10 ft (3 m) to 14 ft (4.3 m) in length	Used to test large-scale hypersonic air-breathing propulsion systems
Icing Research Tunnel	50 to 350 mph	0 to 3.3 × 10^6/ft	6 ft (1.8 m) × 9 ft (2.7 m) × 20 ft (6.1 m)	Used to study the effects of icing on aircraft components and perform detailed studies of basic icing

Facility Name	Speed Range	Reynolds Number	Dimensions	Comments
				phenomena and icing instrumentation
Marshall Space Flight Center				
14 × 14-Inch (35.6 × 35.6-Centimeter) Trisonic Tunnel	Transonic test section: Mach 0.25 to 1.3, 1.46, 1.96; supersonic test section: Mach 2.74 to 4.96	1 to 18 × 10^6/ft	14 in (35.6 cm) × 14 in (35.6 cm) × 24 in (61 cm)	Capable of running subsonic, transonic, and supersonic tests
Hot Gas Facility	Mach 4.1	Not applicable	16 in (40.6 cm) × 16 in (40.6 cm) × 40 in (101.6 cm)	Used for testing solid rocket booster and external tank thermal protection system materials and configurations
High Reynolds Flow Facility (Wind Tunnel Complex)	Mach 0.3 to 3.5	7 to 200 × 10^6/ft	32-in (81.2-cm) diameter	Provided the capability to measure model forces and pressure distributions at high Reynolds numbers

Table 3-41. OAST-2 Investigations[456]

<table>
<tr><th>Investigation</th><th>Principal Investigator</th><th>Objective</th></tr>
<tr><td>Solar Array Module Plasma Interaction Experiment (SAMPIE)</td><td>Dale C. Ferguson, Lewis Research Center, Cleveland, OH</td><td>To determine the arcing and current collection behavior of different types, sizes, and shapes of solar cells, solar modules, and spacecraft materials</td></tr>
<tr><td>Thermal Energy Storage (TES)</td><td>D. Namkoong, Lewis Research Center, Cleveland, OH</td><td>To determine the microgravity behavior of two different thermal energy storage salts that undergo repeated melting and freezing</td></tr>
<tr><td>Experimental Investigation of Spacecraft Glow (EISG)</td><td>G. Swenson, Lockheed Corporation</td><td rowspan="2">To develop an understanding of the physical processes leading to the spacecraft glow phenomena by studying infrared, visible, and far ultraviolet emissions as a function of surface temperature and orbital altitude</td></tr>
<tr><td>Spacecraft Kinetic InfraRed Test (SKIRT)</td><td>D. Jennings, Goddard Space Flight Center, Greenbelt, MD</td></tr>
<tr><td>Emulsion Chamber Technology (ECT)</td><td>J. Gregory, University of Alabama in Huntsville, Huntsville, AL</td><td>To measure background cosmic ray radiation as a function of shielding thickness and radiation energy using photographic films</td></tr>
<tr><td>CRYogenic Two Phase (CRYOTP)</td><td>M. Stoyanof, U.S. Air Force Phillips Laboratory; M. Bello, Aerospace Corporation; M. Buchko, Goddard Space Flight Center, Greenbelt, MD</td><td>To determine the microgravity behavior of two thermal control technologies: nitrogen space heat pipe and cryogenically cooled, vibration-free, phase change material</td></tr>
</table>

[456] "OAST-2 Prelaunch Mission Operation Report," Office of Advanced Concepts and Technology, Report No. C-237-94-62-01, NASA History Division folder 11034, Historical Reference Collection, NASA Headquarters, Washington, DC.

Chapter 4

Table 4-1. Programmed Budget (FY 1989–FY 1998) (thousands of dollars)

	1989	1990	1991	1992	1993	1994	1995	1996	1997	1998
Space and Ground Network, Communications and Data Systems (SFC&DC)	717,300	797,478	828,789	903,275	825,100 [457]	—	—	—	—	—
Tracking and Data Advanced Systems (R&D)	18,800	19,328	20,000	22,000	23,273 [458]	19,600 [459]	—	—	—	—
Mission Communication(s) Services (SAT)	—	—	—	—	546,488 [460]	581,981 [461]	481,200	449,500	418,600	400,800
Ground Network	227,100	251,476	260,700	283,300	306,601	309,300	273,400	259,500	245,600	221,600
Communications and Data Systems	233,300	224,867	257,989	281,400	156,914	206,481	175,800	162,800	147,100	148,100
Space Communications Services (MS) [462]	—	—	—	—	333,715 [463]	248,192	225,000	255,400	*291,400*	*194,200*
Space Network	256,900	321,135	310,100	338,875	199,106	117,674	110,100	157,200	185,100	111,700

[457] Reflected former budget structure.
[458] Reflected restructured appropriations. Included in the Science, Aeronautics, and Technology (SAT) appropriation as part of Mission Communication Services.
[459] Included in the SAT appropriation as part of Mission Communication Services.
[460] Reflected new budget structure. Included an additional $31.8 million previously funded under the Construction of Facilities (CofF) appropriation.
[461] Included an additional $15.6 million previously funded under the CofF appropriation.
[462] NASA's appropriations were reconfigured in FY 1993, eliminating the Space Flight, Control, and Data Communications (SFC&DC) and R&D appropriations and replacing them with the Mission Support (MS) and SAT appropriations. Some Agency funding categories remained intact and were placed entirely into a new appropriation, while others were reconfigured or in some way split between more than one budget category and sometimes even split between appropriations.
[463] Reflected new budget structure.

	1989	1990	1991	1992	1993	1994	1995	1996	1997	1998
Telecommunications	—	—	—	—	134,609	130,518	114,900	98,200	106,300	82,500
Total Networks and Tracking Budget	736,100	816,806	848,789	925,275	848,373 [464]	830,173	706,200	704,900	710,000	595,000
Change	–161,200 [465]	80,706	31,983	76,486	–76,902	–18,200	–123,973	–1,300	5,100	–115,000

[464] This figure shows the total using the former budget structure (including reprogrammed CofF funds). In the reconfigured appropriations, total networks and tracking categories totaled funding of $830,173,000. The discrepancy of $18.2 million is unexplained and unaccounted for in budget documents.
[465] Almost the entire drop in funding reflected a reduction in funds for the Space Network (SN), which dropped from $433.4 million in FY 1988 to $256.9 million in FY 1989. No explanation is given in funding documents for the drop.

Table 4-2. Space and Ground Network, Communications and Data Systems Funding History (in thousands of dollars)

Year (Fiscal)	Submission	Programmed
1989	1,035,300[466]/945,300[467]	717,300
1990	1,102,100/975,200[468]	797,478
1991	868,800/828,800[469]	828,789
1992	953,873/918,275[470]	903,275
1993	921,000/836,230[471]	825,100
1994	820,500/761,300	—[472]

[466] Included SN, GN, and Communications and Data Systems elements. Provided funding for TDRSS operations, spacecraft production, and launch support; operations and maintenance of the tracking, data acquisition, mission control, data processing, and communications facilities; and engineering services and procurement of equipment to sustain and modify the various systems to support continuing, new, and changing flight project requirements.
[467] The reduction of $90 million resulted from congressional action on the FY 1989 budget request. The size of the reduction required significant changes to program plans. Major schedule changes were required in the TDRSS replacement spacecraft and second TDRSS ground terminal (STGT) programs. Additionally, many other program elements were subjected to reduced support capabilities, rephased implementation plans, and deferrals.
[468] The reduction of $127 million below the original budget estimate was consistent with congressional action on the FY 1990 budget. It reflected a general reduction of $100 million, a reduction of $11.4 million for sequestration, and a pro rata share of the general reduction directed in P.L. 101-144 of $15.6 million.
[469] The $40 million reduction was consistent with congressional action. The reduction was accommodated through a TDRSS contract restructuring and a rephasing of some activities. Some work on TDRS-6 was moved to FY 1992, and upgrading of the Spacelab Data Processing Facility was delayed.
[470] The decrease of $35.6 million below the original budget request was consistent with congressional action. It included a $32.8 million reduction to Communications and Data Systems, which was achieved mainly by combining the Customer Data and Operations System (CDOS) with the Earth Science and Applications/Earth Observing System Data Information System (EOSDIS) program and reducing the Advanced X-ray Astrophysics Facility (AXAF) requirements due to a launch delay. Other changes included an $8.7 million reduction in GN funding, which was accommodated by reducing Cassini requirements based on a launch slip and by deferring some other activities. The FY 1992 budget also reflected a $5.9 million increase to SN funding to support additional requirements in the TDRS replacement and STGT programs, which were partially offset by deferring the start of development in the TDRS II program (formerly the Advanced Tracking and Data Relay Satellite [ATDRS]).
[471] The decrease of $84.8 million below the original budget request was consistent with congressional action. The funding level included an increase of $5.2 million due to the redistribution of the Research Operations Support (ROS) account offset by the directed reduction of $65.0 million for TDRS II and a general reduction of $25.0 million. The general reduction was accommodated within the SN (–$4.9 million), GN (–$8.3 million), and Communications and Data Systems (–$11.8 million).
[472] Budget restructured from the SFC&DC appropriation into the MS and SAT appropriations. See the Mission Communications Services table below for MS totals.

Table 4-3. Space Network Funding History (in thousands of dollars)

Year (Fiscal)	Submission	Programmed
1989	538,900[473]/483,900	256,900
1990	582,300/530,707[474]	321,135
1991	331,200/310,100[475]	310,100
1992	347,973/353,875	338,875
1993	298,200/230,085[476]	199,106[477]
1994	173,900/83,500[478]	117,674
1995	154,000/94,000[479]	110,100
1996	206,700/156,700	157,200

[473] SN funding included funding repayment of the loans extended by the Federal Financing Bank for TDRSS development; maintenance and operation of the White Sands, NM, complex and other NASA elements of the SN; support activities such as systems engineering, documentation, and mission planning; equipment modification and replacement; analytical studies to define the spacecraft required for the next-generation TDRSS; the development and integration of an additional spacecraft to replace the TDRS lost in the *Challenger* accident; and the implementation of a second ground terminal at White Sands.
[474] The decrease of $40.4 million reflected program adjustments made to provide a transfer of funds to the TDRS Replacement budget category and to accommodate a portion of the general reductions specified by Congress and a reduction for sequestration. This was accomplished by a major crew reduction following the checkout of TDRS-4 on orbit and the deferral of assembly and test activities planned for TDRS-5 and TDRS-6. In addition, the White Sands complex sustaining equipment modifications were eliminated for FY 1990.
[475] The decrease of $14.3 million reflected program adjustments made to accommodate a portion of the general reduction specified by Congress. This included TDRSS contract restructuring, staffing reductions at the White Sands complex, reduced logistics expenditures, and moving some work on TDRS-6 into FY 1992.
[476] The decrease reflected increased funding requirements of $28.6 million for the STGT, an additional $6.1 million for systems engineering, and an increase of $1.8 million transferred from the ROS account. This was offset by reducing funding requirements of $14.0 million for the basic TDRSS and operations, reducing Replacement Spacecraft by $10.8 million, and deleting $9.9 million associated with the suspended procurement of the TDRS II replenishment spacecraft. As directed by Congress, $15 million was allocated for upgrading the existing Network Control Center (NCC).
[477] Included TDRSS, Space Network Services (new budget category), TDRS Replacement Spacecraft, TDRS Replenishment Spacecraft, and the STGT.
[478] This amount referred to SN funding only in the MS appropriation. An additional $30 million, formerly funded in SN under the old SFC&DC appropriation, moved to the Space Network Customer Service budget category. In FY 1995, the SN was split between the SAT appropriation and the MS appropriation. MS funding included TDRSS, TDRS Replacement Spacecraft, TDRS Replenishment Spacecraft, and the STGT, as well as the new budget category of Space Network Services. The SAT appropriation included specific elements of Space Network Operations and Systems Engineering that were combined in a new budget category called Space Network Customer Service. See individual tables below.
[479] The amount in the "Changes" section of the FY 1996 Budget Estimate shows that FY 1995 funding was reduced by $60 million to $94 million. According to comments, "This funding level reflects congressional direction to reduce funding for the Tracking and Data Relay Satellite (TDRS) Replenishment." To augment funding for TDRS Replenishment (which was $42 million), House Report 103-715 indicated that NASA could reallocate up to $25 million of reimbursement funding and underruns as long as this did not result in any involuntary reductions-in-force in 1995 in the Space or Mission Communications Services programs. In other SN funding, $7.2 million was transferred from the TDRSS to the Space Network Services program to consolidate funding for the operation and support of the White Sands Ground Terminal (WSGT) with funding for the Space Network Services program. As the STGT became operational and the WSGT was taken off line for refurbishment and upgrade, funding for the support of these two operations was provided in this consolidated program element. The operations of the two ground terminals were combined under a single contract beginning in FY 1996. Within the STGT program, increased funding to support the six-month slip was accommodated within program reserves.

1997	185,100/185,100	185,100
1998	161,200/114,200	111,700

Table 4-4. Tracking and Data Relay Satellite System (TDRSS) Funding History (in thousands of dollars)

Year (Fiscal)	Submission	Programmed
1989	313,900[480]/295,800[481]	—
1990	320,800[482]/280,400[483]	43,325
1991	77,200[484]/62,900	54,700
1992	51,100/47,700[485]	30,731
1993	46,200/32,116	25,817
1994	23,300[486]/10,100	—
1995	*7,200*[487]/—[488]	—

[480] Approximately $227 million was for the repayment of the Federal Financing Bank (FFB) loan. The remainder ($86.9 million) was for continuing spacecraft activities, service payments, and operating and maintaining the WSGT.
[481] The decrease of $18 million from the original estimate resulted from a deferral of the buildup of the sixth spacecraft and reduced equipment replacement funding for the WSGT.
[482] The budget category included $227 million for repayment of the FFB loan. The remainder ($93.8 million) was for continuing spacecraft activities, service payments, and operating and maintaining the WSGT.
[483] The decrease of $40.4 million reflected program adjustments made to provide a transfer of funds to the TDRS Replacement and to accommodate a portion of the general reductions specified by Congress and a reduction for sequestration. This was accomplished by a major staff reduction following the checkout of TDRS-4 on orbit and the deferral of assembly and test activities planned for TDRS-5 and TDRS-6. In addition, the White Sands complex sustaining equipment modifications were eliminated for FY 1990.
[484] The budget category no longer included funds for repayment of the FFB loan, as directed by the administration. The outstanding debt was to be paid off in FY 1991 based on an inter-appropriation nonexpenditure transfer authorization.
[485] The decrease of $2.4 million reflected program savings achieved mainly from contract negotiations due to the acceleration of the TDRS-6 contract.
[486] The decrease of $14.1 million reflected $14.6 million in program savings achieved as a result of contract negotiations and crew sharing with the Replacement Spacecraft program, reduced ground operations indirect costs, and an increase of $0.5 million to accommodate the ROS transfer.
[487] During FY 1995, operations and maintenance of the WSGT ceased when the STGT became fully operational. At that time, the original terminal underwent modification. The TDRSS program supported the removal of existing equipment and the preparation of the WSGT for modernization. Remaining TDRSS funding provided for the operations and maintenance staff who removed and installed equipment and conducted the testing and calibration of the new equipment suite. Future funding requirements for the operation of the White Sands complex was provided by the Space Network Services program.
[488] The budget category did not appear in budget documents.

Table 4-5. Federal Financing Bank Payment Funding History (in thousands of dollars)

Year (Fiscal)	Submission	Programmed
1992	32,673[489]/32,675	—[490]

[489] In FY 1991, the outstanding debt to the FFB was paid off. FY 1992 funding repaid the outstanding accrued interest and premiums related to the early payoff of the loan.
[490] No amount shown in budget documents.

Table 4-6. Space Network Operations Funding History (in thousands of dollars)

Year (Fiscal)	Submission	Programmed
1989	42,700/34,800[491]	34,800
1990	39,600/31,507[492]	33,320
1991	41,600/39,000[493]	36,437
1992	46,500/44,900[494]	40,968
1993	61,900/58,163[495]	—
1994	36,700/—[496]	—

[491] The decrease of $11.9 million resulted primarily from reduced contractor support and lower-than-anticipated labor rates for the period.
[492] The decrease of $8.1 million reflected program adjustments made to accommodate a portion of the general reductions specified by Congress and a reduction for sequestration. This was accomplished through reductions in funding for vendor-supplied troubleshooting expertise and on-call maintenance, software maintenance, and advanced planning and documentation for future flight missions. In addition, some support contract staffing reductions were made.
[493] The decrease of $2.6 million reflected program adjustments made to accommodate a portion of the general reductions specified by Congress and accomplished through reductions in support contract staffing in the Flight Dynamics Facility (FDF), the NASA Ground Terminal (NGT), and NCC software maintenance.
[494] The decrease of $1.6 million reflected program adjustments made to accommodate a portion of the general reductions specified by Congress and was accomplished through reductions in the FDF, NGT, and NCC.
[495] The decrease of $3.7 million included an increase of $0.6 million transferred from the ROS account and a decrease of $4.3 million in program adjustments to accommodate a portion of the reductions specified by Congress accomplished by reducing training, documentation, NGT operations, and various other activities.
[496] Elements of this budget category were combined with Systems Engineering and Support in a new budget category, Space Network Customer Services, under the SAT appropriation. See the Space Network Customer Services table below.

Table 4-7. Systems Engineering and Support Funding History (in thousands of dollars)

Year (Fiscal)	Submission	Programmed
1989	25,600/31,600[497]	31,600
1990	32,400/27,400[498]	26,511
1991	34,000/35,400[499]	36,496
1992	51,700/48,000[500]	44,001
1993	59,900/66,706[501]	—
1994	32,500/—[502]	—

[497] The increase of $6 million was to provide continued advanced planning to support the development of space station operational concepts, interface definition for data handling and distribution, and support requirements definition. It was also to initiate hardware and software modifications in the NCC to provide the necessary interface to operate with the STGT at White Sands.
[498] The decrease of $5.0 million reflected the program adjustments made to accommodate a portion of the general reductions specified by Congress. These reductions entailed deferring the NCC central computer replacement, reducing software development, and deferring the replacement of the high data rate recorders for the NGT.
[499] The increase of $1.4 million reflected a program adjustment needed for a software augmentation to the NCC required to interface with the STGT.
[500] The decrease of $3.7 million reflected the program adjustments made to accommodate a portion of the general reductions specified by Congress. It was accomplished mainly by reducing Space Station Freedom (SSF)-related activities once the SSF data processing and communication requirements were simplified as a result of the restructuring activity.
[501] The increase of $6.8 million reflected the addition of $9.8 million to develop implementation systems for improved Compton Gamma Ray Observatory (CGRO) data retrieval, an increase of $0.7 million transferred from the ROS account, and a decrease of $3.8 million in the cancellation of and reductions to studies and long-range planning and analytical engineering efforts.
[502] Elements of this budget category were combined with Space Network Operations in a new budget category, Space Network Customer Services, under the SAT appropriation. See the Space Network Customer Services table below.

Table 4-8. TDRS Replacement Spacecraft Funding History (in thousands of dollars)

Year (Fiscal)	Submission	Programmed
1989	78,800/58,600[503]	59,600
1990	44,400/72,000[504]	89,629
1991	50,200/54,600[505]	51,889
1992	34,200/43,900[506]	43,5768
1993	10,800/—[507]	—
1994	5,700/5,700	5,700
1995	22,200/22,200[508]	17,200
1996	—[509]	—

[503] The decrease of $20.2 million reflected congressional action on the NASA FY 1989 budget request. The reduction was accomplished by terminating most of the long-lead parts procurement for an additional spacecraft and by delaying the launch readiness date of the replacement TDRS from December 1991 to December 1992.

[504] The increase of $27.6 million reflected the internal realignment of network funding to maintain the replacement spacecraft schedule and avoid substantial additional cost increases.

[505] The increase of $4.4 million reflected unexpected development problems with new power amplifiers for TDRS-7 that were required due to obsolescence concerns with the parametric amplifiers used in the previous TDRS.

[506] The increase of $9.7 million reflected an unexpected development problem with new power amplifiers for TDRS-7 that were required due to obsolescence and reliability concerns with the traveling wave tube amplifiers used in the previous TDRS.

[507] The decrease of $10.8 million was due to the restructuring of the integration and test (I&T) phase of TDRS-7 to a later period. The restructuring reflected the sharing of the crew with the TDRSS program during the TDRS-6 launch activities. FY 1993 activities were to be carried out with prior year funding planned for the earlier I&T schedule.

[508] Funded from MS appropriation.

[509] Funding discontinued.

Table 4-9. TDRS Replacement Spacecraft Launch Services Funding History (in thousands of dollars)

Year (Fiscal)	Submission	Programmed
1994	—[510]	34,673
1995	—/15,587[511]	15,600[512]
1996	—	—

[510] The budget category was not established at the time of the budget submission.
[511] Funded from MS appropriation.
[512] The TDRS-7 deployment in August 1995 was followed by on-orbit checkout and characterization testing.

Table 4-10. Second TDRSS Ground Terminal (STGT)/White Sands Ground Terminal (WSGT) System Replacement Funding History (in thousands of dollars)

Year (Fiscal)	Submission	Programmed
1989	70,000/59,100[513]	82,100
1990	139,100[514]/117,200[515]	126,200
1991	100,000/92,800[516]	103,898
1992	118,000/130,200[517]	140,100
1993	44,500/73,100[518]	73,100
1994	27,700/19,000	19,000
1995	18,600/18,600[519]	18,600
1996	200/—[520]	—

[513] The decrease of $10.9 million reflected congressional action and resulted in an anticipated slip of the planned program completion to June 1993 (approximately six months).
[514] $15.5 million specifically allotted for WSGT Replacement.
[515] The decrease of $21.9 million was due largely to a three-month delay in the definitization of the contract. This caused a slower buildup of staffing and materials, differences between the executed contract and the government estimate, and increased savings related to the addition of equipment for the modernization of the existing terminal to the STGT contract, providing reduced acquisition costs through large lot buys of hardware and the avoidance of non-recurring engineering costs for the modernization. The decrease also accommodated a portion of the general reductions specified by Congress and a reduction for sequestration.
[516] The decrease of $7.2 million reflected a slightly slower-than-planned buildup of staffing and materials. Workarounds were developed to maintain the overall work schedule.
[517] The increase of $12.2 million reflected hardware and software development delays that affected assembly and test schedules and resulted in increased costs.
[518] The increase of $28.6 million was to accommodate the cost growth incurred during FY 1993. The cost growth was driven by a lack of engineering model hardware, underestimating the complexity of hardware and software development, and subcontractor technical problems.
[519] Funded from MS appropriation.
[520] Funding discontinued.

Table 4-11. Advanced TDRS (ATDRS)/Tracking and Data Relay Satellite II Funding History (in thousands of dollars)

Year (Fiscal)	Submission	Programmed
1989	4,000/4,000	4,000
1990	6,000/2,200[521]	2,150
1991	28,200/25,400[522]	26,770
1992	14,800/6,500[523]	6,832
1993	74,900[524]/—[525]	—

[521] The decrease of $3.8 million was due to the delay in initiating the Phase B (definition phase) studies. The Request for Proposal was released in the first quarter of FY 1990. The selection of at least three contractors to conduct design studies and prepare design/development proposals late in FY 1990 was expected.
[522] The decrease of $2.8 million was due to reducing the number of Phase B (definition phase) design study contractors from four to three along with a reallocation of funds.
[523] The budget category was redesignated Tracking and Data Relay Satellite II (TDRS II). The decrease of $8.3 million was due to a delay in starting the TDRS II development contract, which had been planned for September 1992.
[524] Intended to provide for preliminary design, development of contractor work packages, contractor make/buy studies, and negotiated subcontracts with a planned “schedule need date” of June 1997 for the first TDRS II.
[525] The decrease of $74.9 million reflected a directed congressional reduction and subsequent cancellation of the TDRS II procurement. The procurement of six spacecraft was first suspended to assess alternatives, including an unsuccessful effort to procure a single spacecraft of the existing design. A search for more affordable alternatives led to the cancellation of TDRS II and the initiation of procurement of spacecraft that would be functionally equivalent to the existing design as an interim solution to NASA’s requirements.

Table 4-12. TDRS Replenishment Spacecraft Funding History (in thousands of dollars)[526]

Year (Fiscal)	Submission	Programmed
1994	48,000[527]/2,600[528]	2,600
1995	100,000[529]/42,000[530]	45,000
1996	195,800/147,200[531]	147,200
1997	162,100/162,100	162,100
1998	107,000/61,000	56,000

[526] Successor to the canceled ATDRS/TDRS II program.
[527] Funding was to provide for a fixed-price development contract award in mid-1994. The launch of the first replenishment spacecraft was expected in mid-1998.
[528] Minimal funding was requested to initiate procurement activities leading up to the contract award early in FY 1995.
[529] Funding was requested to initiate the development of TDRS-8 through TDRS-10 to ensure continuity of network services. Funded from the MS appropriation.
[530] This funding level reflected congressional direction to reduce funding for the TDRS replenishment spacecraft by $60 million. Since the funding shown here was $42 million (below the $60 million level), Congress authorized a reallocation of funding from underruns in other areas and the use of reimbursable funds as long as it did not result in involuntary reductions in personnel.
[531] Of the $45.4 million reduction, $40.4 million was available as a result of the latest contract negotiation of the TDRS Replenishment program and $5.0 million was available from the FY 1995 TDRS Replacement program following the successful launch of TDRS-7. The remaining reduction of $4.6 million was accommodated by reducing the flexibility to meet unexpected changes in implementing, maintaining, and operating the communications systems and facilities.

Table 4-13. TDRS Replenishment Launch Services Funding History (in thousands of dollars)

Year (Fiscal)	Submission	Programmed
1995	—	500
1996	—[532]/3,200	3,200
1997	17,900/17,900	17,900
1998	50,500/49,500	52,000

[532] No funding indicated in the budget documents.

Table 4-14. Space Network Services Funding History (in thousands of dollars)

Year (Fiscal)	Submission	Programmed
1993	—[533]	93,889
1994	—/46,100	55,701
1995	6,000[534]/13,200	13,200
1996	10,700/6,300	6,800
1997	5,100/5,100	5,100
1998	3,700/8,800	3,700

[533] The budget category was not established at the time of the budget submission.
[534] Funding for the operation of the SN ground facilities began to be transferred to the Space Network Services program under the MS appropriation. This budget category combined activities, which supported multiple customers, previously performed under the Space Network Operations and the Systems Engineering and Support programs, in addition to the WSGT operations performed under the TDRSS contract.

Table 4-15. Ground Network Funding History (in thousands of dollars)

Year (Fiscal)	Submission	Programmed
1989	248,100[535]/228,100	227,100
1990	269,600/233,576	251,476
1991	267,800/260,700	260,700
1992	291,700/283,000	283,000
1993	314,600/306,901	306,601
1994	315,980/311,300	309,300
1995	273,400/273,400[536]	273,400
1996	268,800/257,700[537]	259,500
1997	255,600/245,600	245,600
1998	227,700/224,700	221,600

[535] The GN included funding for Earth orbital spaceflight, planetary and solar system exploration, and the AB&SR program. It provided for operating and maintaining the worldwide tracking facilities, engineering support, and procurement of hardware and software to sustain and modify network capabilities as required for new missions. Its elements were the DSN, managed by JPL; STDN, managed by Goddard; the AB&SR tracking and data acquisition facilities, managed by GSFC/Wallops Flight Facility (WFF); and the Western Aeronautical Test Range (WATR), managed by Ames Research Center (ARC)/Dryden Flight Research Facility (DFRF).
[536] Although the total budget submission for the GN did not change from the original to the revised submission, funding increases were made for DSN Systems Implementation and the STDN budget categories. Offsetting reductions were taken for DSN Operations, the AB&SR program, and STDN Operations.
[537] The decrease of $11.1 million reflected deferring the 34-m (111-ft) arraying capability at Goldstone until FY 1998, deleting the 200-watt S-band transmitters for the 26-m (85-ft) subnet, and deleting the asynchronous transfer mode (ATM) upgrade for network communications.

Table 4-16. STDN Systems Implementation Funding History (in thousands of dollars)

Year (Fiscal)	Submission	Programmed
1989	6,200/4,500[538]	4,300
1990	4,400/3,700[539]	6,400
1991	3,200/2,800[540]	2,800
1992	3,600/3,100[541]	3,100
1993	5,500/5,526[542]	5,526
1994	6,100/3,400	3,400
1995	1,900/9,200[543]	4,600
1996	8,500/5,100	6,100
1997	2,400/2,400	2,400
1998	3,000/3,000	3,000

[538] The decrease of $1.7 million reflected program adjustments made to accommodate a portion of the general reduction specified by Congress.
[539] The decrease of $700,000 reflected program adjustments made to accommodate a portion of the general reduction specified by Congress.
[540] The decrease of $400,000 reflected program adjustments made to accommodate a portion of the general reduction specified by Congress. The decrease delayed the replacement of the intrasite communication systems at Bermuda and Merritt Island.
[541] The decrease of $500,000 reflected program adjustments made to accommodate a portion of the general reduction specified by Congress. The decrease delayed the replacement of UHF air-to-ground voice communication systems at Bermuda and Merritt Island that were needed for Space Shuttle missions.
[542] The increase in funds reflected the transfer of funds from the ROS account.
[543] The increase of $7.3 million in STDN Systems was required to support automation of the Bermuda and Merritt Island tracking facilities. To offset this requirement, funding for the AB&SR Systems was reduced $3.2 million, which was accommodated by deferring radar refurbishment activities at WFF and deferring equipment purchases for the WATR.

Table 4-17. STDN Operations Funding History (in thousands of dollars)

Year (Fiscal)	Submission	Programmed
1989	65,700/64,600[544]	64,500
1990	66,600/58,411[545]	55,083
1991	55,200/55,600[546]	55,600
1992	58,700/56,200[547]	56,040
1993	64,500/61,596[548]	62,386
1994	60,700/56,400	55,055
1995	32,200/29,000	28,700
1996	25,300/21,400	22,200
1997	18,600/19,300	19,300
1998	17,100/17,100	16,800

[544] The decrease of $1.1 million reflected program adjustments made to accommodate a portion of the general reduction specified by Congress.
[545] The decrease of $8.2 million reflected program adjustments made to accommodate a portion of the general reduction specified by Congress and a reduction for sequestration.
[546] The increase of $400,000 reflected program adjustments necessary to accommodate the final closure of the Ascension Island station. Although actual operations ceased in FY 1990, cleanup activity continued until April 1991, when the site was restored to its original condition.
[547] The decrease of $2.5 million was necessary to accommodate a portion of the general reduction specified by Congress. It resulted in a drawdown of logistics depot materials.
[548] The decrease of $2.9 million included a decrease of $3.0 million to accommodate a portion of the general reduction specified by Congress achieved by a drawdown of spare parts from the logistics depot and an increase of $0.1 million from the transfer of ROS funds.

Table 4-18. DSN Systems Implementation Funding History (in thousands of dollars)

Year (Fiscal)	Submission	Programmed
1989	50,100/39,700[549]	39,900
1990	63,400/57,400[550]	62,650
1991	60,700/61,900[551]	61,200
1992	82,400/79,300[552]	79,560
1993	82,600/80,301[553]	78,175
1994	89,900/97,500	98,324
1995	86,800/103,800[554]	106,000
1996	107,000/101,700	102,000
1997	102,900/92,900[555]	98,648
1998	80,900/79,100	78,700

[549] The decrease of $10.4 million reflected program adjustments made to accommodate a portion of the general reduction specified by Congress. The reduction resulted in stretching out several major program implementations, including those supporting Ocean Topography Experiment (TOPEX), the microwave observing project, and the development of an improved planetary radar capability.

[550] The decrease of $6.0 million reflected program adjustments made to accommodate a portion of the general reduction specified by Congress and a reduction for sequestration. The reduction was achieved by deferring the replacement of obsolete equipment.

[551] The increase of $1.2 million reflected program adjustments made to modify the 70-m (230-ft) antennas to permit rapid access for repair. Without the modifications, certain types of 70-m antenna failures could require extensive downtime to repair.

[552] The decrease of $3.1 million reflected program adjustments made to accommodate a portion of the general reduction specified by Congress.

[553] The decrease of $2.3 million reflected program adjustments made by deferring and delaying various activities to accommodate a portion of the general reduction specified by Congress.

[554] The increase reflected a reallocation from DSN Operations following a decision to consolidate funding for systems management, engineering, and sustaining investment. Funding was increased $9.0 million for advanced systems technology activities, $1.8 million for an additional system capability in Australia in support of the Galileo mission, and $3.6 million for the continued outfitting of a 34-m (111-ft) antenna transferred to NASA from the Department of the Army. As an offset to these increases, funding was reduced by $15.4 million, principally accommodated by the deferral of Cassini X-band emergency services at the Goldstone 70-m (230-ft) antenna (–$3.7 million), by descoping several DSN automation projects (–$2.5 million), and by the deferral of upgrades for the Very Long Baseline Interferometry (VLBI) and radio science programs (–$2.8 million). The remainder of the reduction was accommodated through the deferral of planned activities.

[555] The reduction of $10 million was achieved by implementing engineering efficiencies and economies that would have a minimal impact on DSN mission support services.

Table 4-19. DSN Operations Funding History (in thousands of dollars)

Year (Fiscal)	Submission	Programmed
1989	99,000/95,700[556]	95,000
1990	103,500/89,361[557]	98,553
1991	108,900/105,200[558]	105,800
1992	109,700/109,700	106,750
1993	119,000/118,000[559]	115,496
1994	112,100/102,900	100,371
1995	106,100/88,200[560]	85,100
1996	85,200/84,900	84,600
1997	87,500/87,500	82,952
1998	80,600/82,800	80,500

[556] The decrease of $3.3 million reflected the rephasing of activities to accommodate a portion of the general reduction specified by Congress.
[557] The decrease of $14.1 million reflected the rephasing of network activities supporting a variety of Agency programs to accommodate a portion of the general reduction specified by Congress and a reduction for sequestration.
[558] The decrease of $3.7 million reflected the slowdown of several network enhancement activities and a reduction in technical support to accommodate a portion of the general funding reduction specified by Congress.
[559] The decrease of $1.0 million reflected program adjustments made to accommodate a portion of the general reduction specified by Congress.
[560] Funding for DSN Operations was reduced by $17.9 million, which represented the reallocation of funding for systems management to DSN Systems Implementation.

Table 4-20. Aeronautics, Balloons, and Sounding Rocket (AB&SR) Support Systems Implementation Funding History (in thousands of dollars)

Year (Fiscal)	Submission	Programmed
1989	9,300/6,800[561]	6,800
1990	11,800/7,700[562]	10,400
1991	18,400/14,600[563]	14,800
1992	14,700/12,600[564]	15,700
1993	17,600/17,591[565]	21,386
1994	20,500/26,300	27,250
1995	20,000/16,800	23,400
1996	17,700/19,600	19,600
1997	19,400/19,400	19,200
1998	20,000/13,100	12,400

[561] The decrease of $2.5 million reflected program adjustments made to accommodate a portion of the general reduction specified by Congress. The reduction was accomplished by deferring system, supply, and support services procurements.

[562] The decrease of $4.1 million reflected program adjustments made to accommodate a portion of the general reduction specified by Congress and a reduction for sequestration. The reduction was partially achieved by deferring system implementations of aging radar systems at DFRF and S-band systems at WFF.

[563] The decrease of $3.8 million reflected program adjustments made to accommodate a portion of the general reduction specified by Congress. The decrease was accommodated by deferring the replacement of aging radar systems at DFRF and WFF.

[564] The decrease of $2.1 million reflected program adjustments made to accommodate a portion of the general reduction specified by Congress. The decrease was accommodated by deferring the replacement of balloon facility telemetry equipment and radar and communications systems at DFRF and WFF.

[565] The decrease reflected program adjustments to accommodate a portion of the general reduction specified by Congress, mostly offset by an increase due to the transfer of funds from the ROS account.

Table 4-21. AB&SR Support Operations Funding History (in thousands of dollars)

Year (Fiscal)	Submission	Programmed
1989	17,800/16,800[566]	16,600
1990	19,900/17,004[567]	18,390
1991	21,400/20,600[568]	20,500
1992	22,600/22,100[569]	21,850
1993	25,400/23,887[570]	23,622
1994	26,680/24,800	24,900
1995	26,400/26,400	25,600
1996	25,100/25,000	25,000
1997	24,800/24,100	23,100
1998	23,100/29,600	30,200

[566] The decrease of $1 million reflected program adjustments made to accommodate a portion of the general reduction specified by Congress.
[567] The decrease of $2.9 million reflected program adjustments made to accommodate a portion of the general reduction specified by Congress and a reduction for sequestration.
[568] The decrease of $800,000 reflected program adjustments made to accommodate a portion of the general reduction specified by Congress. The decrease reduced the level of tracking, telemetry, and communications available for AB&SR programs. The programs reduced their level of operations.
[569] The decrease of $500,000 reflected program adjustments made to accommodate a portion of the general reduction specified by Congress, requiring rephasing of the depot upgrade of a DFRF tracking radar system.
[570] The total decrease of $1.5 million reflected an increase of $0.4 million resulting from the transfer of funds from the ROS account along with $1.9 million in program adjustments made to accommodate a portion of the general reduction specified by Congress. The decrease required reductions in operations, engineering, and logistics at the WFF, as well as reductions in spares and test equipment at the WATR.

Table 4-22. Communications and Data Systems/Mission Control and Data Systems Funding History (in thousands of dollars)

Year (Fiscal)	Submission	Programmed
1989	248,300[571]/233,300	233,300
1990	250,200/210,867	224,867
1991	269,800/258,000	257,989
1992	314,200/281,400	281,400
1993	308,200/299,244	156,914[572]
1994	330,620/205,600[573]	206,481
1995	175,800/175,800	175,800
1996	162,200/153,300[574]	162,800
1997	135,800/147,100	147,100
1998	145,000/145,000	148,100

[571] Funds provided for implementing and operating facilities and systems required for data transmission, mission control, and data processing support for spaceflight systems.
[572] Funding reflected the restructuring of appropriations. This budget category, now called Mission Control and Data Systems and part of the SAT appropriation, no longer included Communications Systems Implementation and Communications Operations, which moved to the MS appropriation. Mission Control and Data Systems provided for developing and operating facilities and systems required for mission control and data processing for spaceflight missions conducted by Goddard.
[573] The submission reflected the restructuring of appropriations. This budget category, now called Mission Control and Data Systems and part of the SAT appropriation, no longer included Communications Systems Implementation and Communications Operations, which moved to the MS appropriation.
[574] The decrease of $8.9 million was accomplished by achieving operational efficiencies and reducing maintenance and operations staffing through normal attrition and as reengineering efforts took effect, which included extensive reuse of software.

Table 4-23. Communications Systems Implementation Funding History (in thousands of dollars)

Year (Fiscal)	Submission	Programmed
1989	12,100/10,400[575]	10,400
1990	12,500/11,400[576]	9,535
1991	13,500/11,600[577]	11,600
1992	10,300/10,300	10,300
1993	8,700/8,769[578]	8,694
1994	14,600/11,800[579]	—
1995	9,800/—[580]	—

[575] The decrease of $1.7 million reflected program adjustments made to accommodate a portion of the general reduction specified by Congress. Implementation of the facility communications for the STGT was slipped for six months as part of this accommodation.
[576] The decrease of $1.7 million reflected program adjustments made to accommodate a portion of the general reduction specified by Congress and a reduction for sequestration.
[577] The decrease of $1.9 million reflected program adjustments made to accommodate a portion of the general reduction specified by Congress. As a result, the planned replacement of the Shuttle video system was canceled.
[578] The decrease reflected the transfer of funds from the ROS account.
[579] Restructuring of appropriations placed this budget category in the MS appropriation.
[580] The budget category no longer appeared in budget documents.

Table 4-24. Communications Operations Funding History (in thousands of dollars)

Year (Fiscal)	Submission	Programmed
1989	116,300/108,400[581]	109,300
1990	115,500/99,737[582]	106,054
1991	120,300/118,200[583]	118,189
1992	129,600/123,400[584]	122,640
1993	131,200/128,054[585]	125,915
1994	124,520/119,100[586]	—
1995	105,100/—[587]	—

[581] The decrease of $7.9 million reflected program adjustments made to accommodate a portion of the general reduction specified by Congress. The adjustments included delaying the implementation of new requirements on the PSCN and savings associated with the revised Shuttle manifest.
[582] The decrease of $15.8 million reflected program adjustments made to accommodate a portion of the general reduction specified by Congress and a reduction for sequestration. The adjustments included delaying the implementation of new requirements on the PSCN and NASCOM. New requirements on NASCOM were met by time-sharing existing circuitry at the expense of operational performance.
[583] The decrease of $2.1 million reflected program adjustments made to accommodate a portion of the general reduction specified by Congress. The adjustments included delaying the implementation of new capabilities in requirements on the PSCN and NASCOM by time-sharing existing circuitry.
[584] The decrease of $6.2 million reflected program adjustments to the PSCN, including delaying implementation of new requirements and deferring planned improvements to existing services. The adjustments also reflected fewer Shuttle missions and the sharing of existing resources. Planned augmentations, such as the upgrade of the Time Division Multiple Access (TDMA) system in the NASCOM network, were deferred until FY 1994 to coincide with anticipated new service requirements in preparation for Space Station Freedom (SSF).
[585] The decrease of $3.1 million reflected an increase of $1.6 million transferred from the ROS account with program adjustments to the PSCN, including delaying the implementation of new requirements and deferring planned improvements to existing services. Planned augmentation was deferred until FY 1995.
[586] Restructuring of appropriations placed this budget category in the MS appropriation.
[587] The budget category no longer appeared in budget documents.

Table 4-25. Space Communications Services Funding History (in thousands of dollars)[588]

Year (Fiscal)	Submission	Programmed
1993	—[589]	333,715[590]
1994	—[591]/214,400	248,192
1995	268,900/226,487	225,000
1996	319,400/269,400[592]	255,400
1997	291,400/277,700	291,400
1998	245,700/194,200[593]	194,200

[588] Consisted of SN and Telecommunications budget categories in the MS appropriation.
[589] The old budget structure was still in effect at the time of the budget submission.
[590] Reflected a new budget structure that included the SN and Telecommunications budget categories.
[591] The new budget structure with this budget category was not established at the time of the budget submission.
[592] The decrease reflected a $50.0 million general reduction as directed by Congress.
[593] The decrease reflected a pending reduction of $4.5 million.

Table 4-26. Telecommunications Funding History (in thousands of dollars)[594]

Year (Fiscal)	Submission	Programmed
1993	—[595]	134,609
1994	139,120[596]/130,900	130,518
1995	114,900/114,900	114,900
1996	112,700/112,700	98,200
1997	106,300/92,600	106,300
1998	84,500/84,500[597]	82,500

[594] Telecommunications was included in the new MS appropriation as of FY 1995. Telecommunications supported the operation, maintenance, and improvement of the NASCOM network and the PSCN.
[595] The new budget category was not established at the time of the budget submission.
[596] The amount was the total of amounts requested for Communications Systems Implementation and Communications Operations under the previous appropriation structure. This category was placed in the new MS appropriation in FY 1995.
[597] The budget category name was changed to NASA Integrated Services Network (NISN), a consolidation of the NASCOM network and the PSCN.

Table 4-27. Mission Communication(s) Services Funding History (in thousands of dollars)

Year (Fiscal)	Submission	Programmed
1993	—[598]	546,488
1994	—[599]/589,100[600]	581,981[601]
1995	481,200/481,200	481,200
1996	461,300/441,300[602]	449,500
1997	420,600/418,600[603]	418,600
1998	400,800/395,800[604]	400,800

[598] The new budget category was not established at the time of the budget submission.
[599] The former budget appropriation structure was still in effect at the time of the initial budget submission. See above table.
[600] Reflected restructured budget structure in the SAT appropriation consisting of the GN, Mission Control and Data Systems, Space Network Customer Services, Advanced Systems, and CofF budget elements.
[601] Reflected restructured budget.
[602] The reduction of $20 million reflected a general reduction as directed by Congress. The reduction was accomplished by implementing economies in support service contractor staffing levels and achieving operational efficiencies in areas such as engineering activities, mission and strategic planning, quality assurance, logistics, documentation, and configuration management.
[603] The reduction of $2 million reflected a reduction of $10 million within the GN program offset by a reallocation of $8 million to the Mission Control and Data Systems program from the Space Access and Technology program.
[604] Reflected a pending reduction of $5.0 million as part of the transfer authority from the SAT appropriation to the Human Space Flight (HSF) appropriation.

Table 4-28. Mission Facilities Funding History (in thousands of dollars)

Year (Fiscal)	Submission	Programmed
1989	8,800/8,800	7,000
1990	7,800/8,300[605]	10,220
1991	11,100/9,000[606]	8,800
1992	22,000[607]/14,000[608]	14,000
1993	17,100/14,241[609]	14,241
1994	18,500/17,500[610]	16,600
1995	14,300/12,000	12,000
1996	11,300/10,300	10,800
1997	9,300/10,500	10,000
1998	13,400/13,400	13,400

[605] The increase of $0.5 million reflected the start of development of an integrated mission control capability for the Small Explorer (SMEX) missions after an adjustment to accommodate a portion of the general reductions specified by Congress.
[606] The decrease of $2.1 million reflected program adjustments made to accommodate a portion of the general reduction specified by Congress. The reduction resulted in a delay in the development of AXAF, SMEX, the Fast Auroral Snapshot Explorer (FAST), and the Submillimeter Wave Astronomy Satellite (SWAS) spacecraft control centers, as well as the deferral of planned replacements of some aging control center equipment.
[607] The increase from FY 1991 to FY 1992 reflected the deferral of work from FY 1991 plus implementation activities required by the increasing queue of scheduled new missions.
[608] The decrease of $8 million reflected a rephasing of the AXAF program mainly due to a launch delay and planned efficiencies in the development of the SMEX Payload Operations Control Center (POCC) to be gained through the reuse of the SMEX 1 POCC systems for SMEX 2.
[609] The decrease of $2.9 million reflected program adjustments made by deferring and delaying various activities to accommodate a portion of the general reduction directed by Congress.
[610] The budget category changed to Mission Control Systems.

Table 4-29. Mission Operations Funding History (in thousands of dollars)

Year (Fiscal)	Submission	Programmed
1989	32,000/31,200[611]	30,900
1990	38,700/29,036[612]	27,200
1991	40,800/41,400[613]	41,400
1992	44,900/48,400[614]	48,400
1993	52,500/50,336[615]	48,336
1994	52,700/52,700[616]	54,000
1995	51,000/51,300	52,500
1996	45,300/45,300	43,200
1997	41,700/43,700	43,700
1998	46,500/46,000	47,300

[611] The decrease of $0.8 million reflected program adjustments made to accommodate a portion of the general reduction specified by Congress. The reduction resulted in a slowdown of software development in FY 1989 for the Upper Atmosphere Research Satellite (UARS), Extreme Ultraviolet Explorer (EUVE), Global Geospace Satellite (GGS), and Collaborative Solar Terrestrial Research (COSTR) spacecraft.
[612] The decrease of $9.7 million largely reflected program adjustments made to accommodate a portion of the general reduction specified by Congress and a reduction for sequestration. The reductions resulted in a slow-down of the unique software development for EUVE, GGS, and COSTR, as well as the deferral of the buildup of institutional capabilities to support the workload resulting from the flight manifest.
[613] The increase of $600,000 was required for the increased number of operating personnel required for new missions—the Gamma Ray Observatory (GRO), UARS, and EUVE—that became operational in FY 1991 and early FY 1992.
[614] The increase of $3.5 million was needed to start the POCC software development required for the July 1995 Solar and Heliospheric Observatory (SOHO) launch date, provide adequate software maintenance for the software used to control the on-orbit spacecraft, and provide software for new institutional systems needed to accommodate the increasing number and complexity of spacecraft controlled by the POCCs.
[615] The decrease of $2.2 million included an increase of $0.3 million associated with the ROS account transfer along with a decrease of $2.5 million resulting from a rephasing of the Tropical Rainfall Measuring Mission (TRMM) mission control software and deferral of institutional software systems.
[616] The budget category name changed to Mission Control Operations.

Table 4-30. Data Processing Systems Implementation Funding History (in thousands of dollars)

Year (Fiscal)	Submission	Programmed
1989	25,800/25,500[617]	26,700
1990	20,900/18,000[618]	18,391
1991	22,800/22,000[619]	22,400
1992	39,800/23,600[620]	24,360
1993	30,000/30,670[621]	29,460
1994	33,600/44,400	46,381
1995	40,600/42,500	42,300
1996	41,400/38,300	46,800
1997	30,900/40,400	41,300
1998	39,700/41,700	3,000

[617] The decrease of $0.3 million reflected program adjustments made to accommodate a portion of the general reduction specified by Congress.
[618] The decrease of $2.9 million reflected program adjustments made to accommodate a portion of the general reduction specified by Congress and a reduction for sequestration. The reductions were in the Mission Operations Data Systems Information Network (MODSIN) and also deferred generalized attitude application software and data processing development.
[619] The decrease of $0.8 million reflected program adjustments made to accommodate a portion of the general reduction specified by Congress. The decrease delayed the Spacelab data processing hardware replacement.
[620] The decrease of $16.2 million reflected simplification of data processing and communication requirements of the SSF program as a result of the program's restructuring and the reduction of the need for a Customer Data and Operations System (CDOS)-type system. CDOS was combined with the EOSDIS program and was to be managed by the Office of Space Science and Applications (OSSA). The SSF program was to provide the necessary data processing capability within its communications system. The decrease reflected the reassignment of CDOS and associated communications capability from the data processing systems program to the Earth Observing System (EOS) and SSF.
[621] The increase of $0.7 million included $0.2 million transferred from the ROS account plus $0.5 million for the Hubble Space Telescope Data Capture Facility (HSTDCF) software conversion to the extended Packet Data Processor (PACOR) system. Conversion of HSTDCF software to the multimission PACOR system would allow operation of the stand-alone HSTDCF to be discontinued.

Table 4-31. Data Processing Operations Funding History (in thousands of dollars)

Year (Fiscal)	Submission	Programmed
1989	53,300/49,000[622]	49,000
1990	54,800/44,394[623]	53,467
1991	61,300/55,800[624]	55,600
1992	67,600/61,700[625]	61,700
1993	68,700/67,174[626]	64,877
1994	86,700/91,000	89,500
1995	69,900/70,000	69,000
1996	64,200/59,400	62,000
1997	53,900/52,500	52,100
1998	45,400/43,900	84,400

[622] The decrease of $4.3 million reflected program adjustments made to accommodate a portion of the general reduction specified by Congress. The budget reduction affected operational support in FY 1989 by reducing staffing at the Telemetry On-line Processing System (TELOPS) Facility and scaling back Spacelab mission support in FY 1989, resulting in the delayed delivery of data from missions that required TELOPS or Spacelab Data Processing Facility (SLDPF) support.
[623] The decrease of $10.4 million reflected program adjustments made to accommodate a portion of the general reduction specified by Congress and a reduction for sequestration. The reduction resulted in the delayed delivery of data from some of the missions supported. Reductions were also made in data systems prototyping, operations, and maintenance of computer operations and attitude support activities.
[624] The decrease of $5.5 million reflected program adjustments made to accommodate a portion of the general reduction specified by Congress. Reductions were made in data systems, computer operations, and maintenance and resulted in the delayed delivery of some mission data.
[625] The decrease of $5.9 million reflected reductions made in data systems, computer operations, and maintenance and deferral of the replacement computer system used for spacecraft simulation and software research and development. Reductions were also made in the SLDPF consistent with fewer Shuttle missions.
[626] The decrease of $1.5 million reflected a $0.7 million increase due to the transfer from the ROS account along with reductions of $2.2 million in operations and maintenance in the SLDPF.

Table 4-32. Space Network Customer Services Funding History (in thousands of dollars)

Year (Fiscal)	Submission	Programmed
1993	—[627]	27,900
1994	—/30,000	30,000
1995[628]	32,000/32,000	32,000
1996	30,300/30,300	27,200
1997	29,200/25,900[629]	25,900
1998	31,100/31,100	31,100

[627] The budget category was not established at the time of the budget submission.
[628] Beginning in FY 1995, funding previously provided under Space Network Operations and Systems Engineering and Support programs was combined. Capabilities representing the services needed to provide user access to the SN were combined in the Space Network Customer Services program under the SAT appropriation. This program provided access to the multimission communications network servicing all TDRS-compatible Earth-orbiting missions. It provided for the operation, maintenance, and improvement of the ground systems and facilities at Goddard, including the NCC, required to schedule user services and to control and operate the SN system.
[629] The decrease of $3 million reflected a reallocation from Space Network Customer Services to Mission Control and Data Systems based on reassessment of program requirements.

Table 4-33. Tracking and Data Advanced Systems/Advanced Technology Funding History (in thousands of dollars)[630]

Year (Fiscal)	Submission	Programmed
1989	18,800/18,800	18,800
1990	19,900/19,345[631]	19,328
1991	20,000/20,000	20,000
1992	22,000/22,000	22,000
1993	23,200/23,273[632]	23,273
1994	24,600/24,600	19,600
1995[633]	—[634]/—	—

[630] R&D appropriation.
[631] The reduction of $555,000 reflected the general reduction provision of P.L. 101-144 and was accommodated through the deferral of activities planned for FY 1990.
[632] The increase of $73,000 was due to a transfer of funds from the ROS account.
[633] The name was changed to Advanced Technology; the category was included in the SAT appropriation.
[634] No longer funded as a separate budget element. Essential activities were included within the Mission Communication Services program.

Table 4-34. Construction of Facilities Funding History (in thousands of dollars)[635]

Year (Fiscal)	Submission	Programmed
1993	—	31,800[636]
1994	—/17,600[637]	15,600
1995	—[638]/—	—

[635] SAT appropriation funding.
[636] FY 1993 funding provided for construction of two 34-m (111-ft) high-efficiency beam wave guide (BWG)-type multifrequency antennas at the Goldstone Deep Space Communications Complex.
[637].FY 1994 funding provided for an additional 34-m (111-ft) BWG antenna at the Canberra Deep Space Communications Complex.
[638] No Construction of Facilities funds were requested in FY 1995.

Table 4-35. Tracking and Data Acquisition Stations, 1989–1998

Station (Location)	**Code Name or Number**	**Latitude/Longitude[639]**	**Type of Station**		**Established**	**Phased Out**	**Equipment/Capabilities**	**Remarks**
			STDN	**DSN**				
Alaska Ground Station (AGS), Chatanika, AK,[640] or Poker Flat Tracking Station (PFTS)								
	Transportable Orbital Tracking System (TOTS)	65°07'N 147°27'W	X		1992		8-m (26-ft) antenna simultaneously transmitted and received at S-band; one- and two-way Doppler and antenna autotracking angle	Supported low-data-rate polar-orbiting spacecraft and sounding rocket launches.
	AGS[641]	65°07'N 147°27'W	X		1995		11.3-m (37-ft) antenna simultaneously transmitted at S-band while receiving at S- and X-bands; one- and two-way Doppler and antenna autotracking angle	Supported primarily high-data-rate polar-orbiting spacecraft.
	Low-Earth Orbiter Terminal (LEO-T)	65°07'N 147°44'W	X		1995		5-m (16-ft) antenna simultaneously transmitted and received at S-band	Provided automated tracking system for low-data-rate orbital support.
Alaska Satellite Facility (ASF), Fairbanks, AK[642] ASF								Downlinked, processed, archived, and distributed synthetic aperture radar (SAR) data from the European Space Agency (ESA), the National Space Development

639 Rounded to the nearest minute.
640 Space Communications Program Office, *Ground Network (GN) Users' Guide, Revision 1* (Greenbelt, MD: Goddard Space Flight Center, 2005), pp. 6-1–6-10, *http://scp.gsfc.nasa.gov/gn/gnusersguide3.pdf* (accessed September 18, 2006).
641 Also known as the EOS Polar Ground Station.
642 Alaska Satellite Facility, *http://www.asf.alaska.edu/about_asf/receiving.html* (accessed September 18, 2006).

Station (Location)	Code Name or Number	Latitude/Longitude[639]	Type of Station		Established	Phased Out	Equipment/Capabilities	Remarks
			STDN	DSN				
								Agency of Japan (NASDA), and Canadian Space Agency (CSA) satellites.
		64°51'N 147°50'W	X		1990		10-m (33-ft) antenna received at X- and S-bands	
		64°51'N 147°51'W	X		1990		11.3-m (37-ft) antenna transmitted at S-band, received at X- and S-bands	
Ascension Island (South Atlantic)	ACN	7°57'S 14°35'W	X	X	1967	1989	9-m (29-ft) USB; VHF telemetry links; FM remoting telemetry; decommutators; telemetry recording; data processing, communications (voice, VHF air-to-ground, teletype, video, and high-speed data); 9-m (29-ft) DSN antenna	Primary USB station for near-Earth Apollo operations. DOD also operated a station on Ascension Island. DSN operations were phased out in 1969.
Bermuda (Atlantic)	BDA	32°15'N 64°50'W	X		1961	1997[643]	C-band radar; 9-m (29-ft) USB; VHF telemetry links; FM remoting telemetry; decommutators; telemetry recording; data processing; communications (voice, VHF air-to-ground, teletype video, high-speed data)	Data received at Bermuda helped decide whether the Shuttle was “go” or “no-go” for orbital insertion. Also provided reentry tracking for Atlantic recovery situations.
Canberra (southeastern Australia) (CAN)								

[643] “Tracking Stations: STDN’s Final Years,” *http://www.bfec.us/bfectxt8a.htm* (accessed March 26, 2007). NASA did not conduct any activities on Bermuda after 1997, although a small number of staff remained at the site until 2001 (Sunny Tsiao, e-mail to author, March 29, 2007).

Station (Location)	Code Name or Number	Latitude/Longitude[639]	Type of Station		Established	Phased Out	Equipment/Capabilities	Remarks
			STDN	DSN				
	33	35°24'S 148°59'E		X	1996	2002	11-m (36-ft) antenna; OVLBI antenna supported X- and Ku-band uplink and downlink	Used orbiting very long base interferometer (OVLBI) technique, which allowed communication with space-based interferometer elements.
	34	35°24'S 148°59'E		X	1997[644]		34-m (111-ft) BWG antenna; transmitted at X- and S-bands, received at X-, S-, and Ka-bands	Transmission and reception equipment was underground, which reduced the weight of the dish and allowed for maintenance while the antenna tracked.
	42 Weemala	35°24'S 148°59'E		X	1964[645]	1999	34-m (111-ft) antenna; S- and X-band transmit and receive	This antenna was extended from a 26-m (85-ft) antenna. Was decommissioned in 1999 and removed in 2000. Supported the Voyager spacecraft.
	43 Ballima	35°24'S 148°59'E		X	1987		70-m (230-ft) antenna; transmitted and received in S- and X-bands; received at L-, X-, S-, K-, and Ku-bands	This antenna was extended from the original 64-m (210-ft) antenna in 1987 to support Voyager 2’s encounter with Neptune.

[644] Glen Nagle, Education and Outreach Manager, Canberra Deep Space Communication Complex, e-mail to author, September 19, 2006. DSS-34 was commissioned in February 1997. Construction was completed in December 1996 per Douglas Mudgway, e-mail to author, September 20, 2006.
[645] “People, Antennas and Equipment,” Canberra Space Centre Fact Sheet, *http://www.cdscc.nasa.gov/PDFs/cdscc_people.pdf* (accessed September 26, 2006).

Station (Location)	Code Name or Number	Latitude/Longitude[639]	Type of Station		Established	Phased Out	Equipment/Capabilities	Remarks
			STDN	DSN				
	45	35°24'S 148°58'E		X	1986		34-m (111-ft) antenna; transmitted at X-band, received at X- and S-bands	Supported the Voyager 2 spacecraft.
	46	35°24'S 148°59'E		X	1984		USB 26-m (85-ft) antenna; main antenna transmitted and received at S-band; acquisition aid antenna received at X-band[646]	This antenna was moved from Honeysuckle Creek in 1983 and transferred from STDN in 1985.
Parkes Radio Telescope (Australia)		33°0'S 148°16'E		X[647]	1961		64-m (210-ft) used as a receiving station when arrayed with DSN telescopes	Arrayed with DSN stations.
Dakar (Senegal)	DKR	14°43'N 17°08'W	X		1981	1993[648]	4.3-m (14-ft) command and receive antenna; UHF voice air-to-ground, command and receive antenna	Supported early Shuttle missions.
Dryden Western Aeronautical Test Range	WATR	34°56'N 117°54'W	X		1978		Two high-accuracy R-716 C-band radars provided time-space position information in support of research aircraft and low-Earth-orbiting spacecraft to	This facility began operating in 1978 for the Shuttle program. Previously, it had provided aeronautics tracking. It received one

646 "Deep Space Station 46," Canberra Deep Space Communications Complex, *http://www.cdscc.nasa.gov/Pages2/pg01i_history.html* (accessed September 18, 2006). DSS 46 receives at X-band, but only from an "acquisition aid" antenna that is actually a feed horn mounted on the edge of the main reflector. It has a wide beam width and significantly lower gain than the main antenna. It is used to acquire spacecraft during launch and early orbit phase. It does not have enough gain to allow the reception of telemetry and is receive only. It is used to acquire the signal under launch conditions when uncertainties in pointing could result in acquisition difficulties at the 34-meter antennas. James Hodder, Deep Space Mission System Service Management Office, Jet Propulsion Laboratory, e-mail to author, September 26, 2006.

647 Australian telescope used in arrays with NASA deep space telescopes.

648 Had been scheduled to close in 1989 but remained open until FY 1994 because of the delay in the new TDRS resulting from the *Challenger* accident and loss of TDRS-B.

Station (Location)	Code Name or Number	Latitude/Longitude[639]	Type of Station		Established	Phased Out	Equipment/Capabilities	Remarks
			STDN	DSN				
							the mission control room complex; 4.3-m (14-ft) S-band antenna; 7-m (23-ft) antenna systems supported downlinked telemetry and video signals in L-, S-, and C-bands while sending uplinked commands in L- or S-band; an additional antenna system operated in L- and S-bands only[649]	4.3-m (14-ft) S-band antenna from the Buckhorn Lake site in 1985, resulting in a total of two 4.3-m (14-ft) antennas at the site.
Goldstone (California)								This complex, in the Mojave Desert, was the largest concentration of NASA tracking and data acquisition equipment.
	ECHO 12	35°18'N 116°44'W		X	1960	1996	34-m (111-ft) STD antenna; transmitted and received	The original 26-m (85-ft) antenna was extended to 34 m (11 ft) in 1979.
	VENUS 13	35°15'N 116°48'W		X	1991		9-m (30-ft) antenna (not in use); 34-m (111-ft) BWG antenna, supported uplink in S-, X-, and Ka-bands and downlink in S-, X-, Ka-, and Ku-bands	The first BWG antenna replaced a 26-m (85-ft) antenna in 1991. It was used as a DSN research and development facility.
	MARS 14	35°26'N 116°54'W		X	1966		70-m (230-ft) antenna transmitted and received in S- and X-bands and	This antenna replaced the 64-m (210-ft) antenna in 1988 to

[649] "About WATR: Telemetry Tracking Systems," *http://www.nasa.gov/centers/dryden/research/Facilities/WATR/about5.html*. Also "About WATR: Space Positioning Systems: *http://www.nasa.gov/centers/dryden/research/Facilities/WATR/about4a.html* (both accessed October 2, 2006).

Station (Location)	Code Name or Number	Latitude/Longitude[639]	Type of Station		Established	Phased Out	Equipment/Capabilities	Remarks
			STDN	DSN				
							received at L-, X-, and S-bands. L- and Ku-bands (22-GHz receive-only) were in a special cone on the antenna used for radio astronomy	support Voyager 2's encounter with Uranus.
	URANUS 15	35°25'N 116°54'W		X	1984		34-m (111-ft) HEF antenna; supported X-band uplink and X- and S-band downlink	Was used for the first time in 1986 to support the Voyager spacecraft. Also used for very-long baseline interferometry (VLBI) and radio-source catalog maintenance.
	16	35°20'N 116°53'W		X	1965		USB 26-m (85-ft) antenna, supported X-band uplink and downlink	Equipment was moved from STDN in 1985. Used for rapidly tracking Earth-orbiting spacecraft.
	17	35°21'N 116°53'W		X	1967		USB 9-m (30-ft) antenna; backup for DSS 16	Transferred from STDN in 1985.
	23	35°20'N 116°53'W		X	1996		11-m (36-ft) OVLBI antenna supported X- and Ku-band uplink and downlink	Primary purpose of the 11-m (36-ft) subnet was to support OVLBI satellites.
	24	35°20'N 116°53'W		X	1995		34-m (111-ft) BWG antenna, supported X- and S-band uplink and downlink	
	25	35°20'N 116°53'W		X	1996		34-m (111-ft) BWG antenna, supported uplink	

Station (Location)	Code Name or Number	Latitude/Longitude[639]	Type of Station		Established	Phased Out	Equipment/Capabilities	Remarks
			STDN	DSN				
							and downlink in X-band and Ka-band	
	26	35°20'N 116°53'W		X	1996		34-m (111-ft) BWG, supported uplink and downlink in X-band and downlink in Ka-band	
	27	35°14'N 116°47'W		X	1995		34-m (111-ft) high-speed BWG (HSB) antenna, supported S-band uplink and downlink[650]	
	28	35°14'N 116°47'W		X	2000		34-m (111-ft) BWG HSB antenna supported S-band uplink and downlink	Was built in 1996 but did not become operational until 2000 due to funding delay.[651]
Goddard Space Flight Center (Greenbelt, MD)[652]	Network Test and Training Facility (NTTF)	38°59'N 76°51'W	X	X	1966	1998	9-m (30-ft) antenna supported S-band uplink and downlink; small X-band piggybacked onto main 9-m S-band dish; 4.3-m (14-ft) S-band antenna	Orbital tracking 11-m antenna was transferred to WFF in 1986. Facility was used to sustain ground network for testing through 1998. Antenna was dismantled in 2005. Some small-scale S-band antenna testing being conducted using a 4.3-m antenna (2007).
GRO Remote	GRTS	35°22'S	X		1994	1996	4.5-m (15-ft) antenna; 11-m	Built to support the

[650] HSB—high (angular-tracking) speed beam waveguide (antenna).
[651] Douglas Mudgway, e-mail to author, October 16, 2006. Also Mudgway, *Uplink-Downlink*, p. 438.
[652] Robin Dixon, former data communications engineer at the Goddard facility, telephone conversation, November 2, 2006, and e-mail to author, March 27, 2007.

Station (Location)	Code Name or Number	Latitude/Longitude[639]	Type of Station		Established	Phased Out	Equipment/Capabilities	Remarks
			STDN	DSN				
Terminal System		148°58'E					(36-ft) antenna	Gamma Ray Observatory in communicating to Earth via TDRSS. Closed the TDRSS zone-of-exclusion over the Indian Ocean. Located at Canberra DSN Complex. Occasionally supported Shuttle missions and the Hubble Space Telescope as they passed over the Indian Ocean and Australia.
Guam Remote Ground Terminal	GRGT	13°36'N 144°51'E	X		1998		Space to Ground Link Terminal (SGLT); 11-m (36-ft) antenna; end-to-end test 4.5-m (15-ft) antenna. Provided an S-band and Ku-band TDRS TT&C link, two S-band single-access (SA) forward and return links, and two Ku-band SA forward and return links	Replaced GRO Remote Terminal System (GRTS).
Guam (Pacific)	GWM	13°18'N 144°44'E	X		1966	1989	9-m (29-ft) USB command and receive; VHF telemetry links; FM remoting telemetry; decommutators; telemetry recording; data	Last mission support was for the Solar Maximum Mission on June 29, 1989.[653]

[653] Henry Iuliano, "NASA Phases Down Guam Tracking Station," *Goddard News* (September 1989): p. 8, NASA History Division folder 6534, Historical Reference Collection, NASA Headquarters, Washington, DC.

Station (Location)	Code Name or Number	Latitude/Longitude[639]	Type of Station		Established	Phased Out	Equipment/Capabilities	Remarks
			STDN	DSN				
							processing; voice, UHF air-to-ground, teletype, video, and high-speed data communications	
Indian Ocean in the Seychelles Islands	INDI[654] or IOS	04°40'S 55°28'E	X		1981	1996	One 18-m (59-ft) antenna	This military site supported the Shuttle and other spacecraft, e.g., GOES. Deactivated when the U.S. government and the local Seychelles government could not agree on the annual rent for the property.
Kauai (Hawaii)	KAUAIH or HAW	22°07'N 157°40'W	X		1961	1989	Two Yagi command; 4.3-m (14-ft) antenna; C-band radar; 9-m (29-ft) USB command and receive 9-m (30-ft) S-band antenna; VHF telemetry links; FM remoting telemetry recording; communications (voice, VHF air-to-ground, teletype, video, and high-speed data)	The Manned Space Flight Network (MSFN) station began operations in 1961 and Data Acquisition Network in 1965.
Madrid (Spain)								
	53	40°26'N 4°15'W		X	1996		11-m (36-ft) OVLBI antenna, supported uplink	Primary purpose of 11-m (36-ft) subnet was to

[654] Schriever Air Force Base Historian, e-mail to author, October 10, 2006. Also "Kodiak Tracking Station," *http://www.kadiak.org/af_track/bob_afscf_1-2.html* (accessed October 5, 2006).

Station (Location)	Code Name or Number	Latitude/Longitude[639]	Type of Station		Established	Phased Out	Equipment/Capabilities	Remarks
			STDN	DSN				
							and downlink at X- and Ku-band	support OVLBI satellites.
	54	40°25'N 4°16'W		X	1997		34-m (111-ft) BWG antenna, supported uplink in S- and X-band, downlink in S-, X- and Ka-bands	
	61 Robledo-I	40°26'N 4°15'W		X	1965	1999	34-m (111-ft) STD antenna; transmitted at S-band and received at S-band and X-band	Expanded from 26 meters.
	63 Robledo-II	40°26'N 4°15'W		X	1987		70-m (230-ft) antenna, transmitted and received in S- and X-bands; received at L-band, X-band, and S-band	Original 64-m (210-ft) antenna operational in 1973 expanded to 70 m (230 ft) in 1987 to support the Voyager spacecraft.
	65 Robledo-III	40°26'N 4°16'W		X	1987		34-m (111-ft) HEF; transmitted at X-band and received at X-band and S-band	Supported the Voyager spacecraft.
	66 Robledo-IV	40°26'N 4°16'W		X	1985		26-m (85-ft) antenna; supported X-band uplink and downlink	Transferred from STDN in 1985.
McMurdo (Antarctica)[655]	MGS	77°50'S 193°20'W	X		1995		10-m (33-ft) antenna simultaneously transmitted at S-band while receiving at S-band and X-band	Designed to collect SAR image data. Supported Canadian SAR mapping of Antarctica. Used TDRS relay, which supported serial clock

[655] *Ground Network (GN) Users' Guide, Revision 1*, pp. 5-1–5-5, *http://scp.gsfc.nasa.gov/gn/gnusersguide3.pdf*.

Station (Location)	Code Name or Number	Latitude/Longitude[639]	Type of Station		Established	Phased Out	Equipment/Capabilities	Remarks
			STDN	DSN				
								and data and other interfaces.
Merritt Island, FL (MILA)[656]	MIL	28°25'N 80°40'W	X		1966		Spacecraft communicating antennas:[657] • Two 9-m (30-ft) S-band command and receive antennas to track moving space vehicles • Two 3-m (10-ft) antennas primarily to relay data between KSC projects and TDRS • Two teltrac and quad helix UHF tracking antennas for voice communication with astronauts in the Shuttle • Two 1.2-m (4-ft) antennas (one S-band, one Ku-band) to communicate with DSN payloads during KSC processing • 4.3-m (14-ft) S-band command and receive antenna connected whenever a 9-m (30-ft)	Located near the Cape Kennedy launch complex, the station was established to provide Earth orbital support to the Apollo program. Used for Shuttle launches and landings.

[656] "MILA" was derived from Merritt Island Launch Annex to Cape Canaveral, the previous name of the area that became known as Kennedy Space Center. "The MILA Story," *http://science.ksc.nasa.gov/facilities/mila/milstor.html* (accessed September 15, 2006).
[657] Ibid.

Station (Location)	Code Name or Number	Latitude/Longitude[639]	Type of Station		Established	Phased Out	Equipment/Capabilities	Remarks
			STDN	DSN				
							antenna was removed from service for refurbishing	
							Support antennas: • Two 1.2-m (4-ft) S-band antennas and a smaller Ku-band antenna to calibrate and test the steerable antennas • 1.8-m (6-ft) microwave antenna to communicate with the PDK tracking station • Two stationary discone UHF antennas to monitor the moveable UHF tracking antennas • Shortwave antenna to monitor the calibrated timing station • C-band radar; VHF telemetry links; FM remoting telemetry; decommutators; telemetry recording; data processing; communications (voice, UHF air-to-ground, teletype, video, and high-speed data)	
Merritt	PDL	29°4'N	X		1979		4.3-m (14-ft) antenna,	Used only for Shuttle

Station (Location)	Code Name or Number	Latitude/Longitude[639]	Type of Station		Established	Phased Out	Equipment/Capabilities	Remarks
			STDN	DSN				
Island "Wing Site" at Ponce de Leon, FL		80°54'W					simultaneously transmitted and received at S-band; fixed UHF cross-dipole antenna to back up the S-band system[658]	support, this station was located to provide communications with the Shuttle during the launch ascent when the solid rocket motor plume blocked signals to the MILA Tracking Station at KSC.[659]
Santiago, Chile	AGO	33°09'S 70°40'W	X		1957	1989	9-m (29-ft) antenna; 12-m (39-ft) antenna; GRARR; USB; 2 SATAN receivers; 1 SATAN command; Yagi command; MOTS	Santiago tracking station was transferred to the Universidad de Chile in October 1989.[660] NASA purchased services from its Center for Space Studies.[661]
South Pole TDRSS Relay System	SPTR	89°59'S 157°47'W[662]	X		1997		7.2-m (24-ft) antenna	Transmitted science data to WSGT via TDRS
Svalbard Satellite Station (Norway)	SvalSat	78°13'N[663] 15°23'E			1997		11-m (36-ft) antenna, downlinked at S- and X band, uplinked at S-band	Most northerly ground station in the world. This commercial Norwegian enterprise acquired data

[658] *Ground Network (GN) Users' Guide*, *Revision 1*, p. 7-5, *http://scp.gsfc.nasa.gov/gn/gnusersguide3.pdf*.
[659] "Tracking Stations," *http://www.bfec.us/bfectxt7.htm* (accessed October 18, 2006).
[660] Center for Space Studies, Universidad de Chile, *Santiago Satellite Tracking Station User's Guide, http://www.cee.uchile.cl/public/manual/brief_en.htm* (accessed September 19, 2006).
[661] "GN Facilities—Chile," *http://scp.gsfc.nasa.gov/gn/chile.htm* (accessed September 14, 2006).
[662] David Israel, Leader, Advanced Technology Development Group, Goddard Space Flight Center, e-mail to author, September 29, 2006.
[663] Debbie Richards, EUMETSAT User Services, e-mail to author, October 5, 2006.

Station (Location)	Code Name or Number	Latitude/Longitude[639]	Type of Station		Established	Phased Out	Equipment/Capabilities	Remarks
			STDN	DSN				
								from NASA on-board instruments.
Wallops Flight Facility (Virginia)[664]					1959			WFF began providing ground station support for scientific satellites in 1986.
Automated Wallops Orbital Tracking Station (AWOTS)			X					
Wallops Ground Station	WGS	37°55'N 75°28'W	X				11.3-m (37-ft) antenna simultaneously transmitted at S-band while receiving at S-band and X-band	
Low-Earth-Orbit Terminal	LEO-T	37°55'N 75°28'W	X				5-m (16-ft) antenna simultaneously transmitted and received at S-band	
Transportable Orbital Tracking System	TOTS	37°55'N 75°28'W	X				8-m (26-ft) antenna simultaneously transmitted and received at S-band	
Other WFF Tracking								
9-Meter Ground Station		37°55'N 75°28'W	X		1959		9-m (29-ft) antenna simultaneously transmitted and received at S-band	
Medium Gain Telemetry Antenna System	MGTAS	37°55'N 75°28'W	X		1959		Two 7.3-m (24-ft) L-band and S-band receive-only antennas	

[664] *Ground Network (GN) Users' Guide, Revision 1*, pp. 4-1–4-69, *http://scp.gsfc.nasa.gov/gn/gnusersguide3.pdf*.

Station (Location)	Code Name or Number	Latitude/Longitude[639]	Type of Station		Established	Phased Out	Equipment/Capabilities	Remarks
			STDN	DSN				
Satellite Automatic Tracking Antenna	SATAN	37°55'N 75°28'W	X		1959		One transmit array and two VHF receive array antennas for simultaneously transmitting and receiving at VHF	
Small Command Antenna on a Medium Pedestal	SCAMP	37°55'N 75°28'W	X		1959		One VHF transmit-only antenna array	
Meteorological Satellite	METEOSAT	37°55'N 75°28'W	X				One 7.3-m (24-ft) L-band receive-only antenna	
18-Foot Mobile System		Varies	X				One 5.5-m (18-foot) L-band and S-band receive-only antenna	
20-Foot Mobile System		Varies	X				One 6.1-m (20-ft) L-band and S-band receive-only antenna	
10-Foot Mobile System		Varies	X				One 3.0-m (10-ft) L-band and S-band receive-only antenna	
8-Foot Mobile System		Varies	X				One 2.4-m (8-ft) L-band and S-band receive-only antenna	
23-Foot Mobile System		Varies	X				One 7.0-m (23-ft) L-band and S-band receive-only antenna	
UHF Command Systems		1) 37°52'N 75°30'W	X				1) Two Orbit quad-helix UHF transmit-only antennas	

Station (Location)	Code Name or Number	Latitude/Longitude[639]	Type of Station		Established	Phased Out	Equipment/Capabilities	Remarks
			STDN	DSN				
		2) Varies					2) Two Taco single-helix UHF transmit-only antennas	
WFF Fixed and Mobile Radar Systems		Fixed: • 37°51'N 75°30'W • 37°51'N 75°30'W • 37°56'N 75°28'W • 37°50'N 75°29'W • 37°50'N 75°29'W • 37°51'N 75°30'W • 37°56'N 75°27'W	X				Fixed: • 18.3-m (60-ft) radar antenna • 18.3-m (60-ft) radar antenna • 5.33-m (17-ft) × 2.74-m (9-ft) radar antenna • 3.67-m (12-ft) by 0.15-m (0.5-ft) radar antenna • 3.67-m (12-ft) radar antenna • 8.84-m (29-ft) radar antenna • 4.88-m (16-ft) radar antenna Mobile: • 2.38-m (8-ft) radar antenna • 2.38-m (8-ft) radar antenna • 3.67-m (12-ft) radar antenna • 3.67-m (12-ft) radar antenna	Consisted of seven fixed radar systems and four mobile radar systems.
VHF Ground Stations		37°N 75°W	X				Two Quad Yagi antennas for simultaneously transmitting and receiving voice at VHF	Used only to support the International Space Station (ISS) and Soyuz spacecraft.

Station (Location)	Code Name or Number	Latitude/Longitude[639]	Type of Station		Established	Phased Out	Equipment/Capabilities	Remarks
			STDN	DSN				
White Sands Space Network Complex (New Mexico)								Comprised ground segment of SN; site of the TDRSS ground station. Located on the Army's White Sands Missile Range.
White Sands Ground Terminal (Cacique)	WSGT	32°21'N 106°22'W	X		1983		After refurbishment: • Two 18.3-m (60-ft) Ku- and S-band antennas (upgraded from original 19-m [62-ft] antennas) • Two 4.5-m with S- and Ku-band antennas • One 6.1-m (20-ft) S-band telemetry and command antenna • C-band radar; communications (voice and teletype)[665]	Decommissioned for upgrades in 1995. Upgrades completed in 1996 and returned to service.
Second TDRSS Ground Terminal (Danzante)	STGT	32°21'N 106°22'W	X		1993		• Three 19-m (62-ft) Ku- and S-band antennas • Three 4.5-m S- and Ku-band antennas	
VHF Air/Ground (A/G) Stations	VHF-1 VHF-2	32°N 106°W	X				• VHF-1: Single Yagi antenna • VHF-2: Quad Yagi for simultaneously	Supported the ISS and Soyuz spacecraft.

[665] "White Sands Complex Is Hub of NASA Worldwide Satellite Communications," NASA Facts, Release No. 91-38, May 9, 1991, NASA History Division folder 6546, Historical Reference Collection, NASA Headquarters, Washington, DC.

Station (Location)	Code Name or Number	Latitude/Longitude[639]	Type of Station		Established	Phased Out	Equipment/Capabilities	Remarks
			STDN	DSN				
							transmitting and receiving voice at VHF	
NASA Ground Terminal	NGT		X				Provided the interfaces with the common carrier and monitored the quality of the service from the TDRSS	Colocated with the WSGT. Abolished when WSGT was shut down for refurbishment. Replaced by Data Interface System (DIS).
Yarragadee (Australia)		29°08'S 115°21'E	X		1980	1991	UHF voice air-to-ground command and receive antenna	Provided STS deorbit burn coverage.
Apollo Range Instrumentation Aircraft	ARIA		X		1966	2001	10-ft (3-m) radome housing a 7-ft (2-m) steerable dish antenna; could receive in S-, C-, L-, and P-bands	Eight instrumented aircraft were used as communications relays to support Apollo operations. Last aircraft discontinued in 2001. Were DOD owned, operated under a reimbursable agreement for NASA.

Source: Linda Ezell, *NASA Historical Data Book, Volume III, 1969–1978, Programs and Projects* (Washington, DC: NASA SP-4012, 1988), pp. 415–423. Also Judy Rumerman, *NASA Historical Data Book, Volume VI, 1979–1988* (Washington, DC: NASA SP-4012, 2000), pp. 342–349.

Table 4-36. TDRSS 1-7 Baseline Service

TDRSS 1-7 Baseline Service	Service		
Single access (SA)	S-band	FWD	370 kbps
		RTN	6 Mbps
	Ku-band	FWD	25 Mbps
		RTN	300 Mbps
	Number of links per spacecraft		2 S-band single access
			2 Ku-band single access
Number of multiple-access (MA) links per spacecraft		FWD	1 at 300 kbps (8 dB over TDRSS)
		RTN	5 at 300 kbps
Customer tracking			150 m (492 ft) 3 sigma

Source: "TDRS/TDRS H, I, J Baseline Service Comparison," *http://msp.gsfc.nasa.gov/tdrss/services.html* (accessed September 11, 2006).

Table 4-37. TDRS-4 (TDRS-D) Characteristics

Launch date	March 13, 1989
Launch vehicle	STS-29, Space Shuttle *Discovery*
Range	Kennedy Space Center
Program objectives	To provide and maintain improved tracking and data acquisition services for spacecraft in low-Earth orbit through a system of two telecommunications satellites in geosynchronous orbits, with one or more additional satellites to serve as system spares[666]
Mission objectives	To deliver a third TDRS satellite to stationary geosynchronous orbit with sufficient stationkeeping fuel on board to complete the on-orbit constellation and meet the NASA requirement to provide full-capability TDRSS user support services
Program management	NASA Goddard Space Flight Center
Orbit characteristics[667]	
Apogee	35,808 km (22,250 mi)
Perigee	35,768 km (22,225 mi)
Inclination (deg)	0.0
Period (min)	1,436.1
Location	41°W longitude (as of May 1995)
Mass	Deployed: 4,637 lb (2,103 kg)
Dimensions	57.2 ft (17.4 m) across the solar panels; 46.6 ft (14.2 m) across the antennas
Communications[668]	Two 50-lb (23-kg), 16-ft (4.9-m)-diameter SA high-gain parabolic S-band and Ku-band antennas, 30-element MA S-band phased-array antenna, 6.5-ft Ku-band space-to-ground link steerable antenna; 4.8-ft C-band and 3.7-ft K-band antennas
Power source	Solar panels provided 1,700 W; nickel cadmium (NiCd) rechargeable batteries provided full power when the satellite was in Earth's shadow
Propulsion	Liquid monopropellant propulsion for on-orbit use
Contractors	TRW
Remarks	Also known as TDRS-East. The combination of TDRS-1 and TDRS-4 provided the TDRS-West satellite capability.[669]

[666] Office of Space Operations, "Tracking and Data Relay Satellite TDRS-E," Mission Operation Report, Report No. O-313-91-43-05, June 6, 1991, p. 2, NASA History Division folder 6546, Historical Reference Collection, NASA Headquarters, Washington, DC.
[667] *Space Log 1996*, volume 32 (Redondo Beach, CA: TRW, 1997), p. 270.
[668] "The Era of the Tracking and Data Relay Satellite System," NASA Facts Online, NASA Goddard Space Flight Center, *http://www.gsfc.nasa.gov/gsfc/service/gallery/fact_sheets/general/tdrss.htm* (accessed September 19, 2006).
[669] "Tracking and Data Relay Satellite System (TDRSS) Overview," Release No. 91-41, June 7, 1991.

Table 4-38. TDRS-5 (TDRS-E) Characteristics

Launch date	August 2, 1991
Launch vehicle	STS-43, Space Shuttle *Atlantis*
Range	Kennedy Space Center
Program objectives	To provide and maintain improved tracking and data acquisition services for spacecraft in low-Earth orbit through a system of two telecommunications satellites in geosynchronous orbits, with one or more additional satellites to serve as system spares[670]
Mission objectives	To replace TDRS-3 by delivering a fourth TDRS satellite to stationary geosynchronous orbit with sufficient stationkeeping fuel on board to complete the on-orbit constellation and meet the NASA requirement to provide full-capability TDRSS user support services[671]
Program management	NASA Goddard Space Flight Center
Orbit characteristics[672]	
Apogee	35,805
Perigee	35,774
Inclination (deg)	0.0
Period (min)	1,436.3
Location	174°W longitude (as of May 1995)
Mass	Deployed: 4,637 lb (2,103 kg)
Dimensions	57.2 ft (17.4 m) across the solar panels; 46.6 ft (14.2 m) across the antennas
Communications[673]	Two 50-lb (23-kg), 16-ft (4.9 m)-diameter SA high-gain parabolic S-band and Ku-band antennas, 30-element MA S-band phased-array antenna, 6.5-ft Ku-band space-to-ground link steerable antenna; 4.8-ft C-band and 3.7-ft K-band antennas
Power source	Solar panels provided 1,700 W; NiCd rechargeable batteries provided full power when the satellite was in Earth's shadow
Propulsion	Liquid monopropellant propulsion for on-orbit use
Contractors	TRW
Remarks	As a result of on-orbit experience with TDRS-3, this spacecraft was modified to provide multiple fusing of critical coaxial and waveguide switches in each Single Access Compartment (SAC).[674]

[670] Office of Space Operations, "Tracking and Data Relay Satellite TDRS-E," Mission Operation Report, Report No. O-313-91-43-05, June 6, 1991, p. 2, NASA History Division folder 6546, Historical Reference Collection, NASA Headquarters, Washington, DC.
[671] Ibid.
[672] *Space Log 1996*, volume 32 (Redondo Beach, CA: TRW, 1997), p. 291.
[673] "The Era of the Tracking and Data Relay Satellite System," NASA Facts Online, NASA Goddard Space Flight Center, *http://www.gsfc.nasa.gov/gsfc/service/gallery/fact_sheets/general/tdrss.htm* (accessed September 19, 2006).
[674] Office of Space Operations, "Tracking and Data Relay Satellite TDRS-E," Mission Operation Report, Report No. O-313-91-43-05, June 6, 1991, p. 2, NASA History Division folder 6546, Historical Reference Collection, NASA Headquarters, Washington, DC.

Table 4-39. TDRS-6 (TDRS-F) Characteristics

Launch date	January 13, 1993
Launch vehicle	STS-54, Space Shuttle *Endeavour*
Range	Kennedy Space Center
Program objectives	To provide and maintain improved tracking and data acquisition services for spacecraft in low-Earth orbit through a system of two telecommunications satellites in geosynchronous orbits, with one or more additional satellites to serve as system spares[675]
Mission objectives	To deliver a fifth TDRS satellite to stationary geosynchronous orbit with sufficient stationkeeping fuel on board to complete the on-orbit constellation and meet the NASA requirement to provide full-capability TDRSS user support services
Program management	NASA Goddard Space Flight Center
Orbit characteristics[676]	
Apogee	35,792 km (22,240 mi)
Perigee	35,779 km (22,232 mi)
Inclination (deg)	0.6
Period (min)	1,436
Location	62°W (as of May 1995)
Weight	Deployed: 4,637 lb (2,103 kg)
Dimensions	57.2 ft (17.4 m) across the solar panels; 46.6 ft (14.2 m) across the antennas
Communications[677]	Two 50-lb (23-kg), 16-ft (4.9-m)-diameter SA high-gain parabolic S-band and Ku-band antennas, 30-element MA S-band phased-array antenna, 6.5-ft Ku-band space-to-ground link steerable antenna; 4.8-ft C-band and 3.7-ft K-band antennas
Power source	Solar panels provided 1,700 W; NiCd rechargeable batteries provided full power when the satellite was in Earth's shadow
Propulsion	Liquid monopropellant propulsion for on-orbit use
Contractors	TRW
Remarks	This mission replaced S-band return parametric amplifiers with solid-state, low-noise amplifiers.[678]

[675] Office of Space Operations, "Tracking and Data Relay Satellite TDRS-E," Mission Operation Report, Report No. O-313-91-43-05, June 6, 1991, p. 15, NASA History Division folder 6546, Historical Reference Collection, NASA Headquarters, Washington, DC. (No TDRS-F MOR available.) The program objectives for TDRS-F remained the same as for earlier missions.
[676] *Space Log 1996*, volume 32 (Redondo Beach, CA: TRW, 1997), p. 302.
[677] "The Era of the Tracking and Data Relay Satellite System," NASA Facts Online, NASA Goddard Space Flight Center, *http://www.gsfc.nasa.gov/gsfc/service/gallery/fact_sheets/general/tdrss.htm* (accessed September 19, 2006).
[678] "TDRS-F," NSSDC Master Catalog, *http://nssdc.gsfc.nasa.gov/database/MasterCatalog?sc_1993-003B* (accessed August 29, 2006).

Table 4-40. TDRS-7 (TDRS-G) Characteristics

Launch date	July 13, 1995
Launch vehicle	STS-70, Space Shuttle *Discovery*
Range	Kennedy Space Center
Program objectives	To provide and maintain improved tracking and data acquisition services for spacecraft in low-Earth orbit through a system of two telecommunications satellites in geosynchronous orbits, with one or more additional satellites to serve as system spares[679]
Mission objectives	To deliver a sixth TDRS satellite to stationary geosynchronous orbit with sufficient stationkeeping fuel on board to complete the on-orbit constellation and meet the NASA requirement to provide full-capability TDRSS user support services
Program management	NASA Goddard Space Flight Center
Orbit characteristics[680]	
Apogee	35,795 km (22,242 mi)
Perigee	35,774 (22,229 mi)
Inclination (deg)	0.3
Period (min)	1,436
Location	171°W longitude
Weight	Deployed: 4,637 lb (2,103 kg)
Dimensions	57.2 ft (17.4 m) across the solar panels; 46.6 ft (14.2 m) across the antennas
Communications[681]	Two 50-lb (23-kg), 16-ft (4.9-m)-diameter SA high-gain parabolic S-band and Ku-band antennas, 30-element MA S-band phased-array antenna, 6.5-ft Ku-band space-to-ground link steerable antenna; 3.7-ft K-band antennas
Power source	Solar panels provided 1,700 W; NiCd rechargeable batteries provided full power when the satellite was in Earth's shadow
Propulsion	Liquid monopropellant propulsion for on-orbit use
Contractor	TRW
Remarks	The satellite was a replacement for TDRS-B, which was destroyed on *Challenger* in January 1986.

[679] Office of Space Operations, "Tracking and Data Relay Satellite TDRS-E," Mission Operation Report, Report No. O-313-91-43-05, June 6, 1991, p. 2, NASA History Division folder 6546, Historical Reference Collection, NASA Headquarters, Washington, DC. (No TDRS-G MOR available.) The program objectives for TDRS-G remained the same as for earlier missions.
[680] *Space Log 1996*, volume 32 (Redondo Beach, CA: TRW, 1997), p. 322.
[681] "The Era of the Tracking and Data Relay Satellite System," NASA Facts Online, NASA Goddard Space Flight Center, *http://www.gsfc.nasa.gov/gsfc/service/gallery/fact_sheets/general/tdrss.htm* (accessed September 19, 2006).

Chapter 5

Table 5-1. Centers of Excellence and Mission Areas[682]

Field Center	Designated Center of Excellence Area	Prime Mission Areas
Ames Research Center Moffett Field, CA	Information Technology	Aviation Operations Systems, Astrobiology
Dryden Flight Research Center Edwards, CA	Atmospheric Flight Operations	Flight Research
Goddard Space Flight Center Greenbelt, MD	Scientific Research	Earth Science, Physics and Astronomy
Jet Propulsion Laboratory (JPL) Pasadena, CA	Deep Space Systems	Planetary Science and Exploration
Johnson Space Center Houston, TX	Human Operations in Space	Human Exploration, Astro Materials
Kennedy Space Center Kennedy Space Center, FL	Launch and Cargo Processing Systems	Space Launch
Langley Research Center Hampton, VA	Structure and Materials	Airframe Systems, Atmospheric Science
Lewis Research Center Cleveland, OH	Turbomachinery	Aeropropulsion
Marshall Space Flight Center Huntsville, AL	Space Propulsion	Transportation Systems Development, Microgravity
Stennis Space Center Stennis Space Center, MS	Rocket Propulsion Testing	Propulsion Test

[682] *NASA Strategic Management Handbook*, October 1996, p. 15.

Table 5-2A. Property: In-House and Contractor-Held: FY 1989–FY 1993 (dollar amount in thousands)

Category		1989[683]	1990	1991	1992	1993
1.	Total Real Property Value	4,216,135	4,408,147	4,628,918	4,928,101	5,091,767
	Percentage Change	4.1	4.6	5.0	6.5	3.3
	Land Value	117,287	117,295	121,446	121,727	124,289
	Percentage Change	*	*	3.5	0.2	2.1
	Building Value	2,367,585	2,522,610	2,672,903	2,900,031	3,024,472
	Percentage Change	3.8	6.5	6.0	8.5	4.7
	Other Structures and Facilities Value	1,729,127	1,766,906	1,833,222	1,904,995	1,941,657
	Percentage Change	4.9	2.2	3.8	3.9	1.9
	Leasehold Improvement Value	2,136	1,336	1,347	1,348	1,349
	Percentage Change	–1.6	–37.4	0.8	0.07	0.07
2.	Capitalized Equipment Value	3,505,844	3,697,072	4,081,665	8,069,808	4,561,020
	Percentage Change	10.0	5.5	10.4	97.7	–43.5
3.	Fixed Assets-in-Progress Value	497,330	538,624	599,273	634,791	677,369
	Percentage Change	6.3	8.3	11.3	5.9	6.7
4.	Total Investment Value (1+2+3)	8,219,309	8,643,843	9,309,856	13,632,700	10,330,156
	Percentage Change	6.7	5.2	7.7	46.4	–24.2
5.	Number of Acres of Land	134,828	134,828	136,125	136,465	136,493
	Percentage Change	*	*	1.0	0.2	*
	Number of Buildings	2,695	2,728	2,784	2,833	2,849
	Percentage Change	1.6	1.2	2.1	1.8	0.6
	Number of Square Feet of Buildings	36,065,563	36,817,351	37,649,117	38,762,153	39,493,534
	Percentage Change	0.9	2.1	2.3	3.0	1.9

* = Less than 0.05 percent.
Source: “Recorded Value of Capital Type Property In-House and Contractor-Held,” Annual NASA Budget Estimates, Fiscal Year 1991–Fiscal Year 1999; “NASA Real Property Locations by Accountable Reporting Installations,” FY 1989–FY 1998, NASA Facilities Engineering Division.

[683] 1989 percentage change figures are based on FY 1988 amounts stated in Judy Rumerman, *NASA Historical Data Book*, *Volume VI*, *1979–1998* (Washington, DC: NASA SP-4012, 2000), p. 405.

Table 5-2B. Property: In-House and Contractor-Held: FY 1994–FY 1998 (dollar amount in thousands)

Category		1994	1995	1996	1997	1998
1.	Total Real Property Value	5,548,254	5,848,779	5,942,850	6,116,578	5,825,595
	Percentage Change	9.0	5.4	1.6	2.9	–4.8
	Land Value	128,273	128,204	124,352	125,546	124,523
	Percentage Change	3.2	*	–0.3	1.0	–0.8
	Building Value	3,333,267	3,570,165	3,601,010	3,711,219	3,614,752
	Percentage Change	10.2	7.1	0.9	0.3	–2.6
	Other Structures and Facilities Value	2,085,159	2,149,454	2,216,532	2,278,857	2,085,709
	Percentage Change	7.4	3.0	3.1	2.8	–8.5
	Leasehold Improvement Value	1,555	956	956	956	611
	Percentage Change	15.2	–38.5	*	*	–36.1
2.	Capitalized Equipment Value	4,343,131[684]	4,793,484	4,955,842	4,987,438	2,625,073[685]
	Percentage Change	–4.8	10.4	3.4	0.6	–47.4
3.	Fixed Assets-in-Progress Value	599,916	472,372	4,883,299	6,441,291	6,095,587
	Percentage Change	–11.4	–21.3	933.8	31.9	–5.5
4.	Total Investment Value (1+2+3)	10,491,321	11,114,635	15,781,991	17,545,307	14,546,255
	Percentage Change	1.6	5.9	42.0	11.2	–17.1
	Special Tooling[686]	—	—	—	—	340,128
	Percentage Change	—	—	—	—	—
	Special Test Equipment[687]	—	—	—	—	466,510
	Percentage Change	—	—	—	—	—
	Agency-Peculiar Property[688]	—	—	—	—	8,169,476

[684] This figure differs from the amount stated for Capitalized Equipment Value in the “Recorded Value of Capital Property In-House and Contractor-Held as of September 30, 1994 (Dollars in Thousands)” because the amount for the JPL Capitalized Equipment Value was misstated in full dollars ($3,918,821) rather than in K dollars in the report. The percent change from FY 1993 to FY 1994 and FY 1995 to FY 1994 for JPL’s Capitalized Equipment Value was adjusted to be based on the correct figure. The Total Investment Value and Percentage Change from FY 1993 to FY 1994 and FY 1994 to FY 1995 were also adjusted to reflect the correct amount for JPL’s Capitalized Equipment Value. (The adjustment was made per Jay Rosenthal, Resources Team Leader, Facilities Engineering and Real Property Division, NASA Headquarters.)

[685] The dollar amount (and percentage change) may not be meaningful because previous years’ capitalized equipment may have included elements now included in the Special Tooling, Special Test Equipment, or Agency-Peculiar Property categories.

[686] This category was added in the September 30, 1998, report and had not been included in earlier reports. It was defined as “equipment and manufacturing aids (and their components and replacements) of such a specialized nature that, without substantial modification or alteration, their use is limited to development or production of particular supplies or parts, or performance of particular services. Examples include jigs, dies, fixtures, molds, patterns, taps, and gauges.” “Subpart 1845.71—Forms Preparation,” *NASA Far Supplement*, *http://www.nasa.gov/pdf/1044033main_finalrule.pdf* (accessed November 2, 2006).

[687] This category was added in the September 30, 1998, report and not included in earlier reports. It was defined as “equipment used to accomplish special purpose testing in performing a contract, and items or assemblies of equipment.” “Subpart 1845.71—Forms Preparation,” *NASA Far Supplement*, *http://www.nasa.gov/pdf/1044033main_finalrule.pdf* (accessed November 2, 2006).

[688] The category was added in the September 30, 1998, report and was not included in earlier reports. It was defined as “completed items, systems and subsystems, spare parts and components unique to NASA aeronautical and space

Category		1994	1995	1996	1997	1998
	Percentage Change	—	—	—	—	—
5.	Number of Acres of Land	130,962	130,980	129,682	187,240	243,908
	Percentage Change	–4.1	*	–1.0	44.4	30.3
	Number of Buildings	3,027	2,999	2,927	2,230	2,269
	Percentage Change	6.2	–0.9	–2.4	–23.8	1.7
	Number of Square Feet of Buildings	43,761,272	44,684,559	43,017,331	41,206,746	41,651,238
	Percentage Change	10.8	2.1	–3.7	–4.2	1.1

* = Less than 0.05 percent.

Source: “Recorded Value of Capital Type Property In-House and Contractor-Held,” Annual NASA Budget Estimates, Fiscal Year 1991–Fiscal Year 1999. FY 1998 report was not included with FY 2000 Budget Estimate; it was provided by the Headquarters Financial Management Division. “NASA Real Property Locations by Accountable Reporting Installations,” FY 1989–FY 1998, NASA Facilities Engineering Division.

programs. Examples include research aircraft, reusable space vehicles, ground support equipment, prototypes, and mock-ups.” “Subpart 1845.71—Forms Preparation,” *NASA Far Supplement*, *http://www.nasa.gov/pdf/1044033main_finalrule.pdf* (accessed November 2, 2006).

Table 5-3. Value of Real Property Components as a Percentage of Total Real Property: In-House and Contractor-Held (FY 1989–FY 1998)

Component	1989	1990	1991	1992	1993	1994	1995	1996	1997	1998
Land	2.8	2.7	2.6	2.4	2.4	2.3	2.2	2.1	2.1	2.1
Buildings	56.2	57.2	57.7	58.8	59.4	60.1	61.0	60.6	60.7	62.0
Other structures and facilities	41.0	40.1	39.6	38.7	38.1	37.6	36.8	37.3	37.3	35.8
Total real property value[689]	*100.0*	*100.0*	*99.9*	*99.9*	*99.9*	*100.0*	*100.0*	*100.0*	*100.1*	*99.9*

Source: Table 5-2.

[689] Totals may not add up to 100 due to rounding.

Table 5-4A. NASA Facilities Total Investment Value (FY 1989): In-House and Contractor-Held

Facility	Total Real Property Value	Capitalized Equipment	Fixed Assets-in-Progress	Total Investment	Each Center's Percentage of NASA Total Investment
NASA Headquarters	0	50,295	0	50,295	6.1
Office of Space Flight					
Kennedy Space Center	1,134,414	737,617	44,426	1,916,457	23.3
Johnson Space Center	333,493	485,980	18,695	838,168	10.2
Marshall Space Flight Center	477,593	523,260	2,582	1,003,435	12.2
Stennis Space Center	330,263	32,812	0	363,075	4.4
Total	*2,275,763*	*1,779,669*	*65,703*	*4,121,135*	*50.1*
Office of Aeronautics and Space Technology					
Ames Research Center[690]	488,725	391,125	160,753	1,040,603	12.7
Dryden Flight Research Center[691]	—	—	—	—	—
Langley Research Center	587,185	235,135	25,076	830,617	10.1
Lewis Research Center	332,838	182,863	62,820	578,521	7.0
Total	*1,408,748*	*809,123*	*248,649*	*1,409,138*	*29.8*
Office of Space Science and Applications					
Goddard Space Flight Center	293,719	460,067	69,739	823,525	10.0
Jet Propulsion Laboratory	237,905	406,690	113,239	575,906	7.0
Total	*531,624*	*866,757*	*182,978*	*1,399,431*	*17.0*
NASA Total	*4,216,135*	*3,505,844*	*497,330*	*8,219,309*	

Source: "Recorded Value of Capital Type Property In-House and Contractor-Held," Annual NASA Budget Estimates, Fiscal Year 1991–Fiscal Year 2000.

[690] Includes Dryden.
[691] Included with Ames Research Center.

Table 5-4B. NASA Facilities Total Investment Value (FY 1990–FY 1992): In-House and Contractor-Held (at end of fiscal year; in thousands of dollars)

	Total Real Property Value				Capitalized Equipment		
Facility	**1990**	**1991**	**1992**		**1990**	**1991**	**1992**
NASA Headquarters	0	0	0		53,064	69,201	65,301
Office of Space Flight							
Kennedy Space Center[692]	1,159,657	1,176,840	1,208,500		814,215	840,997	4,596,904
Johnson Space Center[693]	344,343	370,540	415,026		515,498	588,985	670,891
Marshall Space Flight Center[694]	494,464	519,768	551,727		563,179	701,871	783,945
Stennis Space Center[695]	352,005	363,404	368,999		35,492	37,144	40,378
Total	*2,350,469*	*2,430,552*	*2,544,252*		*1,928,384*	*2,168,997*	*6,092,118*
Office of Aeronautics and Space Technology							
Ames Research Center[696]	534,439	565,931	616,469		380,929	395,797	417,041
Dryden Flight Research Center[697]	—	—	—		—	—	—
Langley Research Center[698]	610,728	637,603	665,705		242,267	258,377	305,673
Lewis Research Center[699]	340,802	385,918	405,445		210,896	222,056	246,020
Total	*951,530*	*1,023,521*	*1,071,150*		*834,092*	*876,230*	*968,734*
Office of Space Science and Applications							
Goddard Space Flight Center[700]	331,730	353,902	398,671		460,203	502,230	570,252

[692] Includes Kennedy Space Center, Cape Canaveral, FL; Western Test Range, Lompac, CA; and various locations.
[693] Includes Johnson Space Center, Houston, TX; White Sands Test Facility, Las Cruces, NM; and various locations.
[694] Includes Marshall Space Flight Center, Huntsville, AL; Michoud Assembly Facility, LA; Slidell Computer Complex, LA; and various locations.
[695] Includes Stennis Space Center, MS; and various locations.
[696] Includes Ames Research Center, Moffett Field, CA; Dryden Flight Facility (through 1995); and various locations.
[697] Included with Ames Research Center.
[698] Includes Langley Research Center, Hampton, VA, and various locations.
[699] Includes Lewis Research Center, Cleveland, OH; Plum Brook, Sandusky, OH; and various locations.
[700] Includes Goddard Space Flight Center, Greenbelt, MD; the Tracking Stations Network, Wallops Flight Facility, Wallops Island, VA; and various locations.

	Total Real Property Value				Capitalized Equipment		
Facility	**1990**	**1991**	**1992**		**1990**	**1991**	**1992**
Jet Propulsion Laboratory[701]	239,979	255,012	297,247		421,329	465,007	373,403
Total	*571,709*	*608,914*	*695,918*		*881,532*	*967,237*	*943,655*
NASA Total	*3,873,708*	*4,062,987*	*4,311,320*		*3,697,072*	*4,081,665*	*8,069,808*

Source: "Recorded Value of Capital Type Property In-House and Contractor-Held," Annual NASA Budget Estimates, Fiscal Year 1991–Fiscal Year 2000.

[701] Includes the Jet Propulsion Laboratory, Pasadena, CA, and the Deep Space Network.

Table 5-4B. NASA Facilities Total Investment Value (FY 1990–FY 1992): In-House and Contractor-Held (at end of fiscal year; in thousands of dollars) (continued)

	Fixed Assets-in-Progress				**Total Investment**				**Each Center's Percentage of NASA Total Investment**		
Facility	**1990**	**1991**	**1992**		**1990**	**1991**	**1992**		**1990**	**1991**	**1992**
NASA Headquarters	0	0	0		53,064	69,201	65,301		0.6	0.7	0.4
Office of Space Flight											
Kennedy Space Center	43,665	58,549	103,818		2,017,537	2,076,386	5,909,222		23.3	22.3	43.3
Johnson Space Center	28,968	35,148	26,223		888,809	994,673	1,112,140		10.3	10.7	8.2
Marshall Space Flight Center	13,895	5,606	10,218		1,071,538	1,227,245	1,345,890		12.4	13.2	9.9
Stennis Space Center	0	18,889	29,715		307,497	419,431	439,092		3.6	4.5	3.2
Total	*86,528*	*118,192*	*169,974*		*4,285,381*	*4,717,735*	*8,806,344*		*49.6*	*50.7*	*64.6*
Office of Aeronautics and Space Technology											
Ames Research Center[702]	153,830	184,860	231,434		1,069,198	1,146,588	1,265,256		12.4	12.3	9.3
Dryden Flight Research Center[703]	—	—	—		—	—	—		—	—	—
Langley Research Center	24,094	31,551	42,661		877,889	927,531	1,014,039		10.2	10.0	7.4
Lewis Research Center	85,583	65,132	58,549		637,281	673,106	710,014		7.4	7.2	5.2
Total	*263,507*	*281,543*	*332,644*		*2,584,368*	*2,747,225*	*2,989,309*		*29.9*	*29.5*	*21.9*
Office of Space Science and Applications											
Goddard Space Flight Center	59,421	56,043	73,987		851,354	912,175	1,042,910		9.8	9.8	7.7
Jet Propulsion Laboratory	128,368	143,501	58,186		789,676	863,520	728,836		9.1	9.3	5.3
Total	*187,789*	*199,544*	*132,173*		*1,641,030*	*1,775,695*	*1,771,746*		*19.0*	*19.1*	*13.0*
NASA Total	*537,824*	*599,279*	*634,791*		*8,563,843*	*9,309,856*	*13,632,700*				

Source: "Recorded Value of Capital Type Property In-House and Contractor-Held," Annual NASA Budget Estimates, Fiscal Year 1991–Fiscal Year 2000.

[702] Includes Dryden.
[703] Included with Ames Research Center.

Table 5-4C. NASA Facilities Total Investment Value (FY 1993–FY 1995): In-House and Contractor-Held

	Total Real Property Value				**Capitalized Equipment**		
Facility	**1993**	**1994**	**1995**		**1993**	**1994**	**1995**
NASA Headquarters	17	218	0		58,592	47,085	54,401
Office of Space Flight							
Kennedy Space Center	1,247,885	1,272,178	1,374,748		893,976	877,600	898,669
Johnson Space Center	437,475	477,733	500,631		724,493	835,686	775,154
Marshall Space Flight Center	583,230	755,868	742,616		788,983	812,048	803,338
Stennis Space Center	383,127	397,760	404,164		48,140	58,135	56,758
Total	*2,651,010*	*2,903,539*	*3,022,159*		*2,455,592*	*2,583,469*	*2,533,919*
Office of Aeronautics and Space Technology							
Ames Research Center[704]	638,469	735,561	840,188		401,475	422,998	452,186
Dryden Flight Research Center[705]	—	—	—		—	—	—
Langley Research Center	667,995	681,884	708,069		327,435	350,737	345,652
Lewis Research Center	421,276	457,714	475,163		263,969	267,542	270,076
Total	*1,727,740*	*1,875,159*	*2,023,420*		*992,879*	*1,041,277*	*1,067,914*
Office of Space Science and Applications							
Goddard Space Flight Center	416,702	452,111	472,617		645,274	667,381	753,451
Jet Propulsion Laboratory	295,591	317,227	330,583		408,683	3,919[706]	383,799
Total	*712,293*	*769,338*	*803,200*		*1,053,957*	*671,300*	*1,137,250*
NASA Total	*5,091,767*	*5,548,254*	*5,848,779*		*4,561,020*	*4,343,131*	*4,793,484*

Source: "Recorded Value of Capital Type Property In-House and Contractor-Held," Annual NASA Budget Estimates, Fiscal Year 1991–Fiscal Year 2000.

[704] Includes Dryden.
[705] Included with Ames Research Center.
[706] This figure differs from the amount stated for Capitalized Equipment Value in the "Recorded Value of Capital Property In-House and Contractor-Held as of September 30, 1994 (Dollars in Thousands)" because the amount for the JPL Capitalized Equipment Value was misstated in full dollars ($3,918,821) rather than in K dollars as in the report. The total Capitalized Equipment Value and NASA Total were adjusted to reflect the correct figure for JPL Capitalized Equipment. (The adjustment was made per Jay Rosenthal, Resources Team Leader, Facilities Engineering and Real Property Division, NASA Headquarters.)

Table 5-4C. NASA Facilities Total Investment Value (FY 1993–FY 1995): In-House and Contractor-Held (continued)

	Fixed Assets-in-Progress				**Total Investment**				**Each Center's Percentage of NASA's Total Investment**		
Facility	**1993**	**1994**	**1995**		**1993**	**1994**	**1995**		**1993**	**1994**[707]	**1995**
NASA Headquarters	0	0	0		58,609	47,303	54,401		0.6	0.5	0.5
Office of Space Flight											
Kennedy Space Center	136,516	143,912	109,572		2,278,377	2,293,690	2,382,989		22.0	21.9	21.4
Johnson Space Center	40,208	25,941	49,826		1,202,176	1,339,360	1,325,611		11.6	12.8	11.9
Marshall Space Flight Center	15,103	13,003	10,036		1,387,316	1,580,796	1,555,990		13.4	15.1	14.0
Stennis Space Center	31,617	46,533	47,899		462,884	502,428	508,821		4.5	4.8	4.6
Total	*223,444*	*229,389*	*217,333*		*5,330,753*	*5,716,274*	*5,773,411*		*51.6*	*54.5*	*51.9*
Office of Aeronautics and Space Technology											
Ames Research Center[708]	249,486	139,732	81,113		1,289,430	1,298,291	1,373,487		12.5	12.4	12.4
Dryden Flight Research Center[709]	—	—	—		—	—	—		—		—
Langley Research Center	64,785	75,393	54,855		1,060,215	1,108,014	1,108,576		10.3	10.6	10.0
Lewis Research Center	80,996	106,540	96,485		766,241	831,796	841,724		7.4	7.9	7.6
Total	*395,267*	*321,665*	*232,453*		*3,115,886*	*3,238,101*	*3,323,787*		*30.2*	*30.9*	*30.0*
Office of Space Science and Applications											
Goddard Space Flight Center	58,658	48,862	22,586		1,120,634	1,168,354	1,248,654		10.8	11.1	11.2
Jet Propulsion Laboratory	0	0	0		704,274	4,236,048[710]	714,382		6.8	3.1	6.4

[707] Each Center's percentage of NASA's total investment is calculated based on the correct amount for the FY 1994 JPL Capitalized Equipment Value rather than the misstated amount in the "Recorded Value of Capital Type Property In-House and Contractor-Held as of September 30, 1994 (Dollars in Thousands)". (The adjustment was made per Jay Rosenthal, Resources Team Leader, Facilities Engineering and Real Property Division, NASA Headquarters.)
[708] Includes Dryden.
[709] Included in Ames Research Center.
[710] This figure differs from the amount stated for Capitalized Equipment Value in the "Recorded Value of Capital Property In-House and Contractor-Held as of September 30, 1994 (Dollars in Thousands)" because the amount for the JPL Capitalized Equipment Value was given in full dollars ($3,918,821) rather than in K dollars and thus was misstated in the report. The NASA total for FY 1994 was also adjusted to reflect the corrected JPL Capitalized Equipment Value, as was the

	Fixed Assets-in-Progress				Total Investment				Each Center's Percentage of NASA's Total Investment		
Facility	**1993**	**1994**	**1995**		**1993**	**1994**	**1995**		**1993**	**1994**[707]	**1995**
Total	*58,658*	*48,862*	*22,586*		*1,824,908*	*5,404,402*	*1,963,036*		*17.7*	*14.2*	*17.7*
NASA Total	*677,369*	*599,916*	*472,372*		*10,330,156*	*14,406,203*	*11,114,635*				

Source: "Recorded Value of Capital Type Property In-House and Contractor-Held," Annual NASA Budget Estimates, Fiscal Year 1991–Fiscal Year 2000.

Office of Space Science and Applications total. (The adjustment was made per Jay Rosenthal, Resources Team Leader, Facilities Engineering and Real Property Division, NASA Headquarters.)

Table 5-4D. NASA Facilities Total Investment Value (FY 1996–FY 1998): In-House and Contractor-Held

	Total Real Property Value				**Capitalized Equipment**		
Facility	**1996**	**1997**	**1998**		**1996**	**1997**	**1998**
NASA Headquarters	6	0	0		50,696	41,626	35,136
Office of Space Flight							
Kennedy Space Center	1,406,687	1,437,132	1,473,533		833,003	236,272	79,517
Johnson Space Center	521,351	581,282	625,893		815,465	1,394,617	889,131
Marshall Space Flight Center	618,577	629,906	577,923		781,813	772,503	381,134
Stennis Space Center	420,084	425,364	300,169		54,800	58,900	29,467
Total	*2,966,699*	*3,073,684*	*2,977,518*		*2,485,081*	*2,462,292*	*1,379,249*
Office of Aeronautics and Space Technology							
Ames Research Center	784,407	786,403	640,255		353,898	348,899	263,916
Dryden Flight Research Center	107,384	107,785	111,340		256,554	279,785	254,295
Langley Research Center	731,509	741,569	722,116		347,699	373,152	133,033
Lewis Research Center	477,435	480,714	422,215		276,212	273,239	73,461
Total	*2,100,735*	*2,116,471*	*1,895,926*		*1,234,363*	*1,275,075*	*724,705*
Office of Space Science and Applications							
Goddard Space Flight Center	492,649	830,380	534,141		824,315	830,380	390,716
Jet Propulsion Laboratory	382,761	401,927	421,010		361,387	378,251	95,267
Total	*875,410*	*1,232,307*	*955,151*		*1,185,702*	*1,208,631*	*485,983*
NASA Total	*5,942,850*	*6,116,578*	*5,825,595*		*4,955,842*	*4,987,438*	*2,625,073*

Source: "Recorded Value of Capital Type Property In-House and Contractor-Held," Annual NASA Budget Estimates, Fiscal Year 1991–Fiscal Year 2000.

Table 5-4D. NASA Facilities Total Investment Value (FY 1996–FY 1998): In-House and Contractor-Held (continued)

	Fixed Assets-in-Progress			**Total Investment**			**Each Center's Percentage of NASA's Total Investment**		
Facility	**1996**	**1997**	**1998**	**1996**	**1997**	**1998**[711]	**1996**	**1997**	**1998**
NASA Headquarters	41,720	44,687	0	92,422	86,313	35,136	0.6	0.5	0.1
Office of Space Flight									
Kennedy Space Center	141,679	83,068	39,343	2,381,369	1,756,472	1,806,074	15.1	10.0	7.7
Johnson Space Center	231,207	862,968	1,205,129	1,568,023	2,838,867	10,292,068	10.6	10.0	43.8
Marshall Space Flight Center	1,396,268	1,843,091	2,079,438	2,796,658	3,245,500	3,982,835	17.7	16.2	16.9
Stennis Space Center	60,350	67,620	30,550	535,234	551,874	360,186	3.4	3.1	1.5
Total	*1,829,504*	*2,856,747*	*3,354,460*	*7,281,284*	*8,392,713*	*16,441,163*	*46.1*	*47.8*	*69.9*
Office of Aeronautics and Space Technology									
Ames Research Center	93,299	133,738	10,865	1,231,604	1,269,640	928,554	7.8	7.2	3.9
Dryden Flight Research Center	0	5,732	23,140	0	393,126	389,683	0	2.0	1.7
Langley Research Center	75,489	294,728	198,016	1,154,697	1,409,449	1,067,019	7.3	8.0	4.5
Lewis Research Center	141,172	118,462	121,389	894,819	872,415	626,797	5.7	5.0	2.7
Total	*309,960*	*552,660*	*353,410*	*3,281,120*	*3,944,630*	*3,012,053*	*20.8*	*22.5*	*12.8*
Office of Space Science and Applications									
Goddard Space Flight Center	971,428	1,116,601	1,638,960	2,288,392	2,471,477	2,758,218	14.5	14.1	11.7
Jet Propulsion Laboratory	1,724,702	1,870,596	748,757	2,468,850	2,650,774	1,275,799	15.6	15.1	5.4
Total	*2,696,130*	*2,987,197*	*2,387,717*	*4,757,242*	*5,122,251*	*4,034,017*	*30.1*	*29.2*	*17.1*
NASA Total	*4,883,299*	*6,441,291*	*6,095,587*	*15,781,991*	*17,545,307*	*23,522,369*			

Source: "Recorded Value of Capital Type Property In-House and Contractor-Held," Annual NASA Budget Estimates, Fiscal Year 1991–Fiscal Year 2000.

[711] Total Investment includes amounts for special tooling, special test equipment, and Agency-peculiar property, not specified in this table. These categories were introduced in FY 1998.

Table 5-5. Land Owned by Field Center and Fiscal Year in Acres: In-House and Contractor-Held (at end of fiscal year)

Field Center	1989	1990	1991	1992	1993	1994	1995	1996	1997	1998
Ames Research Center	432.5[712]	432.0	432.0	432.0	432.0	3,387.2[713]	3,411.1	3,411.1	3,400.0	3,400.0
Dryden Flight Research Center[714]	—	—	—	—	—	—	—	0	0	0
Goddard Space Flight Center	18,576.5[715]	18,576.5	18,576.5	18,576.5	18,597.8	10,097.0[716]	10,105.0[717]	10,105.0	13,315	13,315
Jet Propulsion Laboratory	155.8	155.8	155.8	155.8	155.8	155.8	155.8	155.8	155.8	155.8
Johnson Space Center	1,821.0[718]	1,821.0	1,821.0	1,783.9	1,783.9	1,783.9	1,783.9	1,783.9	1,764.0	1,764.0
White Sands Test Facility	1,409.0	1,409.0	1,409.0	1,786.3	1,786.3	1,786.3	1,786.3	1,786.3	1,786.3[719]	1,786.3[720]
Kennedy Space Center	82,943.0	82,943.0	82,943.0	82,943.0	82,943.0	82,943.0	82,943.0	82,943.0	82,822.0	139,490.0
Langley Research Center	787.6	787.6	787.6	787.6	787.6	787.6	787.6	787.6	808.0	808.0
Lewis Research Center	6,804.8[721]	6,804.8	6,804.8	6,804.8	6,804.8	6,804.8	6,804.8	6,804.8	7,120.0	7,120.0
Marshall Space Flight Center	1,255.9[722]	1,255.9	2,553.4[723]	2,553.4	2,553.4	2,553.4	2,539.4[724]	1,241.9[725]	2,715.0	2,715.0
Stennis Space Center	20,642.2	20,642.2	20,642.2	20,642.2	20,662.7	20,662.7	20,662.7	20,662.7	20,355.0	20,355.0
Total	*134,827.8*	*134,827.8*	*136,125.3*	*136,465.5*	*136,498.3*	*130,961.7*	*130,979.6*	*129,682.1*	*113,8200*	*170,488*

Source: "NASA Real Property Locations by Accountable Reporting Installations," 1989–1998, Facilities Engineering Division.

[712] Includes Ames Research Center, Moffett Field, CA; Camp Parks, Pleasanton, CA; and Crow's Landing, CA.
[713] Reflects the addition of Moffett Airfield, Moffett Field, CA.
[714] FY 1989–1995 included with Ames Research Center.
[715] Includes Goddard Space Flight Center, Greenbelt, MD; Wallops Flight Facility, Wallops Island, VA; Antenna Tracking Station, Fairbanks, AK; and Antenna Test Range, Las Cruces, NM.
[716] Reflects the transfer of the Alaska Tracking Station, Fairbanks, AK, from NASA to NOAA.
[717] Reflects the addition of the Balloon Launching Facility, Ft. Sumner, NM.
[718] Includes Johnson Space Center, Houston, TX, and industrial plant at Downey, CA.
[719] White Sands Test Facility Land Report as of 1997 (Acres) prepared by NASA Headquarters Facilities Engineering Division.
[720] White Sands Test Facility Land Report as of 1998 (Acres) prepared by NASA Headquarters Facilities Engineering Division.
[721] Includes Lewis Research Center, Cleveland, OH, and Plum Brook Operating Division, Sandusky, OH.
[722] Includes Marshall Space Flight Center, Huntsville, AL; Michoud Assembly Facility, New Orleans, LA; and Slidell Computer Complex, Slidell, LA.
[723] Reflects the addition of the Yellow Creek Facility, Iuka, MS.
[724] Reflects the transfer of Slidell Computer Complex to Slidell, LA.
[725] Reflects the closure of the Yellow Creek Facility.

Table 5-6. Number of Buildings Owned by Field Center and Fiscal Year: In-House and Contractor-Held (at end of fiscal year)

Field Center	**1989**	**1990**	**1991**	**1992**	**1993**	**1994**	**1995**	**1996**	**1997**	**1998**
Ames Research Center	161	174	175	176	176	355	355	355	261	261
Dryden Flight Research Center	67	67	65	70	73	80	80	85	55	55
Goddard Space Flight Center	466	472	458	455	448	401	402	398	295	301
Jet Propulsion Laboratory	314	308	303	307	307	309	314	294	239	262
Johnson Space Center	299	302	315	316	323	324	332	338	266	267
Kennedy Space Center	577	580	606	607	610	617	556	614	338	339
Langley Research Center	179	183	184	182	205	221	233	229	198	200
Lewis Research Center	258	262	262	261	261	261	262	262	249	249
Marshall Space Flight Center	253	255	284	308	319	334	277	237	223	226
Stennis Space Center	121	125	132	141	127	125	125	115	106	109
Total	*2,695*	*2,728*	*2,784*	*2,833*	*2,849*	*3,027*	*2,999*	*2,927*	*2,230*	*2,269*

Source: “NASA Real Property Locations by Accountable Reporting Installations,” 1989–1998, Facilities Engineering Division.

Table 5-7. Number of Square Feet of Buildings Owned by Field Center and Fiscal Year: In-House and Contractor-Held

Field Center	1989	1990	1991	1992	1993	1994	1995	1996	1997	1998
Ames Research Center	2,710,774	2,785,040	2,786,080	2,823,540	2,823,540	5,528,665	5,752,354	5,507,349	5,483,208	5,483,208
Dryden Flight Research Center	551,945	558,183	557,663	688,461	695,238	692,608	735,354	727,086	848,896	848,896
Goddard Space Flight Center	3,683,130	4,115,561	4,132,431	4,320,894	4,386,619	4,528,157	4,592,142	4,566,509	3,433,180	4,547,975
Jet Propulsion Laboratory	2,055,578	2,044,930	2,122,807	2,450,296	2,453,388	2,526,915	2,589,583	2,547,316	2,472,199	2,501,109
Johnson Space Center	5,342,797	5,385,045	5,472,512	5,700,352	5,759,089	6,021,187	6,031,297	6,068,619	4,720,016	4,743,529
Kennedy Space Center	6,732,193	6,469,694	6,504,376	7,202,125	7,347,401	7,398,971	7,847,008	7,258,667	7,184,308	7,306,308
Langley Research Center	2,273,819	2,277,802	2,317,910	2,351,630	2,515,311	2,526,402	2,596,035	2,593,110	3,380,269	3,382,202
Lewis Research Center	3,212,305	3,289,763	3,296,491	3,280,853	3,302,583	3,302,583	3,357,111	3,357,111	3,328,834	3,284,198
Marshall Space Flight Center	7,682,590	7,480,931	8,178,360	8,245,165	8,294,171	9,478,586	9,397,886	8,059,942	7,789,619	7,828,631
Stennis Space Center	1,556,143	1,603,125	1,645,885	1,679,828	1,742,371	1,757,198	1,785,272	1,781,278	1,703,553	1,018,026
Total	*36,065,563*	*36,817,351*	*37,649,117*	*38,762,153*	*39,493,534*	*43,761,272*	*44,684,559*	*43,017,331*	*41,206,746*	*41,651,238*

Source: "NASA Real Property Locations by Accountable Reporting Installations," 1989–1998, Facilities Engineering Division.

Table 5-8. Total Real Property Value by Field Center and Fiscal Year: In-House and Contractor-Held (at end of fiscal year; in thousands of dollars)

Field Center	1989	1990	1991	1992	1993	1994	1995	1996	1997	1998
Headquarters	0	0	0	0	17	218	0	6	0	0
Ames Research Center[726]	488,725	534,439	565,931	616,781	638,469	735,561	840,188	784,407	786,403	640,255
Dryden Flight Research Center[727]	—	—	—	—	—	—	—	107,384	107,785	111,340
Goddard Space Flight Center[728]	293,719	331,730	353,902	398,671	416,702	452,111	472,617	492,649	524,496	534,141
Jet Propulsion Laboratory[729]	237,905	239,979	255,012	297,247	295,591	317,227	330,583	382,761	401,927	421,010
Johnson Space Center[730]	485,980	344,343	370,540	415,026	437,475	477,733	500,631	521,351	581,282	625,893
Kennedy Space Center[731]	1,134,414	1,159,657	1,176,840	1,208,500	1,247,885	1,272,178	1,374,748	1,406,687	1,437,132	1,473,533
Langley Research Center[732]	587,185	610,728	637,603	665,705	667,995	681,884	708,069	731,509	741,569	722,116
Lewis Research Center[733]	332,838	340,802	385,918	405,445	421,276	457,714	475,163	477,435	480,714	422,215
Marshall Space Flight Center[734]	477,593	494,464	519,768	551,727	583,230	755,868	742,616	618,577	629,906	574,923
Stennis Space Center	330,263	352,005[735]	363,404	368,999	383,127	397,760	404,164	420,084	425,364	300,169
Total	*4,216,135*	*4,408,147*	*4,628,918*	*1,904,995*	*5,091,767*	*5,548,254*	*5,848,779*	*5,942,850*	*6,116,578*	*5,825,595*

Source: Table 5-4.

[726] Includes Ames Research Center, Moffett Field, CA; Dryden Flight Facility (through 1995); and various locations.
[727] FY 1989–1995 included with Ames Research Center.
[728] Includes Goddard Space Flight Center, Greenbelt, MD; the Tracking Stations Network, Wallops Flight Facility, Wallops Island, VA; and various locations.
[729] Includes the Jet Propulsion Laboratory, Pasadena, CA, and the Deep Space Network.
[730] Includes Johnson Space Center, Houston, TX; White Sands Test Facility, Las Cruces, NM; and various locations.
[731] Includes Kennedy Space Center, Cape Canaveral, FL; Western Test Range, Lompac, CA; and various locations.
[732] Includes Langley Research Center, Hampton, VA, and various locations.
[733] Includes Lewis Research Center, Cleveland, OH; Plum Brook, Sandusky, OH; and various locations.
[734] Includes Marshall Space Flight Center, Huntsville, AL; Michoud Assembly Facility, LA; Slidell Computer Complex, LA; and various locations.
[735] Includes Stennis Space Center, MS, and various locations.

Table 5-9. Land Value by Field Center and Fiscal Year: In-House and Contractor-Held (at end of fiscal year; in thousands of dollars)

Field Center	1989	1990	1991	1992	1993	1994	1995	1996	1997	1998
Headquarters	0	0	0	0	0	0	0	0	0	0
Ames Research Center	2,929	2,929	2,929	2,929	2,929	6,865[736]	6,865	6,865	6,865	3,936
Dryden Flight Research Center[737]	—	—	—	—	—	—	—	0[738]	0	0
Goddard Space Flight Center	2,872	2,880	2,880	3,096	3,311	3,341	3,341	3,351	3,351	5,483
Jet Propulsion Laboratory	1,188	1,188	1,188	1,188	1,189	1,189	1,189	1,189	1,189	1,046
Johnson Space Center	10,944	10,944	11,324	11,238	11,238	11,256	11,256	11,256	12,450	12,367
Kennedy Space Center	71,345	71,345	71,345	71,345	73,672	73,672	73,672	73,672	73,672	73,672
Langley Research Center	156	156	156	156	156	156	156	156	156	156
Lewis Research Center	2,621	2,621	2,621	2,621	2,621	2,621	2,621	2,621	2,621	2,621
Marshall Space Flight Center	7,171	7,171	10,942	11,093	11,093	11,093	11,024[739]	7,162[740]	7,162	7,162
Stennis Space Center	18,061	18,061	18,061	18,061	18,080	18,080	18,080	18,080	18,080	18,080
Total	*117,287*	*117,295*	*121,446*	*121,727*	*124,289*	*128,273*	*128,204*	*124,352*	*125,546*	*124,523*

Source: "Recorded Value of Capital Type Property In-House and Contractor-Held," Annual NASA Budget Estimates, Fiscal Year 1991–Fiscal Year 2000.

[736] The increase in value reflects the closure of Moffett Air Field and acquisition by NASA.
[737] FY 1989–FY 1995 included with Ames Research Center.
[738] Land not owned by NASA.
[739] Slidell Computer Complex was transferred to the City of Slidell, LA, on December 14, 1994.
[740] The decrease reflects the transfer of the Yellow Creek Facility to the state of Mississippi in accordance with Public Law 104-99, *Making Appropriations for Fiscal Year 1996 To Make a Down Payment Toward a Balanced Budget, and for Other Purposes*, 104th Congress, 2nd session, January 26, 1996.

Table 5-10. Building Value by Field Center and Fiscal Year: In-House and Contractor-Held (at end of fiscal year; in thousands of dollars)

Field Center	1989	1990	1991	1992	1993	1994	1995	1996	1997	1998
Headquarters	0	0	0	0	0	0	0	6	0	0
Ames Research Center	428,349	497,880	527,303	574,152	589,056	636,696	737,166	708,043	709,871	589,948
Dryden Flight Research Center[741]	—	—	—	—	—	—	—	73,405	73,806	77,361
Goddard Space Flight Center	120,462	206,195	226,332	267,094	281,447	308,365	325,756	340,181	348,747	353,845
Jet Propulsion Laboratory	125,798	125,591	138,088	180,630	179,555	200,271	209,564	229,340	242,480	243,355
Johnson Space Center	237,851	245,112	259,747	297,914	312,943	344,021	359,409	374,443	417,183	458,247
Kennedy Space Center	537,011	573,390	581,948	601,650	623,719	629,905	712,590	716,024	735,445	770,456
Langley Research Center	194,080	208,777	217,354	226,670	231,727	248,527	258,007	269,534	275,852	246,866
Lewis Research Center	237,506	245,394	277,420	291,986	305,940	334,673	349,173	350,122	353,262	316,078
Marshall Space Flight Center	306,669	311,288	331,079	342,013	369,289	496,079	481,868	402,248	412,990	413,481
Stennis Space Center	104,698	109,043	113,632	117,922	130,796	134,730	136,632	137,664	141,583	144,215
Total	*2,367,585*	*2,522,610*	*2,672,903*	*2,900,031*	*3,024,472*	*3,333,267*	*3,570,165*	*3,601,010*	*3,711,219*	*3,614,752*

Source: "Recorded Value of Capital Type Property In-House and Contractor-Held," Annual NASA Budget Estimates, Fiscal Year 1991–Fiscal Year 2000.

[741] FY 1989–FY 1995 included with Ames Research Center.

Table 5-11A. Other Structures and Facilities Value by Field Center and Fiscal Year: In-House and Contractor-Held (FY 1989–FY 1993)

Field Center	1989	1990	1991	1992	1993
Headquarters	0	0	0	0	0
Ames Research Center	32,217	33,630	35,699	39,700	46,484
Dryden Flight Research Center[742]	—	—	—	—	—
Goddard Space Flight Center	120,462	122,655	124,679	128,470	131,944
Jet Propulsion Laboratory	109,024	112,165	114,641	114,333	113,756
Johnson Space Center	84,593	88,182	99,364	105,769	113,189
Kennedy Space Center	526,058	514,922	523,547	535,505	550,494
Langley Research Center	392,941	401,795	420,093	438,879	436,112
Lewis Research Center	92,575	92,651	105,741	110,702	112,579
Marshall Space Flight Center	163,753	176,005	177,747	198,621	202,848
Stennis Space Center	207,504	224,901	231,711	233,016	234,251
Total	*1,729,127*	*1,766,906*	*1,833,222*	*1,904,995*	*1,941,657*

Source: "Recorded Value of Capital Type Property In-House and Contractor-Held," Annual NASA Budget Estimates, Fiscal Year 1991–Fiscal Year 2000.

[742] FY 1989–FY 1993 included with Ames Research Center.

Table 5-11B. Other Structures and Facilities Value by Field Center and Fiscal Year: In-House and Contractor-Held (FY 1994–FY 1998)

Field Center	**1994**	**1995**	**1996**	**1997**	**1998**
Headquarters	0	0	0	0	0
Ames Research Center	92,000	96,157	69,499	69,667	46,371
Dryden Flight Research Center[743]	—	—	33,979	33,979	33,979
Goddard Space Flight Center	140,405	143,520	149,117	172,398	174,813
Jet Propulsion Laboratory	114,671	119,164	151,566	157,592	176,239
Johnson Space Center	122,351	129,812	135,498	151,495	155,174
Kennedy Space Center	568,601	588,486	616,991	628,015	629,405
Langley Research Center	433,201	449,906	461,819	465,561	475,094
Lewis Research Center	120,284	123,233	124,556	124,695	102,480
Marshall Space Flight Center	248,696	249,724	209,167	209,754	154,280
Stennis Space Center	244,950	249,452	264,340	265,701	137,874
Total	*2,085,159*	*2,149,454*	*2,216,532*	*2,278,857*	*2,085,709*

[743] FY 1994–FY 1995 included with Ames Research Center.

Table 5-12A. Capitalized Equipment Value by Field Center and Fiscal Year: In-House and Contractor-Held (FY 1989–FY 1993) (at end of fiscal year; in thousands of dollars)

Field Center	1989	1990	1991	1992	1993
Headquarters[744]	50,295	53,064	69,201	65,301	58,592
Ames Research Center	391,125	380,929	395,797	417,041	401,475
Dryden Flight Research Center[745]	—	—	—	—	—
Goddard Space Flight Center	460,067	460,203	502,230	570,252	645,274
Jet Propulsion Laboratory	406,690	421,329	465,007	373,403	408,683
Johnson Space Center	485,980	515,498	588,985	670,891	724,493
Kennedy Space Center	737,617	814,215	840,997	4,596,904	893,976
Langley Research Center	235,135	242,267	258,377	305,673	327,435
Lewis Research Center	182,863	210,896	222,056	246,020	263,969
Marshall Space Flight Center	523,260	563,179	701,871	783,945	788,983
Stennis Space Center	32,812	35,492	37,144	40,378	48,140
Total	*3,505,844*	*3,697,072*	*4,081,665*	*8,069,808*	*4,561,020*

Source: Table 5-4.

[744] Includes NASA Headquarters, Washington, DC, and various locations.
[745] FY 1989–FY 1993 included with Ames Research Center.

Table 5-12B. Capitalized Equipment Value by Field Center and Fiscal Year: In-House and Contractor-Held (FY 1994–FY 1998) (at end of fiscal year; in thousands of dollars)

Field Center	1994	1995	1996	1997	1998[746]
Headquarters[747]	47,085	54,401	50,696	41,626	35,136
Ames Research Center	422,998	452,186	353,898	348,899	263,916
Dryden Flight Research Center[748]	—	—	256,554	279,785	254,295
Goddard Space Flight Center	667,381	753,451	824,315	830,380	390,716
Jet Propulsion Laboratory	3,919[749]	383,799	361,387	378,251	95,267
Johnson Space Center	835,686	775,154	815,465	1,394,617	889,131
Kennedy Space Center	877,600	898,669	833,003	236,272	79,517
Langley Research Center	350,737	345,652	347,699	373,152	133,033
Lewis Research Center	267,542	270,076	276,212	273,239	73,461
Marshall Space Flight Center	812,048	803,338	781,813	772,503	381,134
Stennis Space Center	58,135	56,758	54,800	58,890	29,467
Total	*4,343,131*	*4,793,484*	*4,955,842*	*4,987,438*	*2,625,073*

[746] Does not include special tooling, special test equipment, and Agency-peculiar property included for first time in FY 1998.
[747] Includes NASA Headquarters, Washington, DC, and various locations.
[748] FY 1994–FY 1995 included with Ames Research Center.
[749] This figure differs from the amount stated for Capitalized Equipment Value in the "Recorded Value of Capital Property In-House and Contractor-Held as of September 30, 1994 (Dollars in Thousands)" because the amount for the JPL Capitalized Equipment Value was misstated in full dollars ($3,918,821) rather than in K dollars as in the report. The total FY 1994 NASA Total was adjusted to reflect the correct figure for JPL Capitalized Equipment. (The adjustment was made per Jay Rosenthal, Resources Team Leader, Facilities Engineering and Real Property Division, NASA Headquarters.)

Table 5-13. Land Value as a Percentage of Total Real Property Value by Field Center and Fiscal Year: In-House and Contractor-Held

Field Center	1989	1990	1991	1992	1993	1994	1995	1996	1997	1998
Ames Research Center	0.6	0.5	0.5	0.5	0.5	0.9	0.8	0.9	0.9	0.6
Dryden Flight Research Center[750]	—	—	—	—	—	—	—	0[751]	0	0
Goddard Space Flight Center	1.0	0.9	0.8	0.8	0.8	0.7	0.7	0.7	0.4	1.0
Jet Propulsion Laboratory	0.5	0.5	0.5	0.4	0.4	0.4	0.4	0.3	0.3	0.2
Johnson Space Center	3.3	3.2	3.1	2.7	2.6	2.4	2.2	2.2	2.1	2.0
Kennedy Space Center	6.3	6.2	6.1	5.9	5.9	5.8	5.4	5.2	5.1	5.0
Langley Research Center	*	*	*	*	*	*	*	*	*	*
Lewis Research Center	0.8	0.8	0.7	0.4	0.6	0.6	0.6	0.5	0.5	0.6
Marshall Space Flight Center	1.5	1.5	2.1	2.0	1.9	1.5	1.5	1.2	1.1	1.2
Stennis Space Center	5.5	5.1	5.0	4.9	4.7	4.5	4.5	4.3	4.3	6.0

* = Less than 0.05 percent.

Source: Tables 5-24, 5-29, 5-34, 5-39, 5-43, 5-48, 5-53, 5-58, 5-63, 5-68.

[750] FY 1989–FY 1995 included with Ames Research Center.

[751] Land not owned by NASA.

Table 5-14. Building Value as a Percentage of Total Real Property Value by Field Center and Fiscal Year: In-House and Contractor-Held (at end of fiscal year)

Field Center	1989	1990	1991	1992	1993	1994	1995	1996	1997	
Ames Research Center	92.8	93.1	93.2	93.0	92.3	86.6	87.8	90.2	90.3	92.1
Dryden Flight Research Center[752]	—	—	—	—	—	—	—	68.4	68.5	69.5
Goddard Space Flight Center	58.0	62.2	64.0	67.0	67.5	68.2	69.0	69.1	66.5	66.2
Jet Propulsion Laboratory	52.9	52.3	54.1	60.8	60.7	63.1	63.4	60.0	60.3	57.9
Johnson Space Center	71.3	71.2	70.1	71.8	71.5	72.0	71.8	71.8	71.8	73.2
Kennedy Space Center	47.3	49.4	49.5	49.8	50.0	49.5	51.8	50.9	51.2	52.3
Langley Research Center	33.1	34.2	34.1	34.0	34.7	36.4	36.4	36.8	37.2	34.2
Lewis Research Center	71.4	72.0	71.9	72.0	72.6	73.1	73.5	73.3	73.5	75.1
Marshall Space Flight Center	64.2	63.1	73.7	62.0	63.3	65.6	64.9	65.0	65.6	71.9
Stennis Space Center	31.7	31.0	31.3	32.0	34.1	33.9	33.8	32.8	33.3	48.0

Source: Tables 5-24, 5-29, 5-34, 5-39, 5-43, 5-48, 5-53, 5-58, 5-63, 5-68.

[752] FY 1989–FY 1995 included with Ames Research Center.

Table 5-15. Other Structures and Facilities Value as a Percentage of Total Real Property Value by Field Center and Fiscal Year: In-House and Contractor-Held (at end of fiscal year)

Field Center	1989	1990	1991	1992	1993	1994	1995	1996	1997	1998
Ames Research Center	6.6	6.3	6.3	6.4	7.3	12.5	11.4	8.9	8.9	7.2
Dryden Flight Research Center[753]	—	—	—	—	—	—	—	31.6	31.5	30.5
Goddard Space Flight Center	41.0	37.0	35.2	32.2	31.7	31.1	30.4	30.3	32.9	32.7
Jet Propulsion Laboratory	45.8	46.7	45.0	38.5	44.6	36.1	36.0	40.0	39.2	41.8
Johnson Space Center	25.4	25.6	26.8	25.5	23.7	25.6	25.9	26.0	26.1	24.8
Kennedy Space Center	46.4	44.4	44.5	44.3	44.1	44.7	42.8	43.9	43.7	42.7
Langley Research Center	67.0	65.8	65.9	65.9	64.0	63.5	63.5	63.1	62.8	65.8
Lewis Research Center	27.8	27.2	27.4	27.4	26.7	26.3	25.9	26.1	25.9	24.3
Marshall Space Flight Center	34.3	35.6	34.2	36.0	36.8	32.9	33.6	33.8	33.3	26.8
Stennis Space Center	62.8	63.9	63.8	63.1	61.1	61.6	61.7	62.9	62.5	45.9

Source: Tables 5-24, 5-29, 5-34, 5-39, 5-43, 5-48, 5-53, 5-58, 5-63, 5-68.

[753] FY 1989–FY 1995 included with Ames Research Center.

Table 5-16. Real Property Value of Field Centers Ranked by Percentage of Total Real Property Value: In-House and Contractor-Held (at end of fiscal year; selected years)

Ranking	1989		1992		1996		1998	
1	Kennedy	26.9	Kennedy	24.5	Kennedy	23.7	Kennedy	25.3
2	Langley	13.9	Langley	13.5	Ames	13.2	Langley	12.4
3	Ames	11.6	Ames	12.5	Langley	12.3	Ames	11.0
4	Marshall	11.3	Marshall	11.2	Marshall	10.4	Johnson	10.7
5	Johnson	7.9	Johnson	8.4	Johnson	8.8	Marshall	10.0
6	Lewis	7.9	Lewis	8.2	Goddard	8.3	Goddard	9.2
7	Stennis	7.8	Goddard	8.1	Lewis	8.0	JPL	7.2
8	Goddard	7.0	Stennis	7.5	Stennis	7.1	Lewis	7.2
9	JPL	5.6	JPL	6.0	JPL	6.4	Stennis	5.2
10	Dryden[754]	—	Dryden	—	Dryden	1.8	Dryden	1.9
Total[755]		*99.9*		*99.9*		*100.0*		*100.1*

Source: Tables 5-24, 5-29, 5-34, 5-39, 5-43, 5-48, 5-53, 5-58, 5-63, 5-68.

[754] FY 1989–FY 1995 included with Ames Research Center.
[755] May not equal 100 percent due to rounding.

Table 5-17. Capitalized Equipment Value of Field Centers Ranked by Percentage of Total Capitalized Equipment Value: In-House and Contractor-Held (at end of fiscal year, selected years)

Ranking	**1989**		**1992**		**1996**		**1998**[756]		**1998**[757]	
1	Kennedy	21.0	Kennedy	57.0	Johnson	33.9	Johnson	33.9	Johnson	72.9
2	Marshall	14.9	Marshall	9.7	Goddard	14.9	Goddard	14.9	Marshall	11.5
3	Johnson	13.9	Johnson	8.3	Marshall	14.5	Marshall	14.5	Goddard	5.0
4	Goddard	13.1	Goddard	7.1	Ames	10.1	Ames	10.1	Kennedy	2.5
5	JPL	11.6	Ames	5.2	Dryden	9.7	Dryden	9.7	Ames	2.4
6	Ames	11.2	JPL	4.6	Langley	5.1	Langley	5.1	Dryden	2.2
7	Langley	8.1	Langley	3.8	JPL	3.6	JPL	3.6	Langley	1.3
8	Lewis	5.2	Lewis	3.0	Kennedy	3.0	Kennedy	3.0	JPL	0.9
9	Headquarters	1.4	Headquarters	0.8	Lewis	2.8	Lewis	2.8	Lewis	0.7
10	Stennis	0.9	Stennis	0.5	Headquarters	1.3	Headquarters	1.3	Headquarters	0.3
11	Dryden[758]	—	Dryden	—	Stennis	1.1	Stennis	1.1	Stennis	0.3
Total[759]		*101.3*		*100.0*		*100.0*		*100.0*		*100.0*

Source: Tables 5-20, 5-24, 5-29, 5-34, 5-39, 5-43, 5-48, 5-53, 5-58, 5-63, 5-68; also “Recorded Value of Capital Type Property In-House and Contractor-Held as of September 30, 1998.”

[756] Ranking excluding special tooling, special test equipment, and Agency-peculiar property, included for the first time in FY 1998.
[757] Ranking including special tooling, special test equipment, and Agency-peculiar property.
[758] FY 1989–FY 1995 included with Ames Research Center.
[759] May not equal 100 percent due to rounding.

Table 5-18. Budget Plan Distributed by Appropriation and Field Center: FY 1998 (in thousands of dollars; percentage of total budget plan in parentheses)

Field Center	Human Space Flight[760]	Science, Aeronautics and Technology[761]	Mission Support[762]	Total Budget Plan[763]
Ames Research Center	22,052	381,594	179,053	582,699
	(3.8)	(65.5)	(30.7)	(100)
Dryden Flight Research Center	5,800	140,327	61,820	207,947
	(2.8)	(65.5)	(29.7)	(98)
Goddard Space Flight Center	13,269	2,048,068	411,012	2,472,349
	(0.5)	(82.8)	(16.6)	(99.9)
Jet Propulsion Laboratory	702	1,077,650	23,478	1,101,830
	*	(97.8)	(2.1)	(99.9)
Johnson Space Center	3,856,106	94,820	342,525	4,293,451
	(89.8)	(2.2)	(8.0)	(100)
Kennedy Space Center	303,458	245,646	248,364	797,468
	(38.1)	(30.8)	(31.1)	(100)
Langley Research Center	7,352	418,067	226,182	651,601
	(1.1)	(64.2)	(34.7)	(100)
Lewis Research Center	31,350	374,334	261,368	667,052
	(4.7)	(56.1)	(39.2)	(100)
Marshall Space Flight Center	1,263,768	686,553	379,988	2,330,309
	(54.2)	(29.5)	(16.3)	(100)
Stennis Space Center	47,216	60,890	49,637	157,743
	(29.9)	(38.6)	(31.5)	(100)
Headquarters	8,427	162,051	192,877	363,355
	(2.3)	(44.6)	(53.1)	(100)
Undistributed				
Construction of Facilities: various locations	—	—	3,721	3,721
			(100.0)	(100)
Inspector General	—	—	—	18,152
Total	*5,559,500*	*5,690,000*	*2,380,025*	*13,647,677*
	(40.7)	*(41.7)*	*(17.4)*	

* = Less than 0.05 percent.
Source: NASA Fiscal Year 2000 Budget Estimates.

[760] Includes International Space Station, Russian Program Assurance, Space Shuttle, and Payload Utilization and Operations.
[761] Includes Space Science, Life and Microgravity Sciences and Applications, Earth Science, Aero-Space Technology, Academic Programs, and Mission Communications Services programs.
[762] Includes Safety, Mission Assurance, Engineering, and Advanced Concepts; Space Communication Services; Research and Program Management; and Construction of Facilities programs.
[763] Total percentages may not add up to 100 percent due to rounding.

Table 5-19. NASA Headquarters Major Organizations

Code	Title
1989	
A	Office of the Administrator
B	Office of the Comptroller
C	Office of Commercial Programs
D	Office of Headquarters Operations
E	Office of Space Science and Applications
G	Office of General Counsel
H	Office of Procurement
K	Office of Small and Disadvantaged Business Utilization
L	Office of Communications
M	Office of Space Flight
N	Office of Management
P	Office of the Chief Scientist
Q	Office of Safety, Reliability, Maintainability and Quality Assurance
R	Office of Aeronautics and Space Technology
S	Office of Space Station
T	Office of Space Operations
U	Office of Equal Opportunity Programs
W	Office of Inspector General
X	Office of External Relations
Z	Office of Exploration
1998	
A	Office of the Administrator
B	Office of the Chief Financial Officer
C	Office of Headquarters Operations
E	Office of Equal Opportunity Programs
F	Office of Human Resources and Education
G	Office of the General Counsel
H	Office of Procurement
I	Office of External Relations
J	Office of Management Systems and Facilities
K	Office of Small and Disadvantaged Business Utilization
L	Office of Legislative Affairs
M	Office of Space Flight
P	Office of Public Affairs
Q	Office of Safety and Mission Assurance
R	Office of Aeronautics and Space Transportation Technology
S	Office of Space Science
U	Office of Life and Microgravity Sciences and Applications

Code	Title
W	Office of Inspector General
Y	Office of Earth Science
Z	Office of Policy and Plans

Source: 1989 and 1998 Headquarters Telephone Directories.

Table 5-20. Headquarters Capitalized Equipment Value

1989	1990	1991	1992	1993	1994	1995	1996	1997	1998
50,295	53,064	69,201	65,301	58,592	47,085	54,401	50,696	41,626	35,136

Source: “Recorded Value of Capital Type Property In-House and Contractor-Held,” Annual NASA Budget Estimates, Fiscal Year 1991–Fiscal Year 2000.

Table 5-21. Headquarters Personnel (end of fiscal year)

Category	1989	1990	1991	1992	1993	1994	1995	1996	1997	1998
Permanent Employees[764]	1,727	1,966	2,092	1,998	1,927	1,676	1,502	1,341	1,028	941
Nonpermanent Employees	140	187	203	418	368	314	355	350	290	312
Total Employees	*1,867*	*2,153*	*2,295*	*2,416*	*2,295*	*1,990*	*1,857*	*1,691*	*1,318*	*1,253*
Occupational Code Groups (full-time permanent only)										
200, 700, and 900[765]	502	571	590	588	571	470	407	328	250	225
600[766]	854	970	1,047	959	930	840	786	721	568	536
500[767]	360	415	447	417	394	338	287	271	196	170
300[768]	5	7	6	5	6	6	2	2	3	2
100[769]	6	3	2	1	1	1	1	1	0	0
SES, Senior Technical, Excepted[770]	224[771]	243[772]	272	263	258	222	200	179	127	116
Minority Full-Time Permanent Employees[773]	406	482	532	508	489	456	415	389	298	275
Female Full-Time Permanent Employees	755	867	938	903	869	775	725	668	506	462

Source: FY 1989–FY 1991: The Civil Service Workforce, Office of Management, Office of Personnel Management; FY 1991 permanent-nonpermanent employee breakdown; FY 1992–FY 1998: NASA Workforce Data Cube, Historical Trends, *http://hqpowerplay.hq.nasa.gov/cognos/cgi-bin/ppdscgi.exe?E=/WF%20History%20Detail&LA=en&LO=en-us* (password required) (accessed April 29, 2007).

[764] FY 1989–FY 1991: includes only full-time permanent employees. FY 1992–1998: includes full- and part-time permanent employees.
[765] 200—Support Engineering and Related Positions; 700—Aero-Space Technology Scientific and Engineering; 900—Life Science Support.
[766] 600—Professional Administrative.
[767] 500—Clerical and Nonprofessional Administrative.
[768] 300—Technical Support.
[769] 100—Wage System (Trade and Labor).
[770] Full-time permanent.
[771] Includes SES, NASA Excepted Public Law 3104(a), *Executive Pay Act*, and GS-16 and above employees.
[772] Includes SES, NASA Excepted, Public Law 3104(a), *Executive Pay Act*, and GS-16 and above employees. Total of 243 comes from "Senior Executive Service Excepted and Supergrade Employment," *The Civil Service Workforce, Fiscal Year 1990*, p. 8. The *Fiscal Year 1991 Workforce Report*, p. 13, lists a total of 241 people in "positions above the GS/GM-15 level" at the end of FY 1990, "Positions above the GS/GM-15 Level by Pay Plan and Installation." No explanation for the revised number is given.
[773] Minority consists of all non-white groups listed by NASA (Black, Hispanic, Asian or Pacific Islander, and American Indian).

Table 5-22. Headquarters Funding by Fiscal Year (in thousands of dollars)

Appropriation Title	1989	1990	1991	1992	1993	1994	1995	1996	1997	1998
Research and Development	456,694	517,669	682,703	875,010	—	—	—	—	—	—
Human Space Flight	—	—	—	—	344,100	97,600	60,209	51,674	15,049	8,427
Space Flight Control and Data Communications	81,522	68,787	86,790	161,291	—	—	—	—	—	—
Science, Aeronautics, and Technology	—	—	—	—	657,889	713,062	647,887	550,870	144,416	162,051
Research and Program Management	263,609	274,822	300,774	174,501	—	—	—	—	—	—
Construction of Facilities	16,100	3,272	8,642	1,936	—	—	—	—	—	—
Mission Support[774]	—	—	—	—	338,137	310,915	289,292	246,349	230,057	192,877
Total	*817,925*	*864,550*	*1,078,909*	*939,399*	*1,340,126*	*1,121,577*	*997,388*	*848,893*	*389,522*	*363,355*

Source: "Summary of Budget Plans by Installation by Appropriation," NASA Budget Estimates.

[774] Includes Safety, Reliability and Quality Assurance, Space Communication Services, Research and Program Management, and Construction of Facilities.

Table 5-23. Headquarters Total Procurement Activity by Fiscal Year (in millions of dollars)

	1989	1990	1991	1992	1993	1994	1995	1996	1997	1998
Net Value of Contract Awards	600.0	730.6	954.8	808.6	863.4	811.7	774.5	578.6	217.2	168.8
Percentage of NASA Total	5.5	5.8	7.3	6.0	6.6	6.3	5.8	4.6	1.7	1.3

Source: Annual Procurement Report.

Table 5-24. Ames Research Center In-House and Contractor-Held Property (at end of fiscal year; money amounts in thousands of dollars)

Category	1989	1990	1991	1992	1993	1994	1995	1996	1997	1998
In-House and Contractor-Held Property										
Land (acres)	432.5[775]	432.0	432.0	432.0	432.0	3,387.2[776]	3,411.1	3,411.1	3,400	3,400
Number of Buildings	161	174	175	176	355	355	355	355	261	261
Area of Buildings (square feet)	2,710,774	2,785,040	2,786,080	2,823,540	2,823,540	5,528,665	5,752,354	5,507,349	5,483,208	5,483,208
Value of In-House and Contractor-Held Property										
Land	2,929	2,929	2,929	2,929	2,929	6,865[777]	6,865	6,865	6,865	3,936
Buildings	482,349	497,880	527,303	574,152	589,056	636,696	737,166	708,043	709,871	589,948
Other Structures and Facilities	32,217	33,630	35,699	39,700	46,484	92,000	96,157	69,499	69,667	46,371
Total Real Property Value	*488,725*	*534.439*	*565,931*	*616.469*	*638,884*	*735,561*	*840,188*	*784,407*	*786,403*	*640,255*
Capitalized Equipment Value	391,125	380,929	395,797	417,041	401,475	422,998	452,186	353,898	348,899	263,916
Special Tooling[778]	—	—	—	—	—	—	—	—	—	0
Special Test Equipment[779]	—	—	—	—	—	—	—	—	—	0
Agency-Peculiar Property[780]	—	—	—	—	—	—	—	—	—	13,518

Source: Tables 5-4, 5-5, 5-6, 5-7, 5-9, 5-10, 5-11, 5-12. Also “Recorded Value of Capital Type Property In-House and Contractor-Held as of September 30, 1998.”

[775] Includes Ames Research Center, Moffett Field, CA; Camp Parks, Pleasanton, CA; and Crow’s Landing, CA.
[776] Reflects addition of Moffett Airfield, Moffett Field, CA.
[777] The increase in value reflects the closure of Moffett Air Field and acquisition by NASA.
[778] Category introduced in FY 1998 “Recorded Value of Property” report.
[779] Category introduced in FY 1998 “Recorded Value of Property” report.
[780] Category introduced in FY 1998 “Recorded Value of Property” report.

Table 5-25. Ames Research Center Value of Real Property Components as a Percentage of Total (total real property value in thousands of dollars)

Component	1989	1990	1991	1992	1993	1994	1995	1996	1997	1998
Land	0.6	0.5	0.5	0.5	0.5	0.9	0.8	0.9	0.9	0.6
Buildings	92.8	93.1	93.2	93.0	92.3	86.6	87.8	90.2	90.3	92.1
Other Structures and Facilities	6.6	6.3	6.3	6.4	7.3	12.5	11.4	8.9	8.9	7.2
Total Real Property Value	*488,725*	*534,439*	*565,931*	*616,469*	*638,469*	*735,561*	*840,188*	*784,407*	*786,403*	*640,255*

Source: Table 5-24.

Table 5-26. Ames Research Center Personnel (at end of fiscal year)

Category	1989	1990	1991	1992	1993	1994	1995	1996	1997	1998
Permanent Employees[781]	2,151	2,205	2,263	2,273	2,201	1,715	1,575	1,504	1,414	1,321
Nonpermanent Employees	66	74	143	169	177	89	101	97	130	183
Total Employees[782]	*2,217*	*2,279*	*2,406*	2,442	2,378	1,804	1,676	1,601	1,544	1,504
Occupational Code Groups (permanent only)										
200, 700, and 900	1,164	1,183	1,212	1,202	1,178	968	913	871	837	789
600	307	345	364	368	368	307	289	283	281	279
500	223	216	221	210	186	160	134	122	103	84
300	138	139	150	171	179	107	93	97	91	92
100	319	322	316	295	267	164	138	124	95	72
SES, Senior Technical, Excepted	43	39	45	48	44	35	34	34	32	34
Minority Full-Time Permanent Employees	433	459	491	494	486	414	386	370	353	344
Female Full-Time Permanent Employees	520	547	574	572	548	464	423	403	380	365

Source: FY 1989–FY 1991: The Civil Service Workforce, Office of Management, Office of Personnel Management; FY 1991 permanent-nonpermanent employee breakdown; FY 1992–FY 1998: NASA Workforce Data Cube, Historical Trends, *http://hqpowerplay.hq.nasa.gov/cognos/cgi-bin/ppdscgi.exe?E=/WF%20History%20Detail&LA=en&LO=en-us* (password required) (accessed April 29, 2007).

[781] FY 1989–FY 1991: includes only full-time permanent employees. FY 1992–FY 1998: includes full- and part-time permanent employees.
[782] FY 1989–FY 1993: includes Dryden personnel.

Table 5-27. Ames Research Center Funding by Fiscal Year (in thousands of dollars)

Appropriation Title	1989	1990	1991	1992	1993	1994	1995	1996	1997	1998
Research and Development	288,416	307,941	349,951	427,959	—	—	—	—	—	—
Human Space Flight	—	—	—	—	7,200	0	0	26,296	14,935	22,052
Space Flight Control and Data Communications	16,700	18,700	18,600	18,900	—	—	—	—	—	—
Science, Aeronautics, and Technology	—	—	—	—	475,175	447,756	456,122	390,835	354,383	381,594
Research and Program Management	177,775	187,340	211,155	158,860	—	—	—	—	—	—
Construction of Facilities	29,098	45,019	27,550	62,748	—	—	—	—	—	—
Mission Support	—	—	—	—	217,673	184,914	174,975	173,609	186,791	179,053
Total	*511,989*	*559,000*	*607,256*	*646,129*	*700,018*	*632,670*	*631,097*	*590,740*	*556,109*	*582,699*

Source: "Summary of Budget Plans by Installation by Appropriation," NASA Budget Estimates.

Table 5-28. Ames Research Center Total Procurement Activity by Fiscal Year (in millions of dollars)

	1989	**1990**	**1991**	**1992**	**1993**	**1994**[783]	**1995**	**1996**	**1997**	**1998**
Net Value of Contract Awards	450.6	482.8	520.2	568.0	567.2	594.1	560.8	533.3	507.1	493.1
Percentage of NASA Total	4.1	3.8	3.9	4.2	4.3	4.6	4.2	4.2	4.0	3.9

Source: Annual Procurement Report.

[783] FY 1994 and previous year awards included awards to Dryden.

Table 5-29. Dryden Flight Research Center In-House and Contractor-Held Property (at end of fiscal year; money amounts in thousands of dollars)

Category	1989[784]	1990	1991	1992	1993	1994	1995	1996	1997	1998
In-House and Contractor-Held Property										
Land (acres)	—	—	—	—	—	—	—	0	0	0
Number of Buildings	67	67	65	70	73	80	80	85	55	55
Area of Buildings (square feet)	551,945	558,183	557,663	688,461	695,238	692,608	735,354	727,086	848,896	848,896
Value of In-House and Contractor-Held Property										
Land	—	—	—	—	—	—	—	0	0	0
Buildings	—	—	—	—	—	—	—	73,405	73,806	77,361
Other Structures and Facilities	—	—	—	—	—	—	—	33,979	33,979	33,979
Total Real Property Value	—	—	—	—	—	—	—	*107,384*	*107,785*	*111,340*
Capitalized Equipment Value	—	—	—	—	—	—	—	256,554	279,785	254,295
Special Tooling	—	—	—	—	—	—	—	—	—	0
Special Test Equipment	—	—	—	—	—	—	—	—	—	908
Agency-Peculiar Property	—	—	—	—	—	—	—	—	—	0

Source: Tables 5-4, 5-5, 5-6, 5-7, 5-9, 5-10, 5-11, 5-12. Also "Recorded Value of Capital Type Property In-House and Contractor-Held as of September 30, 1998."

[784] FY 1989–FY 1995 included with Ames Research Center.

Table 5-30. Dryden Flight Research Center Value of Real Property Components as a Percentage of Total (total real property value in thousands of dollars)

Component	1989[785]	1990	1991	1992	1993	1994	1995	1996	1997	1998
Land[786]	—	—	—	—	—	—	—	0	0	0
Buildings	—	—	—	—	—	—	—	68.4	68.5	69.5
Other Structures and Facilities	—	—	—	—	—	—	—	31.6	31.5	30.5
Total Real Property Value	—	—	—	—	—	—	—	*107,384*	*107,785*	*111,340*

Source: Table 5-29.

[785] FY 1989–FY 1995 included with Ames Research Center.
[786] NASA does not own the land at Dryden.

Table 5-31. Dryden Flight Research Center Personnel (at end of fiscal year)

Category	1989	1990	1991	1992	1993[787]	1994	1995	1996	1997	1998
Permanent Employees	—	—	—	—	—	447	433	452	478	507
Nonpermanent Employees	—	—	—	—	—	47	39	45	97	85
Total Employees	—	—	—	—	—	494	472	497	575	592
Occupational Code Groups (permanent only)										
200, 700, and 900	—	—	—	—	—	177	174	189	202	224
600	—	—	—	—	—	79	83	88	101	101
500	—	—	—	—	—	29	26	24	21	18
300	—	—	—	—	—	106	105	120	123	143
100	—	—	—	—	—	50	40	28	28	18
SES, Senior Technical, Excepted	—	—	—	—	—	6	7	9	10	10
Minority Full-Time Permanent Employees	—	—	—	—	—	100	98	108	119	127
Female Full-Time Permanent Employees	—	—	—	—	—	106	101	103	108	106

Source: FY 1989–FY 1991: The Civil Service Workforce, Office of Management, Office of Personnel Management; FY 1991 permanent-nonpermanent employee breakdown; FY 1992–FY 1998: NASA Workforce Data Cube, Historical Trends, *http://hqpowerplay.hq.nasa.gov/cognos/cgi-bin/ppdscgi.exe?E=/WF%20History%20Detail&LA=en&LO=en-us* (password required) (accessed April 29, 2007).

[787] FY 1989–FY 1993 included with Ames Research Center.

Table 5-32. Dryden Flight Research Center Funding by Fiscal Year (in thousands of dollars)[788]

Appropriation Title	1989	1990	1991	1992	1993	1994	1995	1996	1997	1998
Human Space Flight	—	—	—	—	—	5,700	6,100	5,600	5,400	5,800
Science, Aeronautics, and Technology	—	—	—	—	—	51,700	62,119	86,697	93,905	140,327
Mission Support	—	—	—	—	—	39,764	49,335	43,867	59,284	61,820
Total	—	—	—	—	—	*97,164*	*117,554*	*136,164*	*158,589*	*207,947*

Source: "Summary of Budget Plans by Installation by Appropriation," NASA Budget Estimates.

[788] FY 1989–FY 1993 included with Ames Research Center.

Table 5-33. Dryden Flight Research Center Total Procurement Activity by Fiscal Year (in millions of dollars)

	1989	**1990**	**1991**	**1992**	**1993**	**1994[789]**	**1995**	**1996**	**1997**	**1998**
Net Value of Contract Awards	—	—	—	—	—	—	96.0	108.4	132.4	156.6
Percentage of NASA Total	—	—	—	—	—	—	0.7	0.8	1.0	1.3

Source: Annual Procurement Report.

[789] FY 1994 and previous years' awards included with Ames Research Center.

Table 5-34A. Goddard Space Flight Center In-House and Contractor-Held Property (at end of fiscal year; money amounts in thousands of dollars) (FY 1989–FY 1993)

Category	1989	1990	1991	1992	1993
In-House and Contractor-Held Property					
Land (acres)[790]	18,576.5	18,576.5	18,576.5	18,576.5	18,597.8
Number of Buildings	466	472	458	455	448
Area of Buildings (square feet)	3,683,130	4,114,561	4,132,431	4,302,894	4,386,619
Value of In-House and Contractor-Held Property					
Land	2,872	2,880	2,880	3,096	3,311
Buildings	170,385	206,195	226,332	267,094	281,447
Other Structures and Facilities	120,462	122,655	124,679	128,470	131,944
Leasehold Improvements	0	0	11	11	0
Total Real Property Value	*293,719*	*331,730*	*353,902*	*398,660*	*416,702*
Capitalized Equipment Value	460,067	460,203	502,230	570,252	645,274
Special Tooling	—	—	—	—	—
Special Test Equipment	—	—	—	—	—
Agency-Peculiar Property	—	—	—	—	—

Source: Tables 5-4, 5-5, 5-6, 5-7, 5-9, 5-10, 5-11, 5-12.

[790] Includes Goddard Space Flight Center, Greenbelt, MD; Wallops Flight Facility, Wallops Island, VA; the Antenna Tracking Station, Fairbanks, AK; and the Antenna Test Range, Las Cruces, NM.

Table 5-34B. Goddard Space Flight Center In-House and Contractor-Held Property (at end of fiscal year; money amounts in thousands of dollars) (FY 1994–FY 1998)

Category	1994	1995	1996	1997	1998
In-House and Contractor-Held Property					
Land (acres)[791]	10,097.0 [792]	10,105.0 [793]	10,105.0	13,315	13,315
Number of Buildings	401	402	398	295	301
Area of Buildings (square feet)	4,528,157	4,592,142	4,566,509	3,433,180	4,547,975
Value of In-House and Contractor-Held Property					
Land	3,341	3,341	3,351	3,351	5,483
Buildings	308,365	325,756	340,181	348,747	353,845
Other Structures and Facilities	140,405	143,520	149,117	172,398	174,813
Leasehold Improvements	0	0	0	0	0
Total Real Property Value	*452,111*	*472,617*	*492,649*	*524,496*	*534,141*
Capitalized Equipment Value	667,381	753,451	824,315	830,380	390,716
Special Tooling	—	—	—	—	6,666
Special Test Equipment	—	—	—	—	79,682
Agency-Peculiar Property	—	—	—	—	108,053

Source: Tables 5-4, 5-5, 5-6, 5-7, 5-9, 5-10, 5-11, 5-12. Also "Recorded Value of Capital Type Property In-House and Contractor-Held as of September 30, 1998."

791 Includes Goddard Space Flight Center, Greenbelt, MD; Wallops Flight Facility, Wallops Island, VA; and the Antenna Test Range, Las Cruces, NM.
792 Reflects the transfer of Alaska Tracking Station, Fairbanks, AK, from NASA to NOAA.
793 Reflects the addition of the Balloon Launching Facility, Ft. Sumner, NM.

Table 5-35. Goddard Space Flight Center Value of Real Property Components as a Percentage of Total (total real property value in thousands of dollars)

Component	1989	1990	1991	1992	1993	1994	1995	1996	1997	1998
Land	1.0	0.9	0.8	0.8	0.8	0.7	0.7	0.7	0.4	1.0
Buildings	58.0	62.2	64.0	67.0	67.5	68.2	69.0	69.1	66.5	66.2
Other Structures and Facilities	41.0	37.0	35.2	32.2	31.7	31.1	30.4	30.3	32.9	32.7
Total Real Property Value	*293,719*	*331,730*	*353,902*	*398,671*	*416,702*	*452,111*	*472,617*	*492,649*	*524,496*	*534,141*

Source: Table 5-34.

Table 5-36. Goddard Space Flight Center Personnel (at end of fiscal year)

Category	1989	1990	1991	1992	1993	1994	1995	1996	1997	1998
Permanent Employees[794]	3,735	3,873	3,999	4,014	3,974	3,880	3,595	3,526	3,411	3,218
Nonpermanent Employees	125	119	166	190	187	160	118	111	107	126
Total Employees	*3,860*	*3,992*	*4,165*	*4,204*	*4,161*	*4,040*	*3,713*	*3,637*	*3,518*	*3,344*
Occupational Code Groups (permanent only)										
200, 700, and 900	2,014	2,136	2,240	2,233	2,224	2,208	2,106	2,077	1,976	1,867
600	750	786	819	831	827	806	754	732	776	771
500	435	434	439	436	420	387	338	325	288	231
300	458	442	433	408	390	364	291	280	264	241
100	78	75	68	65	69	70	67	68	67	63
SES, Senior, Technical, Excepted	47	48	59	60	69	65	63	64	57	57
Minority Full-Time Permanent Employees	585	629	661	687	712	738	726	719	731	694
Female Full-Time Permanent Employees	1,044	1,112	1,176	1,182	1,178	1,167	1,113	1,094	1,102	1,051

Source: FY 1989–FY 1991: The Civil Service Workforce, Office of Management, Office of Personnel Management; FY 1991 permanent-nonpermanent employee breakdown; FY 1992–FY 1998: NASA Workforce Data Cube, Historical Trends, *http://hqpowerplay.hq.nasa.gov/cognos/cgi-bin/ppdscgi.exe?E=/WF%20History%20Detail&LA=en&LO=en-us* (password required) (accessed April 29, 2007).

[794] FY 1989–FY 1991: includes only full-time permanent employees. FY 1992–FY 1998: includes full- and part-time permanent employees.

Table 5-37. Goddard Space Flight Center Funding by Fiscal Year (in thousands of dollars)

Appropriation Title	1989	1990	1991	1992	1993	1994	1995	1996	1997	1998
Research and Development	641,839	921,290	1,153,016	1,156,939	—	—	—	—		
Human Space Flight	—	—	—	—	14,400	9,200	12,050	10,365	8,500	13,269
Space Flight Control and Data Communications	548,259	632,636	674,180	665,623	—	—	—	—	—	—
Science, Aeronautics, and Technology	—	—	—	—	1,669,133	1,825,311	2,123,862	1,975,293	2,190,562	2,048,068
Research and Program Management	254,502	264,677	303,006	249,989	—	—	—	—	—	—
Construction of Facilities	14,104	30,067	36,942	44,502	—	—	—	—		
Mission Support	—	—	—	—	590,653	486,860	494,415	525,697	548,359	411,012
Total	*1,458,704*	*1,848,670*	*2,167,144*	*2,117,153*	*2,274,186*	*2,321,371*	*2,539,327*	*2,511,355*	*2,747,421*	*2,472,349*

Source: “Summary of Budget Plans by Installation by Appropriation,” NASA Budget Estimates.

Table 5-38. Goddard Space Flight Center Total Procurement Activity by Fiscal Year (in millions of dollars)

	1989	**1990**	**1991**	**1992**	**1993**	**1994**	**1995**	**1996**	**1997**	**1998**
Net Value of Contract Awards	1,606.7	1,823.6	2,003.8	2,044.3	2,181.2	2,221.8	2,354.4	2,381.7	2,719.6	2,752.7
Percentage of NASA Total	14.8	14.4	15.2	15.2	16.6	17.2	17.6	18.8	21.3	21.9

Source: Annual Procurement Report.

Table 5-39A. JPL In-House and Contractor-Held Property (at end of fiscal year; money amounts in thousands of dollars) (FY 1989–FY 1993)

Category	1989	1990	1991	1992	1993
In-House and Contractor-Held Property					
Land (acres)	155.8	155.8	155.8	155.8	155.8
Number of Buildings	314	308	303	307	307
Area of Buildings (square feet)	2,055,578	2,044,930	2,122,807	2,450,296	2,453,388
Value of In-House and Contractor-Held Property					
Land	1,188	1,188	1,188	1,188	1,189
Buildings	125,798	125,591	138,088	180,630	179,555
Other Structures and Facilities	109,024	112,165	114,641	114,333	113,756
Leasehold Improvements	1,895	1,035	1,095	1,096	1,091
Total Real Property Value	*237,905*	*239,979*	*255,012*	*297,247*	*295,591*
Capitalized Equipment Value	406,690	421,329	465,007	373,403	408,683
Special Tooling	—	—	—	—	—
Special Test Equipment	—	—	—	—	—
Agency-Peculiar Property	—	—	—	—	—

Source: Tables 5-4, 5-5, 5-6, 5-7, 5-9, 5-10, 5-11, 5-12.

Table 5-39B. JPL In-House and Contractor-Held Property (at end of fiscal year; money amounts in thousands of dollars) (FY 1994–FY 1998)

Category	1994	1995	1996	1997	1998
In-House and Contractor-Held Property					
Land (acres)	155.8	155.8	155.8	155.8	155.8
Number of Buildings	309	314	294	239	262
Area of Buildings (square feet)	2,526,915	2,589,583	2,547,316	2,472,199	2,501,109
Value of In-House and Contractor-Held Property					
Land	1,189	1,189	1,189	1,189	1,046
Buildings	200,271	209,564	229,340	242,480	243,355
Other Structures and Facilities	114,671	119,164	151,566	157,592	176,239
Leasehold Improvements	1,096	621	666	666	370
Total Real Property Value	*317,227*	*330,538*	*382,761*	*401,261*	*421,010*
Capitalized Equipment Value	3,919[795]	383,799	361,387	378,251	95,267
Special Tooling	—	—	—	—	568
Special Test Equipment	—	—	—	—	0
Agency-Peculiar Property	—	—	—	—	10,197

Source: Tables 5-4, 5-5, 5-6, 5-7, 5-9, 5-10, 5-11, 5-12. Also “Recorded Value of Capital Type Property In-House and Contractor-Held as of September 30, 1998.”

[795] This figure differs from the amount stated for Capitalized Equipment Value in the “Recorded Value of Capital Property In-House and Contractor-Held as of September 30, 1994 (Dollars in Thousands)” because the amount for the JPL Capitalized Equipment Value was misstated in full dollars ($3,918,821) rather than in K dollars as in the report. (The adjustment was made per Jay Rosenthal, Resources Team Leader, Facilities Engineering and Real Property Division, NASA Headquarters.)

Table 5-40. JPL Value of Real Property Components as a Percentage of Total (total real property value in thousands of dollars)

Component	1989	1990	1991	1992	1993	1994	1995	1996	1997	1998
Land	0.5	0.5	0.5	0.4	0.4	0.4	0.4	0.3	0.3	0.2
Buildings	52.9	52.3	54.1	60.8	60.7	63.1	63.4	60.0	60.3	57.9
Other Structures and Facilities	45.8	46.7	45.0	38.5	44.6	36.1	36.0	40.0	39.2	41.8
Total Real Property Value	*237,905*	*239,979*	*255,012*	*297,247*	*295,591*	*317,227*	*330,583*	*382,761*	*401,927*	*420,640*

Source: Table 5-39.

Table 5-41. JPL Funding by Fiscal Year (in thousands of dollars)

Appropriation Title	1989	1990	1991	1992	1993	1994	1995	1996	1997	1998
Research and Development	583,621	572,450	649,292	670,556	—	—	—	—	—	—
Human Space Flight	—	—	—	—	1,500	400	15	2,600	2,750	702
Space Flight Control and Data Communications	124,669	153,966	150,399	177,739	—	—	—	—	—	—
Science, Aeronautics, and Technology	—	—	—	—	778,524	878,652	923,045	1,037,248	845,965	1,077,650
Research and Program Management	—	—	—	—	—	—	—	—	—	—
Construction of Facilities	4,376	12,141	34,562	12,399	—	—	—	—	—	—
Mission Support	—	—	—	—	27,152	23,209	22,174	30,097	29,292	23,478
Total	*712,666*	*738,557*	*834,253*	*860,694*	*807,176*	*902,261*	*945,243*	*1,069,945*	*878,007*	*1,101,830*

Source: "Summary of Budget Plans by Installation by Appropriation," NASA Budget Estimates.

Table 5-42. NASA Resident Office/JPL Total Procurement Activity by Fiscal Year (in millions of dollars)

	1989	1990	1991	1992	1993	1994	1995	1996	1997	1998
Net Value of Contract Awards	1,063.3	1,138.5	1,173.8	1,263.7	1,068.4	1,118.1	1,162.9	1,211.3	1,140.1	1,192.0
Percentage of NASA Total	9.8	9.1	8.9	9.4	8.1	8.7	8.7	9.5	8.9	9.5

Source: Annual Procurement Report.

Table 5-43A. Johnson Space Center In-House and Contractor-Held Property (at end of fiscal year; money amounts in thousands of dollars) (FY 1989–FY 1993)

Category	**1989**	**1990**	**1991**	**1992**	**1993**
In-House and Contractor-Held Property					
Land (acres)	3,230.0[796]	3,230.0	3,230.0	3,570.2	3,570.2
Number of Buildings	299	302	315	316	323
Area of Buildings (square feet)	5,342,797	5,385,045	5,472,512	5,700,352	5,759,089
Value of In-House and Contractor-Held Property					
Land	10,944	10,944	11,324	11,238	11,238
Buildings	237,851	245,112	259,747	297,914	312,943
Other Structures and Facilities	84,593	88,182	99,364	105,769	113,189
Leasehold Improvements	105	105	105	105	105
Total Real Property Value	*333,493*	*344,238*	*370,435*	*414,921*	*437,370*
Capitalized Equipment Value	485,980	515,498	588,985	670,891	724,493
Special Tooling	—	—	—	—	—
Special Test Equipment	—	—	—	—	—
Agency-Peculiar Property	—	—	—	—	—

Source: Tables 5-4, 5-5, 5-6, 5-7, 5-9, 5-10, 5-11, 5-12.

[796] Includes Johnson Space Center, Houston, TX; White Sands Test Facility, Las Cruces, NM; and an industrial plant at Downey, CA.

Table 5-43B. Johnson Space Center In-House and Contractor-Held Property (at end of fiscal year; money amounts in thousands of dollars) (FY 1994–FY 1998)

Category	1994	1995	1996	1997	1998
In-House and Contractor-Held Property					
Land (acres)	3,570.2	3,570.2	3,570.2	3,570.2	3,570.2
Number of Buildings	324	332	338	266	267
Area of Buildings (square feet)	6,021,187	6,031,297	6,068,619	4,720,016	4,743,529
Value of In-House and Contractor-Held Property					
Land	11,256	11,256	11,256	12,450	12,367
Buildings	344,021	359,409	374,443	417,183	458,247
Other Structures and Facilities	122,351	129,812	135,498	151,495	155,174
Leasehold Improvements	105	105	105	105	105
Total Real Property Value	*477,628*	*500,477*	*521,197*	*581,128*	*625,893*
Capitalized Equipment Value	835,686	775,154	815,465	1,394,617	889,131
Special Tooling	—	—	—	—	43,654
Special Test Equipment	—	—	—	—	224,449
Agency-Peculiar Property	—	—	—	—	7,303,812

Source: Tables 5-4, 5-5, 5-6, 5-7, 5-9, 5-10, 5-11, 5-12. Also "Recorded Value of Capital Type Property In-House and Contractor-Held as of September 30, 1998."

Table 5-44. Johnson Space Center Value of Real Property Components as a Percentage of Total (total real property value in thousands of dollars)

Component	1989	1990	1991	1992	1993	1994	1995	1996	1997	1998
Land	3.3	3.2	3.1	2.7	2.6	2.4	2.2	2.2	2.1	2.0
Buildings	71.3	71.2	70.1	71.8	71.5	72.0	71.8	71.8	71.8	73.2
Other Structures and Facilities	25.4	25.6	26.8	25.5	23.7	25.6	25.9	26.0	26.1	24.8
Total Real Property Value	*333,388*	*344,343*	*370,540*	*415,026*	*437,475*	*477,733*	*500,631*	*521,351*	*581,282*	*625,893*

Source: Table 5-43.

Table 5-45. Johnson Space Center Personnel (at end of fiscal year)

Category	1989	1990	1991	1992	1993	1994	1995	1996	1997	1998
Permanent Employees[797]	3,578	3,615	3,677	3,646	3,636	3,536	3,407	3,352	3,151	2,991
Nonpermanent Employees	126	112	174	273	285	210	177	193	200	249
Total Employees	*3,704*	*3,727*	*3,851*	3,919	3,921	3,746	3,584	3,545	3,351	3,240
Occupational Code Groups (permanent only)										
200,700, and 900	2,340	2,360	2,402	2,390	2,382	2,368	2,296	2,258	2,143	2,044
600	576	611	649	645	661	636	604	611	557	529
500	452	446	430	417	406	374	357	339	303	272
300	201	189	188	175	169	149	140	134	126	120
100	9	9	8	6	4	3	3	2	1	1
SES, Senior Technical, Excepted	51	54	61	67	69	73	76	75	76	80
Minority Full-Time Permanent Employees	574	604	641	664	676	688	695	699	672	663
Female Full-Time Permanent Employees	1,122	1,167	1,216	1,222	1,226	1,193	1,148	1,135	1,043	996

Source: FY 1989–FY 1991: The Civil Service Workforce, Office of Management, Office of Personnel Management; FY 1991 permanent-nonpermanent employee breakdown; FY 1992–FY 1998: NASA Workforce Data Cube, Historical Trends, *http://hqpowerplay.hq.nasa.gov/cognos/cgi-bin/ppdscgi.exe?E=/WF%20History%20Detail&LA=en&LO=en-us* (password required) (accessed April 29, 2007).

[797] FY 1989–FY 1991: includes only full-time permanent employees. FY 1992–FY 1998: includes full- and part-time permanent employees.

Table 5-46. Johnson Space Center Funding by Fiscal Year (in thousands of dollars)

Appropriation Title	1989	1990	1991	1992	1993	1994	1995	1996	1997	1998
Research and Development	561,678	1,036,648	1,161,735	1,419,927	—	—	—	—	—	—
Human Space Flight	—	—	—	—	2,329,400	1,604,300	2,804,237	3,073,329	3,802,521	3,856,106
Space Flight Control and Data Communications	1,049,250	1,129,200	1,185,700	1,297,921	—	—	—	—	—	—
Science, Aeronautics, and Technology	—	—	—	—	167,812	231,081	146,897	103,969	90,571	94,280
Research and Program Management	299,435	320,630	338,460	245,944	—	—	—	—	—	—
Construction of Facilities	24,925	59,746	53,891	31,523	—	—	—	—	—	—
Mission Support	—	—	—	—	350,434	354,634	376,023	370,764	378,280	342,525
Total	*1,935,288*	*2,546,224*	*2,739,786*	*2,979,315*	*2,847,646*	*2,190,015*	*3,327,157*	*3,548,062*	*4,271,372*	*4,293,451*

Source: “Summary of Budget Plans by Installation by Appropriation,” NASA Budget Estimates.

Table 5-47. Johnson Space Center Total Procurement Activity by Fiscal Year (in millions of dollars)

	1989	1990	1991	1992	1993	1994	1995	1996	1997	1998
Net Value of Contract Awards	2,304.0	2,760.4	2,641.9	2,686.9	2,644.4	1,952.4	1,754.0	3,291.7	3,998.4	3,958.4
Percentage of NASA Total	21.2	22.0	20.1	19.9	20.1	15.1	13.1	25.9	31.3	31.5

Source: Annual Procurement Report.

Table 5-48. Kennedy Space Center In-House and Contractor-Held Property (at end of fiscal year; money amounts in thousands of dollars)

Category	1989	1990	1991	1992	1993	1994	1995	1996	1997	1998
In-House and Contractor-Held Property										
Land (acres)	82,943	82,943	82,943	82,943	82,943	82,943	82,943	82,943	82,822	139,490
Number of Buildings	577	580	606	607	610	617	556	614	338	339
Area of Buildings (square feet)	6,732,193	6,469,694	6,504,376	7,202,125	7,347,401	7,398,971	7,847,008	7,258,667	7,184,308	7,306,308
Value of In-House and Contractor-Held Property										
Land	71,345	71,345	71,345	71,345	73,672	73,672	73,672	73,672	73,672	73,672
Buildings	537,011	573,390	581,948	601,650	623,719	629,905	712,590	716,024	735,445	770,456
Other Structures and Facilities	526,058	514,922	523,547	535,505	550,494	568,601	588,486	616,991	628,015	629,405
Total Real Property Value	*1,134,414*	*1,159,657*	*1,176,840*	*1,208,500*	*1,247,885*	*1,272,178*	*1,374,748*	*1,406,687*	*1,437,132*	*1,473,533*
Capitalized Equipment Value	737,617	814,215	840,997	4,596,904	893,976	877,600	898,669	833,003	236,272	79,517
Special Tooling	—	—	—	—	—	—	—	—	—	1,239
Special Test Equipment	—	—	—	—	—	—	—	—	—	58,227

Source: Tables 5-4, 5-6, 5-7, 5-8, 5-9, 5-10, 5-11, 5-12. Also "Recorded Value of Capital Type Property In-House and Contractor-Held as of September 30, 1998."

Table 5-49. Kennedy Space Center Value of Real Property Components as a Percentage of Total (total real property value in thousands of dollars)

Component	1989	1990	1991	1992	1993	1994	1995	1996	1997	1998
Land	6.3	6.2	6.1	5.9	5.9	5.8	5.4	5.2	5.1	5.0
Buildings	47.3	49.4	49.5	49.8	50.0	49.5	51.8	50.9	51.2	52.3
Other Structures and Facilities	46.4	44.4	44.5	44.3	44.1	44.7	42.8	43.9	43.7	42.7
Total Real Property Value	*1,134,414*	*1,159,657*	*1,176,840*	*1,208,500*	*1,247,885*	*1,272,178*	*1,374,748*	*1,406,687*	*1,437,132*	*1,473,533*

Source: Table 5-48.

Table 5-50. Kennedy Space Center Personnel (at end of fiscal year)

Category	**1989**	**1990**	**1991**	**1992**	**1993**	**1994**	**1995**	**1996**	**1997**	**1998**
Permanent Employees[798]	2,423	2,466	2,571	2,555	2,513	2,364	2,208	2,113	1,894	1,749
Nonpermanent Employees	81	76	113	226	250	190	155	107	105	109
Total Employees	*2,504*	*2,542*	*2,684*	2,781	2,763	2,554	2,363	2,220	1,999	1,858
Occupational Code Groups (permanent only)										
200, 700, and 900	1,434	1,468	1,553	1,549	1,520	1,450	1,371	1,302	1,164	1,071
600	392	406	416	419	429	414	417	426	400	377
500	328	319	319	300	286	255	204	179	141	126
300	266	268	277	274	265	234	207	199	185	171
100	3	5	6	6	6	5	2	0	0	0
SES, Senior Technical, Excepted	33	34	32	31	30	28	25	24	27	28
Minority Full-Time Permanent Employees	302	322	364	376	380	387	380	367	344	322
Female Full-Time Permanent Employees	685	716	761	763	760	741	700	664	606	555

Source: FY 1989–FY 1991: The Civil Service Workforce, Office of Management, Office of Personnel Management; FY 1991 permanent-nonpermanent employee breakdown; FY 1992–FY 1998: NASA Workforce Data Cube, Historical Trends, *http://hqpowerplay.hq.nasa.gov/cognos/cgi-bin/ppdscgi.exe?E=/WF%20History%20Detail&LA=en&LO=en-us* (password required) (accessed April 29, 2007).

798 FY 1989–FY 1991: includes only full-time permanent employees. FY 1992–FY 1998: includes full- and part-time permanent employees.

Table 5-51. Kennedy Space Center Funding by Fiscal Year (in thousands of dollars)

Appropriation Title	1989	1990	1991	1992	1993	1994	1995	1996	1997	1998
Research and Development	112,020	150,278	210,292	269,752	—	—	—	—	—	—
Human Space Flight					1,250,200	1,125,200	1,024,560	935,249	281,400	303,458
Space Flight Control and Data Communications	824,200	857,300	923,700	1,081,700	—	—	—	—	—	—
Science, Aeronautics, and Technology	—	—	—	—	37,495	40,040	50,462	28,334	35,285	245,646
Research and Program Management	268,723	277,438	298,955	155,464	—	—	—	—	—	—
Construction of Facilities	24,571	60,602	66,633	61,078	—	—	—	—	—	—
Mission Support	—	—	—	—	277,030	278,806	257,364	251,359	246,440	248,364
Total	*1,229,514*	*1,345,618*	*1,499,580*	*1,567,295*	*1,564,725*	*1,444,046*	*1,332,386*	*1,214,942*	*563,125*	*797,468*

Source: "Summary of Budget Plans by Installation by Appropriation," NASA Budget Estimates.

Table 5-52. Kennedy Space Center Total Procurement Activity by Fiscal Year (in millions of dollars)

	1989	**1990**	**1991**	**1992**	**1993**	**1994**	**1995**	**1996**	**1997**	**1998**
Net Value of Contract Awards	1,179.5	1,275.9	1,409.7	1,484.6	1,415.4	1,315.0	1,257.2	1,090.8	446.3	454.7
Percentage of NASA Total	10.8	10.2	10.7	11.0	10.8	10.2	9.4	8.6	3.5	3.6

Source: Annual Procurement Report.

Table 5-53A. Langley Research Center In-House and Contractor-Held Property (at end of fiscal year; money amounts in thousands of dollars) (FY 1989–FY 1993)

Category	1989	1990	1991	1992	1993
In-House and Contractor-Held Property					
Land (acres)	787.6	787.6	787.6	787.6	787.6
Number of Buildings	179	183	184	182	205
Area of Buildings (square feet)	2,273,819	2,277,802	2,317,910	2,351,630	2,515,311
Value of In-House and Contractor-Held Property					
Land	156	156	156	156	156
Buildings	194,088	208,777	217,354	226,670	231,727
Other Structures and Facilities	392,941	401,795	420,093	438,879	436,112
Total Real Property Value	*587,185*	*610,728*	*637,603*	*665,705*	*667,995*
Capitalized Equipment Value	285,135	242,267	258,377	305,673	327,435
Special Tooling	—	—	—	—	—
Special Test Equipment	—	—	—	—	—
Agency-Peculiar Property	—	—	—	—	—

Source: Tables 5-4, 5-5, 5-6, 5-7, 5-9, 5-10, 5-11, 5-12.

Table 5-53B. Langley Research Center In-House and Contractor-Held Property (at end of fiscal year; money amounts in thousands of dollars) (FY 1994–FY 1998)

Category	1994	1995	1996	1997	1998
In-House and Contractor-Held Property					
Land (acres)	787.6	787.6	787.6	808	808
Number of Buildings	221	233	229	198	200
Area of Buildings (square feet)	2,526,402	2,596,035	2,593,110	3,380,269	3,382,202
Value of In-House and Contractor-Held Property					
Land	156	156	156	156	156
Buildings	248,527	258,007	269,534	275,852	246,866
Other Structures and Facilities	433,201	449,906	461,819	465,561	475,094
Total Real Property Value	*681,884*	*708,069*	*731,509*	*741,569*	*722,116*
Capitalized Equipment Value	350,737	345,652	347,699	373,152	133,033
Special Tooling	—	—	—	—	8,358
Special Test Equipment	—	—	—	—	3,524
Agency-Peculiar Property	—	—	—	—	1,972

Source: Tables 5-4, 5-5, 5-6, 5-7, 5-9, 5-10, 5-11, 5-12. Also “Recorded Value of Capital Type Property In-House and Contractor-Held as of September 30, 1998.”

Table 5-54. Langley Research Center Value of Real Property Components as a Percentage of Total (total real property value in thousands of dollars)

Component	**1989**	**1990**	**1991**	**1992**	**1993**	**1994**	**1995**	**1996**	**1997**	**1998**
Land	*	*	*	*	*	*	*	*	*	*
Buildings	33.1	34.2	34.1	34.0	34.7	36.4	36.4	36.8	37.2	34.2
Other Structures and Facilities	67.0	65.8	65.9	65.9	64.0	63.5	63.5	63.1	62.8	65.8
Total Real Property Value	*587,185*	*610,728*	*637,603*	*665,705*	*667,995*	*681,884*	*708,069*	*731,509*	*741,569*	*722,116*

* = Less than 0.05 percent.
Source: Table 5-53.

Table 5-55. Langley Research Center Personnel (at end of fiscal year)

Category	1989	1990	1991	1992	1993	1994	1995	1996	1997	1998
Permanent Employees[799]	2,864	2,961	2,969	2,975	2,879	2,802	2,520	2,489	2,423	2,259
Nonpermanent Employees	139	152	204	250	235	219	231	161	149	135
Total Employees	*3,003*	*3,113*	*3,173*	3,225	3,114	3,021	2,751	2,650	2,572	2,394
Occupational Code Groups (permanent only)										
200, 700, and 900	1,363	1,434	1,443	1,434	1,402	1,371	1,256	1,240	1,218	1,146
600	287	304	308	326	323	311	278	288	305	298
500	284	281	275	269	249	245	219	205	196	172
300	917	930	933	918	885	861	753	739	689	632
100	13	12	10	8	2	0	0	0	0	0
SES, Senior Technical, Excepted	34	39	40	46	52	45	44	44	49	42
Minority Full-Time Permanent Employees	380	410	418	440	436	438	432	428	418	401
Female Full-Time Permanent Employees	667	699	721	731	712	716	664	647	636	609

Source: FY 1989–FY 1991: The Civil Service Workforce, Office of Management, Office of Personnel Management; FY 1991 permanent-nonpermanent employee breakdown; FY 1992–FY 1998: NASA Workforce Data Cube, Historical Trends, *http://hqpowerplay.hq.nasa.gov/cognos/cgi-bin/ppdscgi.exe?E=/WF%20History%20Detail&LA=en&LO=en-us* (password required) (accessed April 29, 2007).

[799] FY 1989–FY 1991: includes only full-time permanent employees. FY 1992–FY 1998: includes full- and part-time permanent employees.

Table 5-56. Langley Research Center Funding by Fiscal Year (in thousands of dollars)

Appropriation Title	1989	1990	1991	1992	1993	1994	1995	1996	1997	1998
Research and Development	241,296	250,980	279,441	341,978						
Human Space Flight					3,400	1,600	1,521	5,167	8,700	7,352
Space Flight Control and Data Communications	14,300	3,800	330	201	—	—	—	—	—	—
Science, Aeronautics, and Technology	—	—	—	—	312,313	443,964	376,798	390,138	424,036	419,067
Research and Program Management	189,190	197,879	214,531	172,851	—	—	—	—	—	—
Construction of Facilities	29,217	25,515	33,955	31,355	—	—	—	—	—	—
Mission Support	—	—	—	—	227,885	229,256	227,805	212,500	220,279	226,182
Total	*474,003*	*478,174*	*528,257*	*546,385*	*543,598*	*674,820*	*606,124*	*607,805*	*653,015*	*651,601*

Source: "Summary of Budget Plans by Installation by Appropriation," NASA Budget Estimates.

Table 5-57. Langley Research Center Total Procurement Activity by Fiscal Year (in millions of dollars)

	1989	1990	1991	1992	1993	1994	1995	1996	1997	1998
Net Value of Contract Awards	384.0	399.7	404.6	436.0	436.1	507.0	528.9	489.3	544.7	501.4
Percentage of NASA Total	3.5	3.2	3.1	3.2	3.3	3.9	4.0	3.9	4.3	4.0

Source: Annual Procurement Report.

Table 5-58A. Lewis Research Center In-House and Contractor-Held Property (at end of fiscal year; money amounts in thousands of dollars) (FY 1989–FY 1993)

Category	1989	1990	1991	1992	1993
In-House and Contractor-Held Property					
Land (acres)	6,804.8[800]	6,804.8	6,804.8	6,804.8	6,804.8
Number of Buildings	258	262	262	261	261
Area of Buildings (square feet)	3,212,305	3,289,763	3,296,491	3,280,853	3,302,583
Value of In-House and Contractor-Held Property					
Land	2,621	2,621	2,621	2,621	2,621
Buildings	237,506	245,394	277,420	291,986	305,940
Other Structures and Facilities	92,575	92,651	105,741	110,702	112,579
Leasehold Improvements	136	136	136	136	136
Total Real Property Value	*332,838*	*340,666*	*385,782*	*405,309*	*421,140*
Capitalized Equipment Value	182,863	210,896	222,056	246,020	263,969
Special Tooling	—	—	—	—	—
Special Test Equipment	—	—	—	—	—
Agency-Peculiar Property	—	—	—	—	—

Source: Tables 5-4, 5-5, 5-6, 5-7, 5-9, 5-10, 5-11, 5-12.

[800] Includes Lewis Research Center, Cleveland, OH, and Plum Brook Operating Division, Sandusky, OH.

Table 5-58B. Lewis Research Center In-House and Contractor-Held Property (at end of fiscal year; money amounts in thousands of dollars) (FY 1994–FY 1998)

Category	1994	1995	1996	1997	1998
In-House and Contractor-Held Property					
Land (acres)	6,804.8	6,804.8	6,804.8	7,120.0	7,120.0
Number of Buildings	261	262	262	249	249
Area of Buildings (square feet)	3,302,583	3,357,111	3,357,111	3,328,834	3,284,198
Value of In-House and Contractor-Held Property					
Land	2,621	2,621	2,621	2,621	2,621
Buildings	334,673	349,173	350,122	353,262	316,978
Other Structures and Facilities	120,284	123,233	124,556	124,695	102,480
Leasehold Improvements	136	136	136	136	136
Total Real Property Value	*457,578*	*475,027*	*477,299*	*480,578*	*422,215*
Capitalized Equipment Value	267,542	270,076	276,212	273,239	73,461
Special Tooling	—	—	—	—	1,308
Special Test Equipment	—	—	—	—	894
Agency-Peculiar Property	—	—	—	—	7,530

Source: Tables 5-4, 5-5, 5-6, 5-7, 5-9, 5-10, 5-11, 5-12. Also “Recorded Value of Capital Type Property In-House and Contractor-Held as of September 30, 1998.”

Table 5-59. Lewis Research Center Value of Real Property Components as a Percentage of Total (total real property value in thousands of dollars)

Component	**1989**	**1990**	**1991**	**1992**	**1993**	**1994**	**1995**	**1996**	**1997**	**1998**
Land	0.8	0.8	0.7	0.4	0.6	0.6	0.6	0.5	0.5	0.6
Buildings	71.4	72.0	71.9	72.0	72.6	73.1	73.5	73.3	73.5	75.1
Other Structures and Facilities	27.8	27.2	27.4	27.4	26.7	26.3	25.9	26.1	25.9	24.3
Total Real Property Value	*332,702*	*340,802*	*385,918*	*405,445*	*421,276*	*457,714*	*475,163*	*477,435*	*480,714*	*420,079*

Source: Table 5-58.

Table 5-60. Lewis Research Center Personnel (at end of fiscal year)

Category	1989	1990	1991	1992	1993	1994	1995	1996	1997	1998
Permanent Employees[801]	2,749	2,728	2,835	2,861	2,799	2,522	2,324	2,264	2,123	1,998
Nonpermanent Employees	83	92	106	83	44	61	46	35	41	46
Total Employees	*2,832*	*2,820*	*2,941*	2,944	2,843	2,583	2,370	2,299	2,164	2,044
Occupational Code Groups (permanent only)										
200, 700, and 900	1,509	1,500	1,612	1,592	1,550	1,401	1,309	1,263	1,169	1,099
600	270	284	301	315	325	296	271	296	294	280
500	258	243	237	224	208	183	159	142	118	104
300	234	297	327	337	349	315	287	290	274	252
100	478	404	358	329	301	260	235	214	206	202
Not Classified	—	—	—	—	0	1	7	7	0	0
SES, Senior Technical, Excepted	38	39	45	46	47	34	25	24	28	38
Minority Full-Time Permanent Employees	358	381	456	475	467	456	442	430	407	396
Female Full-Time Permanent Employees	561	572	615	621	613	559	519	513	484	462

Source: FY 1989–FY 1991: The Civil Service Workforce, Office of Management, Office of Personnel Management; FY 1991 permanent-nonpermanent employee breakdown; FY 1992–FY 1998: NASA Workforce Data Cube, Historical Trends, *http://hqpowerplay.hq.nasa.gov/cognos/cgi-bin/ppdscgi.exe?E=/WF%20History%20Detail&LA=en&LO=en-us* (password required) (accessed April 29, 2007).

[801] FY 1989–FY 1991: includes only full-time permanent employees. FY 1992–FY 1998: includes full- and part-time permanent employees.

Table 5-61. Lewis Research Center Funding by Fiscal Year (in thousands of dollars)

Appropriation Title	1989	1990	1991	1992	1993	1994	1995	1996	1997	1998
Research and Development	389,314	497,888	554,493	679,608	—	—	—	—	—	—
Human Space Flight	—	—	—	—	364,200	132,300	17,500	44,136	20,299	31,350
Space Flight Control and Data Communications	11,000	56,400	122,760	46,500	—	—	—	—	—	—
Science, Aeronautics, and Technology	—	—	—	—	388,804	557,467	497,670	428,097	472,620	374,334
Research and Program Management	196,188	206,006	230,060	172,326	—	—	—	—	—	—
Construction of Facilities	26,683	33,804	43,262	22,765	—	—	—	—	—	—
Mission Support	—	—	—	—	249,629	240,281	221,675	222,192	234,938	261,368
Total	*623,185*	*794,098*	*950,575*	*939,399*	*1,002,633*	*930,048*	*736,845*	*694,425*	*727,857*	*667,052*

Source: "Summary of Budget Plans by Installation by Appropriation," NASA Budget Estimates.

Table 5-62. Lewis Research Center Total Procurement Activity by Fiscal Year (in millions of dollars)

	1989	**1990**	**1991**	**1992**	**1993**	**1994**	**1995**	**1996**	**1997**	**1998**
Net Value of Contract Awards	542.5	686.5	812.4	831.6	873.5	776.5	759.2	635.9	592.9	583.5
Percentage of NASA Total	5.0	5.5	6.2	6.2	6.6	6.0	5.7	5.0	4.6	4.7

Source: Annual Procurement Report.

Table 5-63A. Marshall Space Flight Center In-House and Contractor-Held Property (at end of fiscal year; money amounts in thousands of dollars) (FY 1989–FY 1993)

Category	1989	1990	1991	1992	1993
In-House and Contractor-Held Property					
Land (acres)	1,255.9[802]	1,255.9	2,553.4[803]	2.553.4	2,553.4
Number of Buildings	253	255	284	308	319
Area of Buildings (square feet)	7,682,590	7,480,931	8,178,360	8,245,165	8,294,171
Value of In-House and Contractor-Held Property					
Land	7,171	7,171	10,942	11,093	11,093
Buildings	306,669	311,288	331,079	342,013	369,289
Other Structures and Facilities	163,753	176,005	177,747	198,621	202,848
Total Real Property Value	*477,593*	*494,464*	*519,768*	*551,727*	*583,230*
Capitalized Equipment Value	523,260	563,179	701,871	783,945	788,983
Special Tooling	—	—	—	—	—
Special Test Equipment	—	—	—	—	—
Agency-Peculiar Property	—	—	—	—	—

Source: Tables 5-4, 5-5, 5-6, 5-7, 5-9, 5-10, 5-11, 5-12.

[802] Includes Marshall Space Flight Center, Huntsville, AL; Michoud Assembly Facility, New Orleans, LA; and Slidell Computer Complex, Slidell, LA.
[803] Reflects the addition of the Yellow Creek Facility, Iuka, MS.

Table 5-63B. Marshall Space Flight Center In-House and Contractor-Held Property (at end of fiscal year; money amounts in thousands of dollars) (FY 1994–FY 1998)

Category	1994	1995	1996	1997	1998
In-House and Contractor-Held Property					
Land (acres)	2,553.4	2,539.4	1,241.9	2,715	2,715
Number of Buildings	334	277	237	223	226
Area of Buildings (square feet)	9,478,586	9,397,886	8,059,942 [804]	7,789,619	7,828,631
Value of In-House and Contractor-Held Property					
Land	11,093	11,024 [805]	7,162 [806]	7,162	7,162
Buildings	496,079	481,868	402,248	412,990	413,481
Other Structures and Facilities	248,696	249,724	209,167	209,754	154,280
Total Real Property Value	*755,868*	*742,616*	*618,577*	*629,906*	*574,923*
Capitalized Equipment Value	812,048	803,338	781,813	772,503	381,134
Special Tooling	—	—	—	—	278,335
Special Test Equipment	—	—	—	—	98,826
Agency-Peculiar Property	—	—	—	—	570,179

Source: Tables 5-4, 5-5, 5-6, 5-7, 5-9, 5-10, 5-11, 5-12. Also “Recorded Value of Capital Type Property In-House and Contractor-Held as of September 30, 1998.”

[804] Reflects the closure of the Yellow Creek Facility.
[805] Slidell Computer Complex was transferred to the city of Slidell, LA, on December 14, 1994.
[806] Decrease reflects the transfer of the Yellow Creek Facility to the state of Mississippi in accordance with Public Law 104-99, *Making Appropriations for Fiscal Year 1996 To Make a Down Payment Toward a Balanced Budget, and for Other Purposes*, 104th Congress, 2nd session, January 26, 1996.

Table 5-64. Marshall Space Flight Center Value of Real Property Components as a Percentage of Total (total real property value in thousands of dollars)

Component	1989	1990	1991	1992	1993	1994	1995	1996	1997	1998
Land	1.5	1.5	2.1	2.0	1.9	1.5	1.5	1.2	1.1	1.2
Buildings	64.2	63.1	73.7	62.0	63.3	65.6	64.9	65.0	65.6	71.9
Other Structures and Facilities	34.3	35.6	34.2	36.0	36.8	32.9	33.6	33.8	33.3	26.8
Total Real Property Value	*477,593*	*494,464*	*519,768*	*551,727*	*583,230*	*755,868*	*742,616*	*618,577*	*629,906*	*577,923*

Source: Table 5-63.

Table 5-65. Marshall Space Flight Center Personnel (at end of fiscal year)

Category	1989	1990	1991	1992	1993	1994	1995	1996	1997	1998
Permanent Employees[807]	3,609	3,619	3,788	3,739	3,653	3,325	3,123	3,086	2,888	2,727
Nonpermanent Employees	94	115	190	237	221	140	99	59	62	66
Total Employees	*3,703*	*3,734*	*3,978*	3,976	3,874	3,465	3,222	3,145	2,950	2,793
Occupational Code Groups (permanent only)										
200, 700, and 900	2,351	2,376	2,514	2,462	2,410	2,236	2,117	2,101	1,968	1,854
600	597	605	620	629	626	568	531	546	517	510
500	481	466	476	452	421	353	320	295	265	233
300	180	172	178	178	176	157	145	136	130	122
100	0	0	0	0	0	0	0	0	0	0
SES, Senior Technical, Excepted	51	56	61	61	67	62	60	59	60	58
Minority Full-Time Permanent Employees	382	396	435	438	436	434	437	430	426	420
Female Full-Time Permanent Employees	1,101	1,138	1,226	1,216	1,178	1,101	1,057	1,042	983	931

Source: FY 1989–FY 1991: The Civil Service Workforce, Office of Management, Office of Personnel Management; FY 1991 permanent-nonpermanent employee breakdown; FY 1992–FY 1998: NASA Workforce Data Cube, Historical Trends, *http://hqpowerplay.hq.nasa.gov/cognos/cgi-bin/ppdscgi.exe?E=/WF%20History%20Detail&LA=en&LO=en-us* (password required) (accessed April 29, 2007).

[807] FY 1989–FY 1991: includes only full-time permanent employees. FY 1992–FY 1998: includes full- and part-time permanent employees.

Table 5-66. Marshall Space Flight Center Funding by Fiscal Year (in thousands of dollars)

Appropriation Title	1989	1990	1991	1992	1993	1994	1995	1996	1997	1998
Research and Development	946,419	960,375	966,059	962,507	—	—	—	—	—	—
Human Space Flight					2,316,600	1,887,100	1,537,508	1,502,684	1,463,046	1,263,768
Space Flight Control and Data Communications	1,760,400	1,677,138	1,937,275	1,678,301	—	—	—	—	—	—
Science, Aeronautics, and Technology	—	—	—	—	412,920	518,889	612,523	609,852	713,427	686,553
Research and Program Management	253,417	269,267	286,155	231,657	—	—	—	—	—	—
Construction of Facilities	37,269	30,629	63,671	56,459	—	—	—	—	—	—
Mission Support	—	—	—	—	375,132	432,584	378,722	353,140	378,707	379,988
Total	*2,997,505*	*2,937,409*	*3,253,160*	*3,144,023*	*3,104,652*	*2,838,573*	*2,528,753*	*2,465,676*	*2,555,180*	*2,330,309*

Source: “Summary of Budget Plans by Installation by Appropriation,” NASA Budget Estimates.

Table 5-67. Marshall Space Flight Center Total Procurement Activity by Fiscal Year (in millions of dollars)

	1989	1990	1991	1992	1993	1994	1995	1996	1997	1998
Net Value of Contract Awards	2,649.4	3,154.6	3,124.8	3,234.1	3,001.8	2,493.2	2,501.8	2,234.9	2,321.3	2,075.4
Percentage of NASA Total	24.4	25.1	23.7	24.0	22.8	19.3	18.8	17.6	18.1	16.5

Source: Annual Procurement Report.

Table 5-68. Stennis Space Center In-House and Contractor-Held Property (at end of fiscal year; money amounts in thousands of dollars)

Category	1989	1990	1991	1992	1993	1994	1995	1996	1997	1998
In-House and Contractor-Held Property										
Land (acres)	20,642.2	20,642.2	20,642.2	20,642.2	20,662.7	20,662.7	20,662.7	20,662.7	20,355	20,355
Number of Buildings	121	125	132	141	127	125	125	115	106	109
Area of Buildings (square feet)	1,556,143	1,603,125	1,645,885	1,679,828	1,742,371	1,757,198	1,785,272	1,781,278	1,703,553	1,018,026
Value of In-House and Contractor-Held Property										
Land	18,061	18,061	18,061	18,061	18,080	18,080	18,080	18,080	18,080	18,080
Buildings	104,698	109,043	113,632	117,922	130,796	134,730	136,632	137,664	141,583	144,215
Other Structures and Facilities	207,504	224,901	231,711	233,016	234,251	244,950	249,452	264,340	265,701	137,874
Total Real Property Value	*330,263*	*352,005*	*363,404*	*368,999*	*383,127*	*397,760*	*404,164*	*420,084*	*425,364*	*300,169*
Capitalized Equipment Value	32,812	3,697,072	4,081,665	8,069,808	4,561,020	8,258,033	4,793,484	4,955,842	4,987,438	29,467

Source: Tables 5-4, 5-5, 5-6, 5-7, 5-9, 5-10, 5-11, 5-12. Also “Recorded Value of Capital Type Property In-House and Contractor-Held as of September 30, 1998.”

Table 5-69. Stennis Space Center Value of Real Property Components as a Percentage of Total (total real property value in thousands of dollars)

Component	1989	1990	1991	1992	1993	1994	1995	1996	1997	1998
Land	5.5	5.1	5.0	4.9	4.7	4.5	4.5	4.3	4.3	6.0
Buildings	31.7	31.0	31.3	32.0	34.1	33.9	33.8	32.8	33.3	48.0
Other Structures and Facilities	62.8	63.9	63.8	63.1	61.1	61.6	65.4	62.9	62.5	45.9
Total Real Property Value	*330,263*	*352,005*	*363,404*	*368,999*	*383,127*	*397,760*	*404,164*	*420,084*	*425,364*	*300,169*

Source: Table 5-68.

Table 5-70. Stennis Space Center Personnel (at end of fiscal year)

Category	1989	1990	1991	1992	1993	1994	1995	1996	1997	1998
Permanent Employees[808]	183	192	222	223	207	213	207	202	216	214
Nonpermanent Employees	20	14	17	16	28	28	18	21	31	36
Total Employees	*203*	*206*	*239*	239	235	241	225	223	247	250
Occupational Code Groups (permanent only)										
200, 700, and 900	98	103	128	124	117	118	117	117	132	134
600	52	55	55	55	52	52	50	51	54	56
500	31	32	37	35	31	33	35	29	25	21
300	2	2	2	2	2	2	2	2	3	2
100	0	0	0	0	0	0	0	0	0	0
SES, Senior Technical, Excepted	6	6	6	7	7	4	6	6	6	4
Minority Full-Time Permanent Employees	22	23	27	26	25	29	30	31	34	32
Female Full-Time Permanent Employees	60	63	74	73	68	72	80	75	73	71

Source: FY 1989–FY 1991: The Civil Service Workforce, Office of Management, Office of Personnel Management; FY 1991 permanent-nonpermanent employee breakdown; FY 1992–FY 1998: NASA Workforce Data Cube, Historical Trends, *http://hqpowerplay.hq.nasa.gov/cognos/cgi-bin/ppdscgi.exe?E=/WF%20History%20Detail&LA=en&LO=en-us* (password required) (accessed April 29, 2007).

[808] FY 1989–FY 1991: includes only full-time permanent employees. FY 1992–FY 1998: includes full- and part-time permanent employees.

Table 5-71. Stennis Space Center Funding by Fiscal Year (in thousands of dollars)

Appropriation Title	1989	1990	1991	1992	1993	1994	1995	1996	1997	1998
Research and Development	16,303	12,176	16,540	24,069	—	—	—	—	—	—
Human Space Flight	—	—	—	—	41,000	39,500	51,200	53,300	52,200	47,216
Space Flight Control and Data Communications	21,300	26,900	24,600	37,600	—	—	—	—	—	—
Science, Aeronautics, and Technology	—	—	—	—	8,691	10,559	20,015	69,067	87,930	60,890
Research and Program Management	23,526	25,137	28,536	14,264	—	—	—	—	—	—
Construction of Facilities	21,045	11,843	25,595	16,786	—	—	—	—	—	—
Mission Support	—	—	—	—	35,374	40,677	35,795	39,295	48,562	49,637
Total	*82,174*	*76,056*	*95,271*	*96,319*	*85,065*	*90,736*	*107,010*	*161,662*	*188,692*	*157,743*

Source: "Summary of Budget Plans by Installation by Appropriation," NASA Budget Estimates.

Table 5-72. Stennis Space Center Total Procurement Activity by Fiscal Year (in millions of dollars)

	1989	**1990**	**1991**	**1992**	**1993**	**1994**	**1995**	**1996**	**1997**	**1998**
Net Value of Contract Awards	96.4	112.6	113.0	120.4	109.0	120.2	128.5	143.3	169.5	224.6
Percentage of NASA Total	0.0	0.9	0.0	0.9	0.8	0.9	1.0	1.1	1.3	1.8

Source: Annual Procurement Report.

Chapter 6

Table 6-1. Total Permanent and Non-Permanent Workforce (at end of fiscal year)

Personnel	1989	1990	1991	1992	1993	1994	1995	1996	1997	1998
Civil Service (Permanent and Non-Permanent)	23,893	24,873	25,736	26,146	25,584	23,938	22,233	21,508	20,238	19,272
Full-Time Permanent	23,019	23,625	24,416	24,059	23,567	22,288	20,720	20,155	18,853	17,754
Non-Permanent[809]	874	1,248	1,320	2,087	2,017	1,650	1,513	1,353	1,385	1,518
Net Change Permanent and Non-Permanent	1,070	980	863	410	–562	–1,646	–1,705	–725	–1,270	–966
Percentage Change, Full- and Part-Time Permanent	4.7	4.1	3.5	1.6	–2.1	–6.4	–7.1	–3.3	–5.9	–4.8
Net Change Full-Time Permanent	1,028	606	791	–357	–492	–1,279	–1,568	–565	–1,302	–1,099
Percentage Change Full-Time Permanent	4.7	2.6	3.3	–1.5	–2.0	–5.4	–7.0	–2.7	–6.5	–5.8

Source: FY 1989–FY 1991, Civil Service Workforce Reports; FY 1992–FY 1998, Workforce Data Cube, *http://hqpowerplay.hq.nasa.gov/cognos/cgi-bin/ppdscgi.exe?E=/WF%20History%20Detail&LA=en&LO=en-us* (accessed April 24, 2007).

[809] Includes part-time permanent, term appointment, student, and other non-permanent employees.

Table 6-2. Accessions and Separations of Full-Time Permanent Employees and Percentage Change (at end of fiscal year)

Activity of Employee	1989	1990	1991	1992	1993[810]	1994	1995	1996	1997	1998
Accessions[811]	2,735	2,062	2,130	757	396	656	445	103	165	208
Separations	1,695	1,459	1,327	982	815	1,989	1,985	660	1,420	1,307
Net Accessions	1,040	603	803	–225	–419	–1,333	–1,540	–557	–1,255	–1,099
Percentage Change	4.5	2.6	3.4	–0.9	–1.7	–5.7	–7.0	–2.7	–6.2	–5.8

Source: FY 1989–FY 1991, Civil Service Workforce Reports; FY 1992–FY 1998, Workforce Data Cube.

[810] FY 1992–FY 1998 from Hires and Losses portions of public NASA workforce data cube, *http://hqpowerplay.hq.nasa.gov/workforce/moredata.html* (accessed April 5, 2007).
[811] Includes all full-time permanent gains and conversions.

Table 6-3. Buyouts, FY 1994–FY 1998 (at end of fiscal year)

NASA Center	FY 1994	FY 1995	FY 1996	FY 1997	FY 1998	Center Total
Ames Research Center	48	118	1	36	96	299
Dryden Flight Research Center	0	57	0	0	0	57
Goddard Space Flight Center	81	297	1	144	146	669
Headquarters	174	133	3	158	66	534
Johnson Space Center	223	160	2	140	145	670
Kennedy Space Center	163	182	0	192	154	691
Langley Research Center	55	282	1	34	135	507
Lewis Research Center	199	187	1	107	98	592
Marshall Space Flight Center	344	220	3	203	158	928
Stennis Space Center	4	13	0	5	12	34
Office of Inspector General	7	5	0	0	0	12
Total	*1,298*	*1,654*	*12*	*1,019*	*1,010*	*4,993*

Source: "Buyouts," NASA Data Cube, *http://hqpowerplay.hq.nasa.gov/workforce/moredata.html* (accessed December 5, 2006).

Table 6-4. Permanent Full-Time Employees by NASA Occupational Code Group: Number on Board (at end of fiscal year)

Occupational Code Group	1989	1990	1991	1992	1993	1994	1995	1996	1997	1998
200, 700, 900 (Scientists/Engineer)	12,775	13,131	13,694	13,574	13,354	12,767	12,066	11,746	11,059	10,453
Percentage of NASA Total	55.5	55.6	56.1	56.4	56.7	57.3	58.2	58.3	58.7	58.9
600 (Professional Admin.)	4,085	4,366	4,579	4,547	4,541	4,309	4,063	4,042	3,853	3,737
Percentage of NASA Total	17.7	18.5	18.8	18.9	19.3	19.3	19.6	20.1	20.4	21.0
Total Professional	*16,860*	*17,497*	*18,273*	*18,121*	*18,029*	*17,188*	*16,254*	*15,896*	*15,023*	*14,325*
Percentage of NASA Total	*73.2*	*74.1*	*74.8*	*75.3*	*76.5*	*77.1*	*78.4*	*78.9*	*79.7*	*80.7*
300 (Technical Support)	2,401	2,446	2,494	2468	2,421	2,301	2,025	1,999	1,888	1,777
Percentage of NASA Total	10.4	10.4	10.2	10.3	10.3	10.3	9.8	9.9	10.0	10.0
500 (Clerical)	2,852	2,852	2,881	2,760	2,601	2,357	2,079	1,931	1,656	1,431
Percentage of NASA Total	12.4	12.1	11.8	11.5	11.0	10.6	10.0	9.6	8.8	8.1
100 (Wage)	906	830	768	710	650	554	487	437	397	356
Percentage of NASA Total	3.9	3.5	3.1	3.0	2.8	2.5	2.4	2.2	2.1	2.0
Total	*23,019*	*23,625*	*24,416*	*24,059*	*23,567*	*22,288*	*20,720*	*20,155*	*18,853*	*17,754*

Source: FY 1989–FY 1991, Civil Service Workforce Reports; FY 1992–FY 1998, Workforce Data Cube.

Table 6-5. Average Annual Salaries of Full-Time Permanent Employees by Pay Plan and Percentage Change from Previous Year (at end of fiscal year)

	1989	1990	1991	1992	1993	1994	1995	1996	1997	1998
GS	42,419	44,286	46,687	49,628	52,486	54,894	57,273	59,755	62,720	65,237
Percentage Change From Preceding Year	3.6	4.4	5.4	6.3	5.8	4.6	4.3	4.3	5.0	4.0
Executive[812]	76,651	79,287	99,986	—	—	—	—	—	—	—
Percentage Change From Preceding Year	4.2	3.4	26.1	—	—	—	—	—	—	—
SES[813]	—	—	—	104,141	107,508	111,595	111,927	114,248	116,828	118,781
Percentage Change From Preceding Year	—	—	—	—	3.2	3.8	0.3	2.1	2.3	1.7
Senior Technical[814]	—	—	—	90,537	93,609	98,387	100,472	103,852	106,956	110,563
Percentage Change From Preceding Year	—	—	—	—	3.4	5.1	2.1	3.4	3.0	3.4
NASA Excepted	—	—	—	95,970	92,075	97,309	89,658	90,902	90,604	90,644
Percentage Change From Preceding Year	—	—	—	—	–4.1	5.7	–7.9	1.4	–0.3	0
Average of Total White Collar[815]	43,226	45,135	48,078	51,079	53,979	56,358	58,687	61,143	64,056	66,627
Percentage Change From Preceding Year	3.6	4.4	6.5	6.2	5.7	4.4	4.1	4.2	4.8	4.0

[812] Aggregate of SES, Senior Technical, and NASA Excepted.
[813] Began using SES rather than Executive pay plan beginning with FY 1992.
[814] Began using Senior Technical rather than Executive beginning with FY 1992.
[815] Includes all pay plans except blue collar (wage system).

	1989	1990	1991	1992	1993	1994	1995	1996	1997	1998
Total Blue Collar (Wage Grade)	32,510	33,230	34,261	35,997	37,802	39,189	40,584	41,826	43,323	44,517
Percentage Change From Preceding Year	5.3	2.2	3.1	5.1	5.0	3.7	3.6	3.1	3.6	2.8
Other Pay Plans	—[816]	—	—	116,779	121,179	120,886	121,399	121,542	121,930	124,829
Average All NASA	*42,804*	*44,717*	*47,643*	*50,628*	*53,528*	*55,924*	*58,253*	*60,715*	*63,610*	*66,173*
Percentage Change From Preceding Year	*3.9*	*4.5*	*6.5*	*6.3*	*5.7*	*4.5*	*4.2*	*4.2*	*4.8*	*4.0*

Source: FY 1989–FY 1991, Civil Service Workforce Reports; FY 1992–FY 1998, Workforce Data Cube.

[816] “Other pay plans” were not included in FY 1989–FY 1991 Civil Service Workforce Reports.

Table 6-6. Educational Profile of Full-Time Permanent Employees: Number on Board (at end of fiscal year)

Educational Level	1989	1990	1991	1992	1993	1994	1995	1996	1997	1998
Doctorate	1,649	1,725	1,821	1,717	1,739	1,694	1,654	1,641	1,638	1,612
Master's or Equivalent	4,025	4,251	4,483	4,677	4,727	4,578	4,373	4,397	4,273	4,074
Bachelor's	9,971	10,251	10,699	10,455	10,156	9,666	9,033	8,627	7,899	7,395
Associate	1,179	1,265	1,372	1,298	1,274	1,274	1,244	1,194	1,142	1,095
High School (no degree)	6,195	6,133	6,041	5,912	5,671	5,076	4,416	4,296	3,901	3,578
Total Degreed Employees[817]	*16,824*	*17,492*	*18,375*	*18,147*	*17,896*	*17,212*	*16,304*	*15,859*	*14,952*	*14,176*

Source: FY 1989–FY 1991, Civil Service Workforce Reports; FY 1992–FY 1998, Workforce Data Cube.

[817] Includes employees with associate degree.

Table 6-7. Educational Profile of Full-Time Permanent Employees: Percentage (at end of fiscal year)

Educational Level	1989	1990	1991	1992	1993	1994	1995	1996	1997	1998
Doctorate	7.2	7.3	7.5	7.1	7.4	7.6	8.0	8.1	8.7	9.1
Master's or Equivalent	17.5	18.0	18.4	19.4	20.1	20.5	21.1	21.8	22.7	22.9
Bachelor's	43.3	43.4	43.8	43.5	43.1	43.4	43.6	42.8	41.9	41.7
Associate	5.1	5.4	5.6	5.4	5.4	5.7	6.0	5.9	6.1	6.2
High School (no degree)	26.9	26.0	24.7	24.6	24.1	22.8	21.3	21.3	20.7	20.2
Total Degreed Employees[818]	*73.1*	*71.2*	*75.3*	*75.4*	*75.9*	*77.2*	*78.7*	*78.7*	*79.3*	*79.8*

Source: Tables 6-1 and 6-6.

[818] Includes employees with associate degree.

Table 6-8. Paid Employees by NASA Installation: Number on Board (Permanent and Other) (at end of fiscal year)

Installation	1989	1990	1991	1992	1993	1994	1995	1996	1997	1998
Ames Research Center	2,217	2,279	2,406	2,442	2,378	1,804	1,676	1,601	1,544	1,504
Dryden Flight Research Center[819]	—	—	—	—	—	494	472	497	575	592
Goddard Space Flight Center	3,860	3,992	4,169	4,204	4,161	4,040	3,713	3,637	3,518	3,344
Johnson Space Center	3,704	3,727	3,851	3,919	3,921	3,746	3,584	3,545	3,351	3,240
Kennedy Space Center	2,504	2,542	2,684	2,781	2,763	2,554	2,363	2,220	1,999	1,858
Langley Research Center	3,003	3,113	3,173	3,225	3,114	3,021	2,751	2,650	2,572	2,394
Lewis Research Center	2,832	2,820	2,941	2,944	2,843	2,583	2,370	2,299	2,164	2,044
Marshall Space Flight Center	3,703	3,734	3,978	3,976	3,874	3,465	3,222	3,145	2,950	2,793
Stennis Space Center	203	206	239	239	235	241	225	223	247	250
Headquarters	1,867	2,153	2,295	2,416	2,295	1,990	1,857	1,691	1,318	1,253
Total	*23,893*	*22,287*	*25,736*	*26,146*	*25,584*	*23,938*	*22,233*	*21,508*	*20,238*	*19,272*

Source: FY 1989–FY 1991, Civil Service Workforce Reports and Workforce Books in Office of Human Resources; FY 1992–FY 1998, Workforce Data Cube.

[819] FY 1989–FY 1993: Dryden figures included with Ames Research Center.

Table 6-9. Paid Employees by NASA Installation: Percentage of NASA Total (Permanent and Other) (at end of fiscal year)

Installation	**1989**	**1990**	**1991**	**1992**	**1993**	**1994**	**1995**	**1996**	**1997**	**1998**
Ames Research Center	9.3	9.3	9.4	9.3	9.3	7.5	7.5	7.4	7.6	7.8
Dryden Flight Research Center[820]	—	—	—	—	—	2.1	2.1	2.3	2.8	3.1
Goddard Space Flight Center	16.2	16.3	16.2	16.2	16.3	16.9	16.7	16.9	17.4	17.4
Johnson Space Center	15.5	15.2	15.0	14.9	15.3	15.6	16.1	16.5	16.6	16.8
Kennedy Space Center	10.5	10.3	10.4	10.4	10.8	10.7	10.6	10.3	9.9	9.6
Langley Research Center	12.6	12.7	12.3	12.3	12.2	12.6	12.4	12.3	12.7	12.4
Lewis Research Center	11.9	11.5	11.4	11.4	11.1	10.8	10.7	10.7	10.7	10.6
Marshall Space Flight Center	15.5	15.2	15.5	15.1	15.1	14.5	14.5	14.6	14.6	14.5
Stennis Space Center	0.8	0.8	0.9	0.9	0.9	1.0	1.0	1.0	1.2	1.3
Headquarters	7.8	8.8	8.9	9.4	9.0	8.3	8.4	7.9	6.5	6.5
Total	*100.0*	*100.0*	*100.0*	*100.0*	*100.0*	*100.0*	*100.0*	*99.9*	*100.0*	*100.0*

Source: FY 1989–FY 1991, Civil Service Workforce Reports and Workforce Books in Office of Human Resources; FY 1992–FY 1998, Workforce Data.

[820] FY 1989–FY 1993: included with Ames Research Center.

Table 6-10. Paid Employees by NASA Installation: Changes in Number on Board (Permanent and Other)

Installation	1989	1990	1991 [821]	1992	1993	1994	1995	1996	1997	1998	Total
Ames Research Center[822]	48	62	127	36	–64	–574	–128	–75	–57	–40	–665
Dryden Flight Research Center[823]	—	—	—	—	—	494	–22	25	78	17	592
Goddard Space Flight Center	133	132	177	35	–43	–121	–327	–76	–119	–174	–383
Johnson Space Center	206	23	124	68	2	–175	–162	–39	–194	–111	–258
Kennedy Space Center	174	38	142	97	–18	–209	–191	–143	–221	–141	–472
Langley Research Center	37	110	60	52	–111	–93	–270	–101	–78	–178	–572
Lewis Research Center	116	–12	121	3	–101	–260	–213	–71	–135	–120	–672
Marshall Space Flight Center	274	31	244	–2	–102	–409	–243	–77	–195	–157	–636
Stennis Space Center	44	3	33	0	–4	6	–16	–2	24	3	91
Headquarters	38	286	142	121	–121	–305	–133	–166	–373	–65	–576
Total	*1,070*	*673*	*1,170*	*410*	*–562*	*–1,646*	*–1,705*	*–725*	*–1,270*	*–966*	*–3,551*

Source: Table 6-8.

[821] FY 1991 total employees available from Agency-Wide Workforce Reports BPD700002/AM-220-01, p. 1000.
[822] FY 1989–FY 1993: Includes Dryden employees.
[823] FY 1989–FY 1993: Dryden figures included with Ames Research Center.

Table 6-11. Full-Time Permanent Employees by NASA Installation: Number on Board (at end of fiscal year)

Installation	1989	1990	1991	1992	1993	1994	1995	1996	1997	1998
Ames Research Center	2,151	2,205	2,263	2,246	2,178	1,706	1,567	1,497	1,407	1,316
Dryden Flight Research Center[824]	—	—	—	—	—	442	429	449	475	504
Goddard Space Flight Center	3,735	3,873	3,999	3,973	3,930	3,835	3,556	3,482	3,371	3,173
Johnson Space Center	3,578	3,615	3,677	3,633	3,622	3,530	3,400	3,344	3,130	2,966
Kennedy Space Center	2,423	2,466	2,571	2,548	2,506	2,358	2,201	2,106	1,890	1,745
Langley Research Center	2,864	2,961	2,969	2,955	2,861	2,788	2,506	2,472	2,408	2,248
Lewis Research Center	2,749	2,728	2,835	2,797	2,733	2,455	2,261	2,205	2,061	1,937
Marshall Space Flight Center	3,609	3,619	3,788	3,721	3,633	3,314	3,113	3,078	2,880	2,719
Stennis Space Center	183	192	222	216	202	205	204	199	214	213
Headquarters	1,727	1,966	2,092	1,970	1,902	1,655	1,483	1,323	1,017	933
Total	*23,019*	*23,625*	*24,416*	*24,059*	*23,567*	*22,288*	*20,720*	*20,155*	*18,853*	*17,754*

Source: FY 1989–FY 1991, Civil Service Workforce Reports; FY 1992–FY 1998, Workforce Data Cube.

[824] FY 1989–FY 1993: Dryden figures included with Ames Research Center.

Table 6-12. Other Than Full-Time Permanent Employees by NASA Installation: Number on Board (at end of fiscal year)

Installation	1989	1990	1991	1992	1993	1994	1995	1996	1997	1998
Ames Research Center	66	74	143	196	200	98	109	104	137	188
Dryden Flight Research Center[825]	—	—	—	—	—	52	43	48	100	88
Goddard Space Flight Center	125	119	166	231	231	205	157	155	147	171
Johnson Space Center	126	112	174	286	299	216	184	201	221	274
Kennedy Space Center	81	76	113	233	257	196	162	114	109	113
Langley Research Center	139	152	204	270	253	233	245	178	164	146
Lewis Research Center	83	92	106	147	110	128	109	94	103	107
Marshall Space Flight Center	94	115	190	255	241	151	109	67	70	74
Stennis Space Center	20	14	17	23	33	36	21	24	33	37
Headquarters	140	187	203	446	393	335	374	368	301	320
Total	*874*	*941*	*1,316*	*1,164*	*894*	*669*	*553*	*527*	*667*	*818*

Source: FY 1989–FY 1990, Civil Service Workforce Reports; FY 1992–FY 1998, Workforce Data Cube. FY 1991 data derived from Table 6-8 (not printed in FY 1991 Civil Service Workforce Report).

[825] FY 1989–FY 1993: included with Ames Research Center figures.

Table 6-13. NASA Full-Time Permanent Excepted, SES, and Senior Technical Employees by NASA Installation: Number on Board (at end of fiscal year)

Installation	1989	1990	1991	1992	1993	1994	1995	1996	1997	1998
Ames Research Center	43	39	45	48	44	35	34	34	32	34
Dryden Flight Research Center[826]	—	—	—	—	—	6	7	9	10	10
Goddard Space Flight Center	47	48	59	60	69	65	63	64	57	57
Johnson Space Center	51	54	61	67	69	73	76	75	76	80
Kennedy Space Center	33	34	32	31	30	28	25	24	27	28
Langley Research Center	34	39	40	46	52	45	44	44	49	42
Lewis Research Center	38	39	45	46	47	34	25	24	28	38
Marshall Space Flight Center	51	56	61	61	67	62	60	59	60	58
Stennis Space Center	6	6	6	7	7	4	6	6	6	4
Headquarters	224	243	272	263	258	222	200	179	127	116
Total	*527*	*558*	*621*	*629*	*643*	*574*	*540*	*518*	*472*	*467*
Percentage of Total NASA Full-Time Permanent Workforce	*2.6*	*2.6*	*2.7*	*2.6*	*2.7*	*2.6*	*2.6*	*2.6*	*2.5*	*2.6*

Source: FY 1989–FY 1991, Civil Service Workforce Reports; FY 1992–FY 1998, Workforce Data Cube.

[826] FY 1989–FY 1993: Dryden included with Ames Research Center figures.

Table 6-14. NASA Permanent Full-Time Excepted, SES, and Senior Technical Employees by NASA Installation: Percentage of NASA Total Senior Grade Employees (at end of fiscal year)

Installation	1989	1990	1991	1992	1993	1994	1995	1996	1997	1998
Ames Research Center	8.2	7.0	7.2	7.3	6.7	5.9	6.4	6.7	6.7	7.2
Dryden Flight Research Center[827]	—	—	—	—	—	1.0	1.3	1.7	2.1	2.1
Goddard Space Flight Center	8.9	8.6	9.5	9.1	10.4	10.9	11.6	12.2	11.9	12.1
Johnson Space Center	9.7	9.7	9.8	10.3	10.6	12.4	13.9	14.4	16.4	17.0
Kennedy Space Center	6.3	6.1	5.2	4.7	4.5	4.7	4.6	4.6	5.7	6.0
Langley Research Center	6.5	7.0	6.4	7.0	7.9	7.6	8.1	8.4	10.3	8.9
Lewis Research Center	7.2	7.0	7.2	7.0	7.1	5.7	4.6	4.6	5.9	8.3
Marshall Space Flight Center	9.7	10.0	9.8	9.3	10.1	10.4	11.0	11.6	12.8	12.3
Stennis Space Center	1.1	1.1	1.0	1.1	1.1	0.8	1.3	1.3	1.5	1.1
Headquarters	42.5	43.5	43.8	44.2	41.6	40.6	37.2	34.6	26.8	24.9
Total	*100.0*	*100.0*	*100.0*	*100.0*	*100.0*	*100.0*	*100.0*	*100.0*	*100.0*	*100.0*

Source: Derived from table 6-13.

[827] FY 1989–FY 1993, Dryden included with Ames Research Center.

Table 6-15. Scientific and Technical Full-Time Permanent Employees (Occupational Code Groups 200, 700, and 900) by NASA Installation: Number on Board (at end of fiscal year)

Installation	1989	1990	1991	1992	1993	1994	1995	1996	1997	1998
Ames Research Center	1,164	1,183	1,212	1,202	1,178	968	913	871	837	789
Dryden Flight Research Center[828]	—	—	—	—	—	177	174	189	202	224
Goddard Space Flight Center	2,014	2,136	2,240	2,233	2,224	2,208	2,106	2,077	1,976	1,867
Johnson Space Center	2,340	2,360	2,402	2,390	2,382	2,368	2,296	2,258	2,143	2,044
Kennedy Space Center	1,434	1,468	1,553	1,549	1,520	1,450	1,371	1,302	1,164	1,071
Langley Research Center	1,363	1,434	1,443	1,434	1,402	1,371	1,256	1,240	1,218	1,146
Lewis Research Center	1,509	1,500	1,612	1,592	1,550	1,401	1,309	1,263	1,169	1,099
Marshall Space Flight Center	2,351	2,376	2,514	2,462	2,410	2,236	2,117	2,101	1,968	1,854
Stennis Space Center	98	103	128	124	117	118	117	117	132	134
Headquarters	502	571	590	588	571	470	407	328	250	225
Total	*12,775*	*13,131*	*13,694*	*13,574*	*13,354*	*12,767*	*12,066*	*11,746*	*11,059*	*10,453*

Source: FY 1989–FY 1991, Civil Service Workforce Reports; FY 1992–FY 1998, Workforce Data Cube.

[828] FY 1989–FY 1993: included with Ames Research Center figures.

Table 6-16. Technical Support Full-Time Permanent Employees (Occupational Code Group 300) by NASA Installation: Number on Board (at end of fiscal year)

Installation	1989	1990	1991	1992	1993	1994	1995	1996	1997	1998
Ames Research Center	138	139	150	171	179	107	93	97	91	92
Dryden Flight Research Center[829]	—	—	—	—	—	106	105	120	123	143
Goddard Space Flight Center	458	442	433	408	390	364	291	280	264	241
Johnson Space Center	201	189	188	175	169	149	140	134	126	120
Kennedy Space Center	266	268	277	274	265	234	207	199	185	171
Langley Research Center	917	930	933	918	885	861	753	739	689	632
Lewis Research Center	234	297	327	337	349	315	287	290	274	252
Marshall Space Flight Center	180	172	178	178	176	157	145	136	130	122
Stennis Space Center	2	2	2	2	2	2	2	2	3	2
Headquarters	5	7	6	5	6	6	2	2	3	2
Total	*2,401*	*2,446*	*2,494*	*2,468*	*2,421*	*2,301*	*2,025*	*1,999*	*1,888*	*1,777*

Source: FY 1989–FY 1991, Civil Service Workforce Reports; FY 1992–FY 1998, Workforce Data Cube.

[829] FY 1989–FY 1993: included with Ames Research Center figures.

Table 6-17. Wage Full-Time Permanent Employees (Occupational Code Group 100) by NASA Installation: Number on Board (at end of fiscal year)

Installation	1989	1990	1991	1992	1993	1994	1995	1996	1997	1998
Ames Research Center	319	322	316	295	267	164	138	124	95	72
Dryden Flight Research Center[830]	—	—	—	—	—	51	41	28	28	18
Goddard Space Flight Center	78	75	68	65	69	70	67	68	67	63
Johnson Space Center	9	9	8	6	4	3	3	2	1	1
Kennedy Space Center	3	5	6	6	6	5	2	0	0	0
Langley Research Center	13	12	10	8	2	0	0	0	0	0
Lewis Research Center	478	404	358	329	301	260	235	214	206	202
Marshall Space Flight Center	0	0	0	0	0	0	0	0	0	0
Stennis Space Center	0	0	0	0	0	0	0	0	0	0
Headquarters	6	3	2	1	1	1	1	1	0	0
Total	*906*	*830*	*768*	*710*	*650*	*554*	*487*	*437*	*397*	*356*

Source: FY 1989–FY 1991, Civil Service Workforce Reports; FY 1992–FY 1998, Workforce Data Cube.

[830] FY 1989–FY 1993: included with Ames Research Center figures.

Table 6-18. Professional Administrative Full-Time Permanent Employees (Occupational Code Group 600) by NASA Installation: Number on Board (at end of fiscal year)

Installation	1989	1990	1991	1992	1993	1994	1995	1996	1997	1998
Ames Research Center	307	345	364	368	368	307	289	283	281	279
Dryden Flight Research Center[831]	—	—	—	—	—	79	83	88	101	101
Goddard Space Flight Center	750	786	819	831	827	806	754	732	776	771
Johnson Space Center	576	611	649	645	661	636	604	611	557	529
Kennedy Space Center	392	406	416	419	429	414	417	426	400	377
Langley Research Center	287	304	308	326	323	311	278	288	305	298
Lewis Research Center	270	284	301	315	325	296	271	296	294	280
Marshall Space Flight Center	597	605	620	629	626	568	531	546	517	510
Stennis Space Center	52	55	55	55	52	52	50	51	54	56
Headquarters	854	970	1,047	959	930	840	786	721	568	536
Total	*4,085*	*4,366*	*4,579*	*4,547*	*4,541*	*4,309*	*4,063*	*4,042*	*3,853*	*3,737*

Source: FY 1989–FY 1991, Civil Service Workforce Reports; FY 1992–FY 1998, Workforce Data Cube.

[831] FY 1989–FY 1993: included with Ames Research Center figures.

Table 6-19. Clerical Full-Time Permanent Employees (Occupational Code Group 500) by NASA Installation: Number on Board (at end of fiscal year)

Installation	1989	1990	1991	1992	1993	1994	1995	1996	1997	1998
Ames Research Center	223	216	221	210	186	160	134	122	103	84
Dryden Flight Research Center[832]	—	—	—	—	—	29	26	24	21	18
Goddard Space Flight Center	435	434	439	436	420	387	338	325	288	231
Johnson Space Center	452	446	430	417	406	374	357	339	303	272
Kennedy Space Center	328	319	319	300	286	255	204	179	141	126
Langley Research Center	284	281	275	269	249	245	219	205	196	172
Lewis Research Center	258	243	237	224	208	183	159	142	118	104
Marshall Space Flight Center	481	466	476	452	421	353	320	295	265	233
Stennis Space Center	31	32	37	35	31	33	35	29	25	21
Headquarters	360	415	447	417	394	338	287	271	196	170
Total	*2,852*	*2,852*	*2,881*	*2,760*	*2,601*	*2,357*	*2,079*	*1,931*	*1,656*	*1,431*

Source: FY 1989–FY 1991, Civil Service Workforce Reports; FY 1992–FY 1998, Workforce Data Cube.

[832] FY 1989–FY 1993: included with Ames Research Center figures.

Table 6-20. Agency, Minority, and Female Full-Time Permanent Employees by Grade Range: Number on Board (at end of fiscal year)

Grade of Employee	1989	1990	1991	1992	1993	1994	1995	1996	1997	1998
GS-1–6										
Minority[833]	603	624	626	594	528	480	431	388	335	265
Percentage of Total at Grade	27.2	28.5	29.3	30.8	31.9	32.8	36.2	37.9	40.7	40.9
Female	2,020	1,988	1,949	1,778	1,563	1,390	1,139	974	786	615
Percentage of Total at Grade	91.1	90.8	91.2	92.2	94.5	95.1	95.6	95.1	95.5	94.9
Agency Total at Grade[834]	2,217	2,190	2,136	1,928	1,654	1,462	1,192	1,024	823	648
Percentage of Agency Total at Grade	9.6	9.3	8.7	8.0	7.0	6.6	5.8	5.1	4.4	3.6
GS-7–12										
Minority	1,635	1,727	1,879	1,837	1,788	1,733	1,595	1,488	1,312	1,242
Percentage of Total at Grade	18.6	18.0	23.3	21.4	22.2	24.0	25.5	26.1	26.3	27.1
Female	3,402	3,526	3,725	3,646	3,563	3,324	3,036	2,902	2,613	2,440
Percentage of Total at Grade	38.6	36.8	46.2	42.5	44.3	46.0	48.5	50.8	52.3	53.3
Agency Total at Grade	8,811	9,583	8,061	8,586	8,038	7,229	6,255	5,707	4,998	4,581
Percentage of Agency Total at Grade	38.3	40.6	33.0	35.7	34.1	32.4	30.2	28.3	26.5	25.8
GS-13–15										
Minority	995	1,139	1,299	1,457	1,577	1,708	1,807	1,895	1,972	1,983
Percentage of Total at Grade	9.4	10.2	11.0	11.9	12.5	13.7	14.8	15.2	16.2	17.0
Female	1,039	1,302	1,558	1,784	1,951	2,096	2,261	2,374	2,424	2,446
Percentage of Total at Grade	9.8	11.7	13.2	14.6	15.5	16.8	18.5	19.0	19.9	20.9
NASA Total at Grade	10,564	11,165	11,830	12,203	12,580	12,466	12,243	12,467	12,160	11,699
Percentage of NASA Total at Grade	45.9	47.3	48.5	50.7	53.4	55.9	59.1	61.9	64.5	65.9

[833] Minority includes Black, Hispanic, Asian or Pacific Islander, and Native American employees.
[834] Employees may be both female and minority.

Grade of Employee	1989	1990	1991	1992	1993	1994	1995	1996	1997	1998
SES, Senior Technical, Excepted										
Minority	22	26	33	33	42	54	56	62	60	64
Percentage of Total at Grade	4.2	4.7	5.3	5.2	6.5	9.4	10.4	12.0	12.7	13.7
Female	21	28	33	35	37	45	57	60	64	73
Percentage of Total at Grade	4.0	5.0	5.3	5.6	5.8	7.8	10.6	11.6	13.6	15.6
NASA Total at Grade	527	558	621	629	643	574	540	518	472	467
Percentage of NASA Total at Grade	2.3	2.4	2.5	2.6	2.7	2.6	2.6	2.6	2.5	2.6
Wage System										
Minority	186	190	188	187	172	165	152	138	123	120
Percentage of Total at Grade	20.5	22.9	24.5	26.3	26.5	29.8	31.2	31.6	31.0	33.7
Female	33	37	36	39	37	38	36	33	33	33
Percentage of Total at Grade	3.6	4.5	4.7	5.5	5.7	6.9	7.4	7.6	8.3	9.3
NASA Total at Grade	906	830	768	710	650	554	487	437	397	356
Percentage of NASA Total at Grade	3.9	3.5	3.1	3.0	2.8	2.5	2.4	2.2	2.1	2.0
Total	*23,019*	*23,625*	*24,416*	*24,059*	*23,567*	*22,288*	*20,720*	*20,155*	*18,853*	*17,754*

Source: FY 1989–FY 1991, Civil Service Workforce Reports; FY 1992–FY 1998, Workforce Data Cube.

Table 6-21. Minority Full-Time Permanent Employees: Number on Board (at end of fiscal year)

Minority	**1989**	**1990**	**1991**	**1992**	**1993**	**1994**	**1995**	**1996**	**1997**	**1998**
Black	1,904	2,009	2,130	2,132	2,114	2,121	2,045	2,025	1,929	1,852
Percentage of NASA Total	8.3	8.5	8.7	8.9	9.0	9.5	9.9	10.0	10.2	10.4
Hispanic	713	782	889	899	903	908	890	865	831	806
Percentage of NASA Total	3.1	3.3	3.6	3.7	3.8	4.1	4.3	4.3	4.4	4.5
Asian or Pacific Islander	724	802	880	901	919	938	929	907	875	860
Percentage of NASA Total	3.1	3.4	3.6	3.7	3.9	4.2	4.5	4.5	4.6	4.8
Native American	101	113	126	176	171	173	177	174	167	156
Percentage of NASA Total	0.4	0.5	0.5	0.7	0.7	0.8	0.9	0.9	0.9	0.9
Total	*3,442*	*3,706*	*4,025*	*4,108*	*4,107*	*4,140*	*4,041*	*3,971*	*3,802*	*3,674*
Percentage of NASA Total	*15.0*	*15.7*	*16.5*	*17.1*	*17.4*	*18.6*	*19.5*	*19.7*	*20.2*	*20.7*

Source: FY 1989–FY 1991, Civil Service Workforce Reports; FY 1992–FY 1998, Workforce Data Cube.

Table 6-22. Minority Full-Time Permanent Employees by NASA Occupational Code Group: Number on Board (at end of fiscal year)

Occupational Code Group	1989	1990	1991	1992	1993	1994	1995	1996	1997	1998
200, 700, 900 (Scientists/Engineers)	1,550	1,698	1,878	1,937	1,943	1,990	1,967	1,941	1,878	1,834
Percentage of Total Occupational Code	12.1	12.9	13.7	14.3	14.5	15.6	16.3	16.5	17.0	17.5
600 (Professional Admin.)	643	696	780	807	843	863	860	865	874	869
Percentage of Total Occupational Code	15.7	15.9	17.0	17.7	18.6	20.0	21.2	21.4	22.7	23.3
500 (Clerical)	761	799	844	833	810	779	739	705	611	534
Percentage of Total Occupational Code	26.7	28.0	29.3	30.2	31.1	33.1	35.5	36.5	36.9	37.3
300 (Technical Support)	302	323	335	344	339	343	323	322	316	317
Percentage of Total Occupational Code	12.6	13.2	13.4	13.9	14.0	14.9	16.0	16.1	16.7	17.8
100 (Wage)	186	190	188	187	172	165	152	138	123	120
Percentage of Total Occupational Code	20.5	22.9	24.5	26.3	26.5	29.8	31.2	31.6	31.0	33.7
Total of Entire NASA Workforce	*3,442*	*3,706*	*4,025*	*4,108*	*4,107*	*4,140*	*4,041*	*3,971*	*3,802*	*3,674*
Percentage of NASA Workforce	*15.0*	*15.7*	*16.5*	*17.1*	*17.4*	*18.6*	*19.5*	*19.7*	*20.2*	*20.7*

Source: FY 1989–FY 1991, Civil Service Workforce Reports; FY 1992–FY 1998, Workforce Data Cube.

Table 6-23. Minority Full-Time Permanent Employees by Grade Range: Number on Board (at end of fiscal year)

Grade of Employee	1989	1990	1991	1992	1993	1994	1995	1996	1997	1998
GS-1–6	603	624	626	594	528	480	431	388	335	265
Percentage of NASA Total at Grade	27.2	28.5	29.3	30.8	31.9	32.8	36.2	37.9	40.7	40.9
GS-7–12	1,635	1,727	1,879	1,837	1,788	1,733	1,595	1,488	1,312	1,242
Percentage of NASA Total at Grade	18.6	19.4	20.7	21.4	22.2	24.0	25.5	26.1	26.3	27.1
GS-13–15	995	1,139	1,299	1,457	1,577	1,708	1,807	1,895	1,972	1,983
Percentage of NASA Total at Grade	9.4	10.2	11.0	11.9	12.5	13.7	14.8	15.2	16.2	17.0
SES, Senior Technical, Excepted	22	26	33	33	42	54	56	62	60	64
Percentage of NASA Total at Grade	4.2	4.7	5.3	5.2	6.5	9.4	10.4	12.0	12.7	13.7
Wage System	186	190	188	187	172	165	152	138	123	120
Percentage of NASA Total at Grade	20.5	22.9	24.5	26.3	26.5	29.8	31.2	31.6	31.0	33.7
Total	*3,442*	*3,706*	*4,025*	*4,108*	*4,107*	*4,140*	*4,041*	*3,971*	*3,802*	*3,674*
Percentage of NASA Total[835]	*15.0*	*15.7*	*16.5*	*17.1*	*17.4*	*18.6*	*19.5*	*19.7*	*20.2*	*20.7*

Source: FY 1989–FY 1991, Civil Service Workforce Reports; FY 1992–FY 1998, Workforce Data Cube.

[835] Percentages based on inclusion of employees (all nonminority) in “other pay plans”: FY 1992 (3), FY 1993 (2), FY 1994 (3), FY 1995 (3), FY 1996 (3), FY 1997 (3), and FY 1998 (3).

Table 6-24. Average GS Grade Level of Minority and Nonminority Permanent Employees by NASA Occupational Code Group (1989–1998) (at end of fiscal year)

Occupational Code Group	1989		1990		1991		1992		1993	
	Minority	Nonminority	Minority	Nonminority	Minority	Nonminority	Minority	Nonminority	Minority	Nonminority
Scientists/Engineers	12.2	13.0	12.3	13.1	12.3	13.1	12.6	13.3	12.8	13.4
Professional Admin.	11.4	12.1	11.5	12.1	11.5	12.2	11.7	12.3	11.7	12.3
Clerical	5.7	5.9	5.7	5.9	5.8	6.0	5.9	6.2	6.0	6.3
Technical Support	9.1	10.4	9.3	10.5	9.5	10.5	9.8	10.7	10.2	10.9
All NASA	*10.2*	*11.7*	*10.4*	*11.8*	*10.5*	*11.9*	*10.7*	*12.1*	*10.9*	*12.2*

Occupational Code Group	1994		1995		1996		1997		1998	
	Minority	Nonminority	Minority	Nonminority	Minority	Nonminority	Minority	Nonminority	Minority	Nonminority
Scientists/Engineers	12.9	13.4	13.0	13.4	13.1	13.5	13.2	13.6	13.3	13.6
Professional Admin.	11.8	12.3	11.9	12.4	12.0	12.4	11.9	12.5	11.9	12.5
Clerical	6.2	6.3	6.3	6.4	6.5	6.6	6.6	6.7	6.8	6.8
Technical Support	10.2	11.0	10.5	11.0	10.7	11.2	10.9	11.3	10.9	11.4
All NASA	*11.1*	*12.3*	*10.9*	*12.4*	*11.0*	*12.5*	*11.2*	*12.6*	*11.4*	*12.7*

Source: FY 1989–FY 1991, Civil Service Workforce Reports; FY 1992–FY 1998, Workforce Data Cube.

Table 6-25. Minority Full-Time Permanent Employees by NASA Center: Number on Board (at end of fiscal year)

Installation	1989	1990	1991	1992	1993	1994	1995	1996	1997	1998
Ames Research Center	433	459	491	494	486	414	386	370	353	344
Dryden Flight Research Center[836]	—	—	—	0	0	100	98	108	119	127
Goddard Space Flight Center	585	629	661	687	712	738	726	719	731	694
Johnson Space Center	574	604	641	664	676	688	695	699	672	663
Kennedy Space Center	302	322	364	376	380	387	380	367	344	322
Langley Research Center	380	410	418	440	436	438	432	428	418	401
Lewis Research Center	358	381	456	475	467	456	442	430	407	396
Marshall Space Flight Center	382	396	435	438	436	434	437	430	426	420
Stennis Space Center	22	23	27	26	25	29	30	31	34	32
Headquarters	406	482	532	508	489	456	415	389	298	275
Total	*3,442*	*3,706*	*4,025*	*4,108*	*4,107*	*4,140*	*4,041*	*3,971*	*3,802*	*3,674*

Source: FY 1989–FY 1991, Civil Service Workforce Reports; FY 1992–FY 1998, Workforce Data Cube.

[836] FY 1989–FY 1993: included with Ames Research Center figures.

Table 6-26. Minority Percentage of Full-Time Permanent Employees at Each NASA Center (at end of fiscal year)

Installation	**1989**	**1990**	**1991**	**1992**	**1993**	**1994**	**1995**	**1996**	**1997**	**1998**
Ames Research Center	20.1	20.8	21.7	22.0	22.3	24.3	24.6	24.7	25.1	26.1
Dryden Flight Research Center[837]	—	—	—	—	—	22.6	22.8	24.1	25.1	25.2
Goddard Space Flight Center	15.7	16.2	16.5	17.3	18.1	19.2	20.4	20.6	21.7	21.9
Johnson Space Center	16.0	16.7	17.4	18.3	18.7	19.5	20.4	20.9	21.5	22.4
Kennedy Space Center	12.5	13.1	14.2	14.8	15.2	16.4	17.3	17.4	18.2	18.5
Langley Research Center	13.3	13.8	14.1	14.9	15.2	15.7	17.2	17.3	17.4	17.8
Lewis Research Center	13.0	14.0	16.1	17.0	17.1	18.6	19.5	19.5	19.7	20.4
Marshall Space Flight Center	10.6	10.9	11.5	11.8	12.0	13.1	14.0	14.0	14.8	15.4
Stennis Space Center	12.0	12.0	12.2	12.0	12.4	14.1	14.7	15.6	15.9	15.0
Headquarters	23.5	24.5	25.4	25.8	25.7	27.6	28.0	29.4	29.3	29.5
Total for All Centers	*15.0*	*15.7*	*16.5*	*17.1*	*17.4*	*18.6*	*19.5*	*19.7*	*20.2*	*20.7*

Source: Tables 6-1 and 6-25.

[837] FY 1989–FY 1993: included with Ames Research Center.

Table 6-27. Female Full-Time Permanent Employees by NASA Occupational Code Group: Number on Board (at end of fiscal year)

Occupational Code Group	**1989**	**1990**	**1991**	**1992**	**1993**	**1994**	**1995**	**1996**	**1997**	**1998**
200, 700, 900 (Scientists/Engineers)	1,614	1,757	1,962	2,001	1,982	2,012	1,985	1,934	1,849	1,777
Percentage of Total Occupational Code	12.6	13.4	14.3	14.7	14.8	15.8	16.5	16.5	16.7	17.0
600 (Professional Admin.)	1,925	2,135	2,298	2,363	2,406	2,358	2,302	2,326	2,261	2,240
Percentage of Total Occupational Code	47.1	48.9	50.2	52.0	53.0	54.7	56.7	57.5	58.7	59.9
500 (Clerical)	2,768	2,767	2,795	2,677	2,520	2,277	2,009	1,863	1,596	1,381
Percentage of Total Occupational Code	97.1	(7.0	97.0	97.0	96.9	96.6	96.6	96.5	96.4	96.5
300 (Technical Support)	175	185	210	203	207	209	198	188	182	177
Percentage of Total Occupational Code	7.3	7.6	8.4	8.2	8.6	9.1	9.8	9.4	9.6	10.0
100 (Wage)	33	37	36	39	37	38	36	33	33	33
Percentage of Total Occupational Code	3.6	4.5	4.7	5.5	5.7	6.9	7.4	7.6	8.3	9.3
Total	*6,515*	*6,881*	*7,301*	*7,283*	*7,152*	*6,894*	*6,530*	*6,344*	*5,921*	*5,608*
	28.3	*29.1*	*29.9*	*30.3*	*30.3*	*30.9*	*31.5*	*31.5*	*31.4*	*31.6*

Source: FY 1989–FY 1991, Civil Service Workforce Reports; FY 1992–FY 1998, Workforce Data Cube.

Table 6-28. Female Full-Time Permanent Employees by Grade Range: Number on Board (at end of fiscal year)

Grade of Employee	1989	1990	1991	1992	1993	1994	1995	1996	1997	1998
GS-1–6	2,020	1,988	1,949	1,778	1,563	1,390	1,139	974	786	615
Percentage of NASA Total at Grade	91.1	90.8	91.2	92.2	94.5	95.1	95.6	95.1	95.5	94.9
GS-7–12	3,402	3,526	3,725	3,646	3,563	3,324	3,036	2,902	2,613	2,440
Percentage of NASA Total at Grade	38.6	39.7	41.1	42.5	44.3	46.0	48.5	50.9	52.3	53.3
GS-13–15	1,039	1,302	1,558	1,784	1,951	2,096	2,261	2,374	2,424	2,446
Percentage of NASA Total at Grade	9.0	11.7	13.2	14.6	15.5	16.8	18.5	19.0	19.9	20.9
SES, Senior Technical, Excepted	21	28	33	35	37	45	57	60	64	73
Percentage of NASA Total at Grade	4.0	5.0	5.3	5.6	5.8	7.8	10.6	11.6	13.6	13.9
Wage System	33	37	36	39	37	38	36	33	33	33
Percentage of NASA Total at Grade	3.6	4.5	4.7	5.5	5.7	6.9	7.4	7.6	8.3	9.3
Total	*6,515*	*6,881*	*7,301*	*7,283*	*7,152*	*6,894*	*6,530*	*6,344*	*5,921*	*5,608*
Percentage of NASA Total	*28.3*	*29.1*	*29.9*	*30.3838*	*30.3*	*30.9*	*31.5*	*31.5*	*31.4*	*31.6*

Source: Tables 6-1 and 6-27.

[838] Percentages for FY 1992–FY 1998 based on inclusion of employees in other pay plans (FY 1992: two males and one female; FY 1993: one male and one female; FY 1994: one male and one female; FY 1995: two males and one female; FY 1996: two males and one female; FY 1997: two males and one female; and FY 1998: two males and one female).

Table 6-29. Average GS Grade Level of Male and Female Permanent Employees by NASA Occupational Code Group (1989–1998) (at end of fiscal year)

Occupational Code Group	1989		1990		1991		1992		1993	
	Males	Females	Males	Females	Males	Females	Males	Females	Males	Females
Scientists/Engineers	13.0	11.7	13.1	12.1	13.2	12.1	13.3	12.4	13.4	12.6
Professional Admin.	12.7	11.2	12.7	11.3	12.7	11.4	12.8	11.5	12.8	11.6
Clerical	6.0	5.8	6.0	5.9	6.1	5.9	5.3	5.8	5.3	5.9
Technical Support	10.4	8.5	10.5	8.6	10.6	8.6	9.4	6.3	9.7	6.7
All NASA	*12.6*	*8.9*	*12.6*	*9.2*	*12.7*	*9.4*	*12.5*	*9.3*	*12.6*	*9.5*

Occupational Code Group	1994		1995		1996		1997		1998	
	Males	Females	Males	Females	Males	Females	Males	Females	Males	Females
Scientists/Engineers	13.4	12.7	13.4	12.8	13.5	13.0	13.6	13.1	13.6	13.2
Professional Admin.	12.9	11.6	13.0	11.8	13.1	11.8	13.1	11.8	13.1	11.9
Clerical	5.3	6.0	4.9	5.9	5.1	6.2	5.5	6.3	5.4	6.4
Technical Support	9.8	6.8	10.0	6.8	10.4	7.4	10.6	8.2	10.7	8.2
All NASA	*12.7*	*9.7*	*12.8*	*9.9*	*12.9*	*10.1*	*13.0*	*10.4*	*13.0*	*10.6*

Source: FY 1989–FY 1991, Civil Service Workforce Reports; FY 1992–FY 1998, Workforce Data Cube.

Table 6-30. Female Full-Time Permanent Employees by NASA Installation: Number on Board (at end of fiscal year)

Installation	1989	1990	1991	1992	1993	1994	1995	1996	1997	1998
Ames Research Center	520	547	574	572	548	464	423	403	380	365
Dryden Flight Research Center[839]	—	—	—	—	—	106	101	103	108	106
Goddard Space Flight Center	1,044	1,112	1,176	1,182	1,178	1,167	1,113	1,094	1,102	1,051
Johnson Space Center	1,122	1,167	1,216	1,222	1,226	1,193	1,148	1,135	1,043	996
Kennedy Space Center	685	716	761	763	760	741	700	664	606	555
Langley Research Center	667	699	721	731	712	716	664	647	636	609
Lewis Research Center	561	572	615	621	613	559	519	513	484	462
Marshall Space Flight Center	1,101	1,138	1,226	1,216	1,178	1,101	1,057	1,042	983	931
Stennis Space Center	60	63	74	73	68	72	80	75	73	71
Headquarters	755	867	938	903	869	775	725	668	506	462
Total	*6,515*	*6,881*	*7,301*	*7,283*	*7,152*	*6,894*	*6,530*	*6,344*	*5,921*	*5,608*

Source: FY 1989–FY 1992, Civil Service Workforce Reports; FY 1993–FY 1998, Workforce Data Cube.

[839] FY 1989–FY 1993, included with Ames Research Center figures.

Table 6-31. Females as a Percentage of Full-Time Permanent NASA Employees by Center (at end of fiscal year)

Installation	1989	1990	1991	1992	1993	1994	1995	1996	1997	1998
Ames Research Center	24.2	24.8	25.4	25.5	25.2	27.2	27.0	26.9	27.0	27.7
Dryden Flight Research Center[840]	—	—	—	—	—	24.0	23.5	22.9	22.7	21.0
Goddard Space Flight Center	28.0	28.7	29.4	29.8	30.0	30.4	31.3	31.4	32.7	33.1
Johnson Space Center	31.4	32.3	33.1	33.6	33.8	33.8	33.8	33.9	33.3	33.6
Kennedy Space Center	28.3	29.0	29.6	29.9	30.3	31.4	31.8	31.5	32.1	31.8
Langley Research Center	23.3	23.6	24.3	24.7	24.9	25.7	26.5	26.2	26.4	27.1
Lewis Research Center	20.4	21.0	21.7	22.2	22.4	22.8	23.0	23.3	23.5	23.9
Marshall Space Flight Center	30.5	31.4	32.4	32.7	32.4	33.2	34.0	33.9	34.1	34.2
Stennis Space Center	32.8	32.8	33.3	33.8	33.7	35.1	39.2	37.7	34.1	33.3
Headquarters	43.7	44.1	44.8	45.8	45.7	46.8	48.9	50.5	49.8	49.5
Total	*28.3*	*29.1*	*29.9*	*30.3*	*30.3*	*30.9*	*31.5*	*31.5*	*31.4*	*31.6*

Source: Tables 6-1, 6-30.

[840] FY 1989–FY 1993: included with Ames Research Center.

Table 6-32. Age Profile of Full-Time Permanent Employees by Age Ranges: Number on Board (at end of fiscal year)

Age	1989	1990	1991	1992	1993	1994	1995	1996	1997	1998
Under 25	1,108	1,060	1,047	766	524	410	328	189	112	82
Percentage of NASA Total	4.8	4.5	4.3	3.2	2.2	1.8	1.6	0.9	0.6	0.5
25–29	2,974	3,037	3,135	2,891	2,547	2,180	1,749	1,332	989	692
Percentage of NASA Total	12.9	12.9	12.8	12.0	10.6	9.1	7.3	5.5	4.1	2.9
30–34	2,731	3,076	3,475	3,520	3,547	3,544	3,309	3,007	2,609	2,237
Percentage of NASA Total	11.9	13.0	14.2	14.6	14.7	14.7	13.8	12.5	10.8	9.3
35–39	2,538	2,775	2,955	3,057	3,046	3,189	3,287	3,391	3,355	3,324
Percentage of NASA Total	11.0	11.7	12.1	12.7	12.7	13.3	13.7	14.1	13.9	13.8
40–44	2,751	2,845	3,008	2,816	2,842	2,868	2,951	2,893	2,913	2,903
Percentage of NASA Total	12.0	12.0	12.3	11.7	11.8	11.9	12.3	12.0	12.1	12.1
45–49	3,349	3,228	3,162	3,138	2,969	2,914	2,871	2,880	2,687	2,691
Percentage of NASA Total	14.5	13.7	13.0	13.0	12.3	12.1	11.9	12.0	11.2	11.2
50–54	3,748	3,700	3,644	3,556	3,492	3,127	2,844	2,827	2,736	2,540
Percentage of NASA Total	16.3	15.7	14.9	14.8	14.5	13.0	11.8	11.8	11.4	10.6
55–59	2,460	2,520	2,570	2,710	2,812	2,545	2,191	2,230	2,131	2,008
Percentage of NASA Total	10.7	10.7	10.5	11.3	11.7	10.6	9.1	9.3	8.9	8.3
60+	1,360	1,384	1,420	1,605	1,788	1,511	1,190	1,406	1,321	1,277
Percentage of NASA Total	5.9	5.9	5.8	6.7	7.4	6.3	4.9	5.8	5.5	5.3
Average Age	*42.6*	*42.4*	*42.2*	*42.7*	*43.3*	*43.1*	*42.9*	*43.8*	*44.2*	*44.6*

Source: FY 1989–FY 1991, Civil Service Workforce Reports; FY 1992–FY 1998, Workforce Data Cube.

Table 6-33. Age Profile of Full-Time Permanent Scientists and Engineers (at end of fiscal year)

Age	1989	1990	1991	1992	1993	1994	1995	1996	1997	1998
Under 25	653	563	540	340	187	137	124	54	22	19
Percentage of S&E Total	5.1	4.3	3.9	2.5	1.4	1.0	0.9	0.4	0.2	0.1
25–29	2,090	2,113	2,181	1,986	1,719	1,418	1,095	796	546	373
Percentage of S&E Total	16.4	16.1	15.9	14.6	12.7	10.4	8.1	5.9	4.0	2.7
30–34	1,615	1,937	2,270	2,373	2,464	2,488	2,312	2,100	1,806	1,526
Percentage of S&E Total	12.6	14.8	16.6	17.5	18.2	18.3	17.0	15.5	13.3	11.2
35–39	1,117	1,291	1,439	1,592	1,696	1,888	2,103	2,259	2,301	2,315
Percentage of S&E Total	8.7	9.8	10.5	11.7	12.5	13.9	15.5	16.6	17.0	17.1
40–44	1,104	1,145	1,227	1,206	1,244	1,309	1,389	1,431	1,550	1,648
Percentage of S&E Total	8.6	8.7	9.0	8.9	9.2	9.6	10.2	10.5	11.4	12.1
45–49	1,819	1,650	1,529	1,416	1,261	1,195	1,187	1,229	1,190	1,216
Percentage of S&E Total	14.2	12.6	11.2	10.4	9.3	8.8	8.7	9.1	8.8	9.0
50–54	2,278	2,219	2,139	2,072	1,981	1,751	1,552	1,433	1,315	1,154
Percentage of S&E Total	17.8	16.9	15.6	15.3	14.6	12.9	11.4	10.6	9.7	8.5
55–59	1,368	1,452	1,570	1,672	1,777	1,620	1,460	1,457	1,398	1,284
Percentage of S&E Total	10.7	11.1	11.5	12.3	13.1	11.9	10.8	10.7	10.3	9.5
60+	731	761	799	917	1,025	961	844	987	931	918
Percentage of S&E Total	5.7	5.8	5.8	6.8	7.6	7.1	6.2	7.3	6.9	6.8
Total Number All Ages	*12,775*	*13,131*	*13,694*	*13,574*	*13,354*	*12,767*	*12,066*	*11,746*	*11,059*	*10,453*
Average Age All S&E	*42.2*	*42.0*	*41.7*	*42.7*	*43.3*	*43.1*	*42.9*	*43.8*	*44.2*	*44.6*

Source: FY 1989–FY 1991, Civil Service Workforce Reports; FY 1992–FY 1998, Workforce Data Cube.

Chapter 7

Table 7-1. NASA Budget Authority Amount and as a Percentage of the Total Federal Budget: FY 1989–FY 1998 (in millions of dollars)

Fiscal Year	Real-Year Amount	Percentage of Total Federal Budget	2004 Deflator	Total Inflated 2004 Dollars
1989	10,969	0.9	1.4075	15,439
1990	12,324	1.0	1.3549	16,697
1991	14,016	1.0	1.3063	18,310
1992	14,317	1.0	1.2591	18,026
1993	14,310	1.0	1.2282	17,575
1994	14,570	1.0	1.2010	17,498
1995	13,854	0.9	1.1757	16,288
1996	13,886	0.9	1.1514	15,987
1997	13,711	0.8	1.1297	15,488
1998	13,649	0.8	1.1104	15,154

Source: Office of Management and Budget, Historical Tables, Budget of the United States Government, Fiscal Year 2005, pp. 95–96, *http://www.whitehouse.gov/omb/budget/fy2005/pdf/hist.pdf* (accessed December 13, 2006). Inflation figures are from "Appendix D-1B," *Aeronautics and Space Report of the President, Fiscal Year 2004 Activities* (Washington, DC: NASA, no date), p. 120.

Table 7-2A. NASA Appropriations by Appropriation Title, Fiscal Year, and Percentage Change: FY 1989–FY 1994 (in thousands of dollars)

Fiscal Year	R&D	SFC&DC	R&PM	CofF	Inspector General	Total
1989	4,191,700	4,364,200	1,855,000	275,100	—[841]	10,701,000[842]
Percentage Change from Preceding Year[843]	24.2	11.7	2.4	54.3	—	19.5
1990	5,281,876	4,618,074	1,951,476	591,980	8,659	12,452,065
Percentage Change from Preceding Year	26.0	5.8	5.2	115.2	—	16.4
1991	6,023,600	6,334,132	2,211,900	507,900[844]	10,500	15,088,032
Percentage Change from Preceding Year	14.0	37.2	13.3	–14.2	21.3	21.2
1992	6,413,800	5,157,075	2,242,300	525,000	14,600	14,352,775
Percentage Change from Preceding Year	6.5	–18.9	1.4	3.4	39.1	–4.9
1993	7,089,300	5,086,000	1,615,014	525,000	15,062	14,330,376
Percentage Change from Preceding Year	10.5	–1.4	–28.0	0.0	3.2	–0.2
1994	7,529,300	4,853,500	1,635,508	517,700	15,391	14,551,399
Percentage Change from Preceding Year	6.2	–4.6	1.3	–1.4	2.2	1.5
Total	*27,056,000*	*21,430,707*	*7,704,722*	*2,075,600*	*55,553*	*58,322,582*

Source: Table 7-3.

[841] No Inspector General appropriation included in FY 1989 budget documents.
[842] Includes a one-time appropriation of $15 million for a trust fund.
[843] Comparison with the preceding year is based on FY 1988 data from Judy Rumerman, *NASA Historical Data Book, Volume VI*, *1979–1988* (Washington, DC: NASA SP-4012, 2000), p. 507.
[844] Includes $10 million appropriated specifically for operation and maintenance of a new visitors center at Johnson Space Center and available without fiscal year limitation.

Table 7-2B. NASA Appropriations by Appropriation Title, Fiscal Year, and Percentage Change, FY 1995–FY 1998 (in thousands of dollars)

Fiscal Year	SAT	HSF	MS	Inspector General	Total
1995	5,901,200	5,573,900	2,554,587	16,000	14,445,687[845]
Percentage Change from Preceding Year[846]	—	—	—	—	—
1996	5,928,900	5,456,600	2,502,200	16,000	13,903,700
Percentage Change from Preceding Year	0.5	–2.1	–2.1	0.0	–3.75
1997	5,762,100	5,362,900	2,562,200	17,000	13,704,200
Percentage Change from Preceding Year	–2.8	–1.7	2.4	6.3	–1.4
1998	5,690,000	5,506,500	2,433,200	18,300	13,648,000
Percentage Change from Preceding Year	–1.3	2.7	–5.0	7.7	–0.4
Total	*23,282,200*	*21,899,900*	*10,052,187*	*67,300*	*55,701,587*

Source: Table 7-3.

[845] Total includes one-time appropriation of $400 million for National Aeronautical Facilities.
[846] Change in appropriation categories precludes comparison with prior year.

Table 7-3. NASA's Budget History: FY 1989–FY 1998 (in thousands of dollars)

Fiscal Year/Appropriation Title	Initial Request	Authorization	Appropriation	Adjustments to Appropriation
1989				
R&D	4,446,700	4,322,100	4,191,700	4,237,600[847]
SFC&DC	4,841,200	4,686,200	4,364,200	4,451,600[848]
R&PM	1,915,000	1,915,000	1,855,000	1,926,400[849]
CofF	285,100	290,100	275,100	281,700[850]
Trust Fund	—	—	15,000	—[851]
Total	*11,488,800*	*11,213,400*	*10,701,000*	*10,897,300*
1990				
R&D	5,751,600	—	5,281,876	5,227,776
SFC&DC	5,139,600	—	4,618,074	4,625,715
R&PM	2,032,200	—	1,951,476	2,023,434
CofF	341,800	—	591,980	410,990
Inspector General	8,795	—	8,659	8,659
Total	*13,273,995*	—[852]	*12,452,065*[853]	*12,296,574*[854]
1991				
R&D	7,074,000	—	6,023,600	6,023,522[855]
SFC&DC	5,289,400	—	6,334,132	5,124,334[856]

[847] Based on transfers between accounts (–$29 million) and transfers between federal agencies (unspecified) ($74.9 million). U.S. Congress, Public Law 101-45, *Dire Emergency Supplemental Appropriations and Transfers, Urgent Supplementals, and Correcting Enrollment Errors Act of 1989*, June 30, 1989, 101st Cong., 1st sess. This act allowed for "an additional amount for Research and Program Management, up to $35 million to be derived by transfer from Research and Development and Space Flight, Control, and Data Communications."
[848] Based on transfers between accounts (–$12.6 million) and transfers between federal agencies (unspecified) ($100 million).
[849] Based on transfers between accounts of $65 million, transfers between federal agencies (unspecified) of $6.6 million, and lapse of FY 1989 unobligated funds of $0.2 million.
[850] Based on transfers between accounts (–$23.4 million) and transfers between federal agencies (unspecified) ($15 million).
[851] Trust Fund not included in adjusted appropriations figures. Details in "Summary Reconciliation of Appropriations to Budget Plans," Fiscal Year 1991 Estimates, p. AS 12.
[852] No authorization bill passed.
[853] U.S. Congress, *Departments of Veterans Affairs and Housing and Urban Development, and Independent Agencies Appropriations Act, 1990*, Public Law 101-144, November 9, 1989, 101st Congress, 1st sess.
[854] U.S. Congress, *Dire Emergency Supplemental Appropriations for Disaster Assistance, Food Stamps, Unemployment Compensation Administration, and Other Urgent Needs, and Transfers, and Reducing Funds Budgeted for Military Spending Act of 1990*, Public Law 101-302, May 25, 1990, 101st Congress, 2nd sess., superseded P.L. 101-144. U.S. Congress, *Departments of Veterans Affairs and Housing and Urban Development, Independent Agencies Appropriations Act, 1990*, Public Law 101-144, November 9, 1989, 101st Congress, 1st sess.
[855] Reflects reduction of $78,000 pursuant to P.L. 100-119. U.S. Congress, *A Joint Resolution Increasing the Statutory Limit on the Public Debt*, September 29, 1987, Public Law 100-119, 100th Congress, 1st sess.
[856] Reflects $1,209,732,000 applied to debt reduction and reduction pursuant to P.L. 100-119 of $66,000.

Fiscal Year/Appropriation Title	Initial Request	Authorization	Appropriation	Adjustments to Appropriation
R&PM	2,252,900	—	2,211,900	2,211,632[857]
CofF	497,900	—	507,900[858]	497,894[859]
Inspector General	11,000	—	10,500	10,465[860]
Total	*15,125,200*	—[861]	*15,088,032*	*13,867,847*[862]
1992				
R&D	7,198,500	6,517,000	6,413,800	6,827,606[863]
SFC&DC	5,608,273	5,512,300	5,157,075	5,384,775[864]
R&PM	2,452,300	2,422,300	2,242,300	1,575,856[865]
CofF	480,300	430,300	525,000	531,400[866]
Inspector General	14,600	14,600	14,600	13,877[867]
Total	*15,753,973*	*14,896,500*	*14,352,775*[868]	*14,333,514*[869]
1993				
R&D	7,731,400	7,269,000	7,089,300	7,094,300[870]
SFC&DC	5,266,500	5,519,000	5,086,000	5,058,800[871]
R&PM	1,660,027	1,654,000	1,615,014	1,634,836[872]
CofF	319,200	479,200	525,000	520,000[873]
Inspector General	15,900	15,900	15,062	14,591[874]
Total	*14,993,027*	*14,937,100*	*14,330,376*[875]	*14,332,527*[876]

[857] Reflects reduction pursuant to P.L. 100-119 of $29,000 and lapse of FY 1991 unobligated funds of –$239,000.
[858] Includes $10 million appropriated specifically for operation and maintenance of a new visitors center at Johnson Space Center and available without fiscal year limitation.
[859] Reflects reduction of $6,000 pursuant to P.L. 100-119.
[860] Reflects lapse of FY 1991 unobligated funds in the amount of $35,000.
[861] No authorization bill passed.
[862] Details in “Summary Reconciliation of Appropriations to Budget Plan,” Fiscal Year 1993 Estimates, p. AS 10.
[863] Reflects appropriation transfer ($438,556,000), rescission pursuant to P.L. 102-298 (–$4,050,000), rescission pursuant to P.L. 102-389 (–$14.3 million), and transfer between accounts (–$6.4 million). U.S. Congress, *Rescinding Certain Budget Authority*, June 4, 1992, Public Law 102-298, 102nd Congress, 2nd sess. Also U.S. Congress, *Departments of Veterans Affairs and Housing and Urban Development, and Independent Agencies Appropriations Act, 1993*, 6 October 1992, 102nd Congress, 2nd sess.
[864] Reflects appropriation transfer of $227.7 million.
[865] Reflects appropriation transfer of –$666,256,000 and lapse of FY 1992 unobligated funds in the amount of $188,000.
[866] Reflects transfer between accounts of $6.4 million.
[867] Reflects lapse of FY 1992 unobligated funds of $723,000.
[868] U.S. Congress, *Departments of Veterans Affairs and Housing and Urban Development, and Independent Agencies Appropriations Act, 1992*, Public Law 102-139, October 28, 1991, 102nd Congress, 1st sess.
[869] Details from “Summary Reconciliation of Appropriation to Budget Plans,” Fiscal Year 1994 Estimates, p. AS 9.
[870] Reflects appropriation transfer as specified in P.L. 103-50 of $5 million. U.S. Congress, *Supplemental Appropriations Act of 1993*, July 2, 1993, Public Law 103-50, 103rd Congress, 1st sess.
[871] Reflects rescission/supplemental pursuant to P.L. 103-50 of –$27.2 million.
[872] Reflects rescission/supplemental of $20 million pursuant to P.L. 103-50 and lapse of FY 1993 unobligated funds of $178,000.
[873] Reflects appropriation transfer as specified in P.L. 103-50 of –$5 million.
[874] Reflects lapse of FY 1993 unobligated funds of $471,000.

Fiscal Year/Appropriation Title	Initial Request	Authorization	Appropriation	Adjustments to Appropriation
1994				
R&D	7,712,300	—	7,529,300	7,533,500[877]
SFC&DC	5,316,900	—	4,853,500	4,835,100[878]
R&PM	1,675,000	—	1,635,508	1,672,907[879]
CofF	545,300	—	517,700	492,700[880]
Inspector General	15,500		15,391	14,726[881]
Total	*15,265,000*	—[882]	*14,551,399*	*14,548,933*
1995				
SAT	5,901,200	—	5,901,200	5,933,500[883]
HSF	5,719,900	—	5,573,900	5,514,900[884]
MS	2,662,900	—	2,554,587	2,532,200[885]
National Aeronautical Facilities			400,000	0[886]
Inspector General	16,000	—	16,000	15,800[887]

[875] U.S. Congress, *National Aeronautics and Space Administration Authorization Act, Fiscal Year 1993*, November 4, 1992, Public Law 201-588, 102nd Congress, 2nd session.
[876] Details in "Summary Reconciliation of Appropriations to Budget Plans," Fiscal Year 1995 Estimates, p. AS-12.
[877] Reflects *FY 1994 Emergency Supplemental Appropriations Act* (P.L. 103-211) adding $4.2 million. U.S. Congress, *Making Emergency Supplemental Appropriations for the Fiscal Year Ending September 30, 1994, and for Other Purposes*, February 12, 1994, Public Law 103-211, 103rd Congress, 2nd sess.
[878] Reflects *FY 1994 Emergency Supplemental Appropriations Act* (P.L. 103-211) reducing SFC&DC appropriation by $18.4 million.
[879] Reflects *FY 1994 Emergency Supplemental Appropriations Act* (P.L. 103-211) adding $56 million, reduction of $18 million stated in P.L. 103-327, and lapse of FY 1994 unobligated funds of $601,000. U.S. Congress, *Departments of Veterans Affairs and Housing and Urban Development, and Independent Agencies Appropriations Act, 1995*, September 28, 1994, Public Law 103-327, 103rd Congress, 2nd sess.
[880] Reflects *FY 1994 Emergency Supplemental Appropriations Act* (P.L. 103-211) reducing the CofF appropriation by $25 million.
[881] Reflects lapse of FY 1994 unobligated funds.
[882] No authorization bill passed.
[883] Reflects $35,000 increase pursuant to *Department of Defense Emergency Supplemental Appropriation, FY 1995* (P.L. 104-6) Amending P.L. 103-327, $50,000 increase pursuant to *Department of Defense Appropriations Act, FY 1995* (P.L. 103-335) less final transfer from the Department of Defense for Landsat, and lapse of FY 1995 unobligated funds of $52,700. U.S. Congress, *Emergency Supplemental Appropriations and Rescissions for the Department of Defense to Preserve and Enhance Military Readiness Act of 1995*, April 10, 1995, Public Law 104-6, 104th Congress, 1st sess., *http://frwebgate.access.gpo.gov/cgi-bin/getdoc.cgi?dbname=104_cong_public_laws&docid=f:publ6.104.pdf* (accessed January 16, 2007). Also U.S. Congress, *Department of Defense Appropriations Act, 1995*, September 30, 1994, Public Law 103-335, 103rd Congress, 2nd sess.
[884] Amount stated in "Summary Reconciliation of Appropriations to Budget Plans," FY 1997 Estimates.
[885] Reflects *FY 1995 Emergency Supplemental Appropriations Act* (P.L. 104-19) reducing appropriated amount by $39.3 million and lapse of FY 1995 unobligated funds of $1.1 million. U.S. Congress, *Emergency Supplemental Appropriations for Additional Disaster Assistance, for Anti-terrorism Initiatives, for Assistance in the Recovery from the Tragedy that Occurred at Oklahoma City, and Rescissions Act, 1995*, July 27, 1995, Public Law 104-19, 104th Congress, 1st sess.
[886] Reflects elimination of all funding pursuant to the *Department of Defense Emergency Supplemental Appropriation, FY 1995* (P.L. 104-6) Amending P.L. 103-327.

Fiscal Year/Appropriation Title	Initial Request	Authorization	Appropriation	Adjustments to Appropriation
Total	*14,300,000*	—[888]	*14,445,687*[889]	*13,996,400*[890]
1996				
SAT	6,006,900	—	5,928,900	5,878,900[891]
HSF	5,509,600	—	5,456,600	5,506,600[892]
MS	2,726,200	—	2,502,200	2,482,600[893]
Inspector General	17,300	—	16,000	15,900[894]
Total	*14,260,000*	—[895]	*13,903,700*[896]	*13,884,000*[897]
1997				
SAT	5,862,100	—	5,762,100	5,878,900[898]
HSF	5,362,900	—	5,362,900	5,539,900[899]
MS	2,562,200	—	2,562,200	2,562,200
Inspector General	17,000	—	17,000	17,000
Total	*13,804,200*	—[900]	*13,704,200*[901]	*13,998,000*
1998				
SAT	5,642,000	—	5,690,000	5,690,000
HSF	5,326,500	—	5,506,500	5,559,500[902]

[887] Reflects lapse of FY 1995 unobligated funds of $200,000.
[888] No authorization bill passed.
[889] P.L. 103-327.
[890] Details provided in "Summary Reconciliation of Appropriations to Budget Plan," Fiscal Year 1997 Estimates, p. AS-16.
[891] Reflects reduction of $50,000,000 in accordance with the appropriations transfer authority of the *FY 1996 Omnibus Appropriations Act*. U.S. Congress, *Omnibus Consolidated Rescissions and Appropriations Act of 1996*, April 26, 1996, Public Law 104-134. 104th Congress, 2nd sess., *http://www.nps.gov/legal/laws/104th/104-134.pdf* (accessed January 16, 2007).
[892] Reflects addition of $50 million in accordance with the appropriations transfer authority of *FY 1996 Omnibus Appropriations Act* (P.L. 104-134).
[893] Reflects amount stated in "Summary Reconciliation of Appropriations to Budget Plans," FY 1998 Estimates, and $500,000 reduction due to lapse of FY 1996 unobligated funds.
[894] Reflects $100,000 reduction due to lapse of FY 1996 unobligated funds.
[895] No authorization bill passed.
[896] P.L. 104-134. Direction included in Conference Report H.R. 104-384.
[897] Details provided in "Summary Reconciliation of Appropriations to Budget Plans," Fiscal Year 1998 Estimates.
[898] Reflects reduction of $177,000 due to appropriations transfer authority in *VA-HUD Independent Agencies Appropriations Act, FY 1997* (P.L. 104-204) and $5,000,000 increase due to *Omnibus Consolidated Appropriations Act* (P.L. 104-208). U.S. Congress, *Departments of Veterans Affairs and Housing and Urban Development, and Independent Agencies Appropriations Act, 1997,* September 26, 1996, Public Law 104-204, 104th Congress, 2nd sess. Also U.S. Congress, *Omnibus Consolidated Appropriations Act, 1997*, September 30, 2006, Public Law 104-208, 104th Congress, 2nd sess.
[899] Reflects increase of $177,000 due to appropriations transfer authority in *VA-HUD Independent Agencies Appropriations Act, FY 1997* (P.L. 104-204).
[900] No authorization bill passed.
[901] P.L. 104-204, September 26, 1996.

Fiscal Year/Appropriation Title	Initial Request	Authorization	Appropriation	Adjustments to Appropriation
MS	2,513,200	—	2,433,200	2,380,000[903]
Inspector General	18,300	—	18,300	18,200[904]
Total	*13,500,000*	—[905]	*13,648,000*[906]	*13,647,700*[907]

Source: Annual authorization and appropriation legislation, annual NASA budget estimates.

[902] Reflects increase of $53,000,000 pursuant to the appropriations transfer authority of the *1998 Supplemental Appropriations and Rescissions Act*. U.S. Congress, *1998 Supplemental Appropriations and Rescissions Act*, May 1, 1998, Public Law 105-174, 105th Congress, 2nd sess., *http://frwebgate.access.gpo.gov/cgi-bin/getdoc.cgi?dbname=105_cong_public_laws&docid=f:publ174.pdf* (accessed January 16, 2007).
[903] Reflects decrease of $53 million pursuant to the appropriations transfer authority of the *1998 Supplemental Appropriations and Rescissions Act* (P.L. 105-174) and lapse of FY 1998 unobligated funds of $400,000.
[904] Reflects lapse of FY 1998 unobligated funds of $100,000.
[905] No authorization bill passed.
[906] U.S. Congress, *Department of Veterans Affairs and Housing and Urban Development, and Independent Agencies Appropriations Act, 1998,* October 27, 1997, Public Law 105-65, 105th Congress, 1st sess., *http://frwebgate.access.gpo.gov/cgi-bin/getdoc.cgi?dbname=105_cong_public_laws&docid=f:publ65.pdf* (accessed January 16, 2007).
[907] Details provided in "Summary Reconciliation of Appropriations to Budget Plans," Fiscal Year 2000 Estimates.

Table 7-4A. Appropriations Compared with Budget Requests: FY 1989–FY 1994 (in millions of dollars)

	Research and Development		Space Flight, Control, and Data Communications		Research and Program Management		Construction of Facilities		Inspector General		Total	
	Amount	**Percent**	**Amount**	**Percent**	**Amount**	**Percent**	**Amount**	**Percent**	**Amount**	**Percent**	**Amount**	**Percent**
FY 1989												
Request	4,446,700		4,841,200		1,855,000		285,100		—	—	11,488,800	93.1
Appr.	4,191,700	94.3	4,364,200	90.2	1,915,000	103.2	275,100	96.5	—[908]	—	10,701,000[909]	
FY 1990												
Request	5,751,600		5,139,600		2,032,200		341,800		8,795		13,273,995	93.8
Appr.	5,281,876	91.8	4,618,074	89.9	1,951,476	96.0	591,980	173.2	8,659	98.5	12,452,065	
FY 1991												
Request	7,074,000		5,289,400		2,252,900		497,900		11,000		15,125,200	99.8
Appr.	6,023,600	85.2	6,334,132	119.8	2,211,900	98.2	507,900	102.0	10,500	95.5	15,088,032	
FY 1992												
Request	7,198,500		5,608,273		2,452,300		480,300		14,600		15,753,973	91.1
Appr.	6,413,800	89.1	5,157,075	92.0	2,242,300	91.4	525,000	109.3	14,600	100.0	14,352,775	

[908] Inspector General appropriation not included in FY 1989 budget documents.
[909] Includes $15 million appropriation for a trust fund.

	Research and Development		Space Flight, Control, and Data Communications		Research and Program Management		Construction of Facilities		Inspector General		Total	
	Amount	**Percent**	**Amount**	**Percent**	**Amount**	**Percent**	**Amount**	**Percent**	**Amount**	**Percent**	**Amount**	**Percent**
FY 1993												
Request	7,731,400		5,266,500		1,660,027		319,200		15,900		14,993,027	95.6
Appr.	7,089,300	91.7	5,086,000	96.6	1,615,014	97.3	525,000	164.5	15,062	94.7	14,330,376	
FY 1994												
Request	7,712,300		5,316,900		1,675,000		545,300		15,500		15,265,000	95.3
Appr.	7,529,300	97.6	4,853,500	91.3	1,635,907	97.7	517,700	94.9	15,391	99.3	14,548,933	

Source: Table 7-3.

Table 7-4B. Appropriations Compared with Budget Requests: FY 1995–FY 1998 (in millions of dollars)

	Science, Aeronautics and Technology		Human Spaceflight		Mission Support		Inspector General		Total	
	Amount	Percent	Amount	Percent	Amount	Percent	Amount	Percent	Amount	Percent
FY 1995										
Request	5,901,200		5,719,900		2,662,900		16,000		14,300,000	
Appr.	5,901,200	100.0	5,573,900	97.5	2,554,587	95.9	16,000	100.00	14,445,687 [910]	101.0
FY 1996										
Request	6,006,900		5,509,600		2,726,200		17,300		14,260,000	
Appr.	5,928,900	98.7	5,456,600	99.0	2,502,200	91.8	16,000	92.5	13,903,700	97.5
FY 1997										
Request	5,862,100		5,362,900		2,562,200		17,000		13,804,200	
Appr.	5,762,100	98.3	5,362,900	100.0	2,562,200	100.0	17,000	100.0	13,604,200	98.6
FY 1998										
Request	5,642,000		5,326,500		2,513,200		18,300		13,500,000	
Appr.	5,690,000	100.9	5,506,500	103.4	2,433,200	96.8	18,300	100.0	13,648,700	101.1

Source: Table 7-4.

[910] Includes $400 million for National Aeronautical Facilities.

Table 7-5. Budget Requests, Authorizations, Appropriations, and Obligations: FY 1989–FY 1998 (in millions of dollars)

Fiscal Year	Budget Request	Authorization[911]	Appropriation	Obligation	Expenditure (Operating Plan)
1989	11,488.8	11,213.4	10,701.0	12,299.7	10,897.3
1990	13,274.0	—	12,452.1	13,955.3	12,295.2
1991	15,125.2	—	15,088.0	14,687.0	13,867.8
1992	15,754.0	14,896.5	14,352.8	15,150.0	14,333.5
1993	14,993.0	14,937.1	14,330.4	14,860.8	14,322.5
1994	15,265.0	—	14,551.4	14,645.2	14,548.9
1995	14,300.0	—	14,445.7	15,097.0	13,996.0
1996	14,260.0	—	13,903.7	14,403.3	13,884.0
1997	13,804.2	—	13,704.2	14,594.2	13,708.7
1998	13,500.0	—	13,648.0	14,430.1	13,647.7
Total	*141,764.2*	—	*137,177.3*	*144,122.6*	*135,501.6*

Source: Annual Procurement Report, FY 1991–FY 2000 Budget Estimates.

[911] No authorization bill passed for FYs 1990, 1991, 1994, 1995, 1996, 1997, and 1998.

Table 7-6. Research and Program Management Funding by Installation: FY 1989–FY 1992 (in thousands of dollars)[912]

Installation	1989	1990	1991	1992
Ames Research Center	177,775	187,340	211,155	158,860
Goddard Space Flight Center	254,502	264,636	303,006	249,989
Johnson Space Center	299,435	320,630	338,460	245,944
Kennedy Space Center	268,723	277,438	298,955	155,464
Langley Research Center	189,190	197,879	214,531	172,851
Lewis Research Center	196,188	206,006	230,060	172,326
Marshall Space Flight Center	253,417	269,267	286,155	231,657
Stennis Space Center	23,526	25,137	28,536	14,264
Headquarters	263,609	274,822	300,774	174,501
Total R&PM	*1,926,365*	*2,023,155*	*2,211,632*	*1,575,856*

Source: Tables 5-22, 5-27, 5-37, 5-46, 5-51, 5-56, 5-61, 5-66, 5-71.

[912] Appropriations were reconfigured with the FY 1994 budget, which was the final year showing R&PM funding data (FY 1992).

Table 7-7. Research and Development Funding by Installation: FY 1989–FY 1992 (in thousands of dollars)[913]

Installation	1989	1990	1991	1992
Ames Research Center	288,416	307,941	349,951	427,959
Goddard Space Flight Center	641,839	921,290	1,153,016	1,156,939
Jet Propulsion Laboratory	583,621	572,450	649,292	670,556
Johnson Space Center	561,678	1,036,648	1,161,735	1,419,927
Kennedy Space Center	112,020	150,278	210,292	269,752
Langley Research Center	241,296	250,980	279,441	341,978
Lewis Research Center	389,314	497,888	554,493	679,608
Marshall Space Flight Center	946,419	960,375	966,059	962,507
Stennis Space Center	16,303	12,176	16,540	24,069
Headquarters	456,694	517,669	682,703	875,010
Total R&D	*4,237,600*	*5,227,695*	*6,023,522*	*6,828,305*

Source: Tables 5-22, 5-27, 5-37, 5-41, 5-46, 5-51, 5-56, 5-61, 5-66, 5-71.

[913] Appropriations were reconfigured with the FY 1994 budget, which was the final year showing R&D funding data (FY 1992).

Table 7-8. Space Flight, Control, and Data Communications Funding by Installation: FY 1989–FY 1992 (in thousands of dollars)[914]

Installation	1989	1990	1991	1992
Ames Research Center	16,700	18,700	18,600	18,900
Goddard Space Flight Center	548,259	632,636	674,180	665,623
Jet Propulsion Laboratory	124,669	153,966	150,399	177,739
Johnson Space Center	1,049,250	1,129,200	1,185,700	1,297,921
Kennedy Space Center	824,200	857,300	923,700	1,081,700
Langley Research Center	14,300	3,800	330	201
Lewis Research Center	11,000	56,400	122,760	46,500
Marshall Space Flight Center	1,760,400	1,677,138	1,937,275	1,678,301
Stennis Space Center	21,300	26,900	24,600	37,600
Headquarters	81,522	68,787	86,790	161,291
Total SFC&DC	*4,451,600*	*4,624,827*	*5,124,334*	*5,165,776*

Source: Tables 5-22, 5-27, 5-37, 5-41, 5-46, 5-51, 5-56, 5-61, 5-66, 5-71.

[914] Appropriations were reconfigured with the FY 1994 budget, which was the final year showing SFC&DC funding data (FY 1992).

Table 7-9. Construction of Facilities Funding by NASA Installation: FY 1989–FY 1992 (in thousands of dollars)[915]

Facility	1989	1990	1991	1992
Ames Research Center	29,098	45,019	27,550	62,748
Goddard Space Flight Center	14,104	30,067	36,942	44,502
Jet Propulsion Laboratory	4,376	12,141	34,562	12,399
Johnson Space Center	24,925	59,746	53,891	31,523
Kennedy Space Center	24,571	60,602	66,633	61,078
Langley Research Center	29,217	25,515	33,955	31,355
Lewis Research Center	26,683	33,804	43,262	22,765
Marshall Space Flight Center	37,269	30,629	63,671	56,459
Stennis Space Center	21,045	11,843	25,595	16,786
Headquarters	16,100	3,272	8,642	1,936
Total Construction of Facilities	*227,388*	*312,638*	*394,703*	*341,551*

Source: Tables 5-22, 5-27, 5-37, 5-41, 5-46, 5-51, 5-56, 5-61, 5-66, 5-71.

[915] Appropriations were reconfigured with FY 1994 budget, which was the final year showing CofF funding data (FY 1992).

Table 7-10. Human Spaceflight Funding by NASA Installation: FY 1993–FY 1998 (in thousands of dollars)

Installation	1993	1994	1995	1996	1997	1998
Ames Research Center	7,200	0	0	26,296	14,935	22,052
Dryden Flight Research Center	—[916]	5,700	6,100	5,600	5,400	5,800
Goddard Space Flight Center	14,400	9,200	12,050	10,365	8,500	13,269
Jet Propulsion Laboratory	1,500	400	15	2,600	2,750	702
Johnson Space Center	2,329,400	1,604,300	2,804,237	3,073,329	3,802,521	3,856,106
Kennedy Space Center	1,250,200	1,125,200	1,024,560	935,249	281,400	303,458
Langley Research Center	3,400	1,600	1,521	5,167	8,700	7,352
Lewis Research Center	364,200	132,300	17,500	44,136	20,299	31,350
Marshall Space Flight Center	2,316,600	1,887,100	1,537,508	1,502,684	1,463,046	1,263,768
Stennis Space Center	41,000	39,500	51,200	53,300	52,200	47,216
Headquarters	344,100	97,600	60,209	51,674	15,049	8,427
Total Human Spaceflight	*6,672,000*	*4,902,900*	*5,514,900*	*5,710,400*	*5,674,800*	*5,559,500*

Source: Tables 5-22, 5-27, 5-32, 5-37, 5-41, 5-46, 5-51, 5-56, 5-61, 5-66, 5-71.

[916] Included with Ames Research Center.

Table 7-11. Science, Aeronautics, and Technology Funding by NASA Installation: FY 1993–FY 1998 (in thousands of dollars)

Installation	1993	1994	1995	1996	1997	1998
Ames Research Center	475,175	447,756	456,122	390,835	354,383	381,594
Dryden Flight Research Center	—[917]	51,700	62,119	86,697	93,905	140,327
Goddard Space Flight Center	1,669,133	1,825,311	2,123,862	1,975,293	2,190,562	2,048,068
Jet Propulsion Laboratory	778,524	878,652	923,045	1,037,248	845,965	1,077,650
Johnson Space Center	167,812	231,081	146,897	103,969	90,571	94,280
Kennedy Space Center	37,495	40,040	50,462	28,334	35,285	245,646
Langley Research Center	312,313	443,964	376,798	390,138	424,036	419,067
Lewis Research Center	388,804	557,467	497,670	428,097	472,620	374,334
Marshall Space Flight Center	412,920	518,889	612,523	609,852	713,427	686,553
Stennis Space Center	8,691	10,559	20,015	69,067	87,930	60,800
Headquarters	657,889	713,062	647,887	559,870	144,416	162,051
Total Science, Aeronautics, and Technology	*4,908,756*	*5,718,481*	*5,917,400*	*5,679,400*	*5,453,100*	*5,690,370*

Source: Tables 5-22, 5-27, 5-32, 5-37, 5-41, 5-46, 5-51, 5-56, 5-61, 5-66, 5-71.

[917] Included with Ames Research Center.

Table 7-12. Mission Support Funding by NASA Installation: FY 1993–FY 1998 (in thousands of dollars)

Installation	1993	1994	1995	1996	1997	1998
Ames Research Center	217,673	184,914	174,975	173,609	186,791	179,053
Dryden Flight Research Center	—[918]	39,764	49,335	43,867	59,284	61,820
Goddard Space Flight Center	590,653	486,860	494,415	525,697	548,359	411,012
Jet Propulsion Laboratory	27,152	23,209	22,174	30,097	29,292	23,478
Johnson Space Center	350,434	354,634	376,023	370,764	378,280	342,525
Kennedy Space Center	277,030	278,806	257,364	251,359	246,440	248,364
Langley Research Center	227,885	229,256	227,805	212,500	220,279	226,182
Lewis Research Center	249,629	240,281	221,675	222,192	234,938	261,368
Marshall Space Flight Center	375,132	432,584	378,722	353,140	378,707	379,988
Stennis Space Center	35,374	40,677	35,795	39,295	48,562	49,637
Headquarters	338,137	310,915	289,292	246,349	230,057	192,877
Total Mission Support	*2,689,099*	*2,621,900*	*2,527,575*	*2,468,869*	*2,560,989*	*2,376,304*

Source: Tables 5-22, 5-27, 5-32, 5-37, 5-41, 5-46, 5-51, 5-56, 5-61, 5-66, 5-71.

[918] Included with Ames Research Center.

Table 7-13A. Research and Development/Science, Aeronautics, and Technology Funding by Program: FY 1989–FY 1993 (in thousands of dollars)

Program/Fiscal Year	1989	1990	1991	1992	1993
Space Station	900,000	1,749,600	1,900,000	—	—
Space Station and New Technology Investments	—	—	—	2,002,800	—
Space Transportation Capability Development	674,000	—	602,500	739,700	—
Launch Services	—	—	—	—	180,800
Space Science	—	—	—	—	1,510,400
Life and Microgravity Sciences and Applications	—	—	—	—	407,500
Earth Science/Mission to Planet Earth	403,400	434,200	—	—	936,300
Physics and Astronomy	737,400	859,400	969,200	1,036,700	—
Life Sciences	79,100	106,100	137,400	157,600	—
Planetary Exploration	416,600	390,800	473,700	534,200	—
Space Applications	—	—	850,800	985,100	—
Materials Processing	75,600	101,900	—	—	—
Communications	92,200	77,700	—	—	—
Mission Communication Services	—	—	—	—	546,500
Information Systems	19,900	28,200	—	—	—
Commercial Programs	—	56,500	88,000	147,600	
Academic Programs	—	37,500	55,100	66,800	92,900
Technology Utilization	16,500	—	—	—	—
Commercial Use of Space	28,200		—	—	—
Aeronautics and Space Transportation Technology	—	—	—	—	—
Aeronautical Research and Technology	398,200	442,600	512,000	788,200	769,400
National Aeronautics Facilities	—	—	—	—	—
Space Access and Technology	—	—	—	—	—
Advanced Concepts and Technology	—	—	—	—	464,900
Transatmospheric Research and Technology	69,400	59,000	95,000	4,100	—
Space Research and Technology	285,900	284,100	286,900		—
Safety, Reliability and Quality Assurance	22,400	22,600	33,000	33,600	—
Tracking and Data Advanced Systems	18,800	19,400	20,000	22,000	—
Total	*4,237,600*	*4,669,600*	*6,023,600*	*6,518,400*	*4,908,700*

Table 7-13B. Research and Development/Science, Aeronautics, and Technology Funding by Program: FY 1994–FY 1998 (in thousands of dollars)

Program/Fiscal Year	1994	1995	1996	1997	1998
Space Station	—	—	—	—	—
Space Station and New Technology Investments	—	—	—	—	—
Space Transportation Capability Development	—	—	—	—	—
Launch Services	—	—	—	—	—
Space Science	1,920,900	2,032,600	2,175,900	1,969,300	2,043,800
Life and Microgravity Sciences and Applications	507,500	467,400	304,200	243,700	214,200
Earth Science/Mission to Planet Earth	1,068,000	1,334,100	1,360,800	1,367,300	1,417,300
Physics and Astronomy	—	—	—	—	—
Life Sciences	—	—	—	—	—
Planetary Exploration	—	—	—	—	—
Space Applications	—	—	—	—	—
Materials Processing	—	—	—	—	—
Communications	—	—	—	—	—
Mission Communication Services	581,000	481,200	449,500	418,600	400,800
Information Systems	—	—	—	—	—
Commercial Programs	—	—	—	—	—
Academic Programs	85,500	106,200	—	120,400	130,000
Technology Utilization	—	—	—	—	—
Commercial Use of Space	—	—	—	—	—
Aeronautics and Space Transportation Technology	—	—	1,270,100	1,339,500	1,483,900
Aeronautical Research and Technology	1,067,200	845,500	—	—	—
National Aeronautics Facilities	—	35,000	—	—	—
Space Access and Technology	562,400	605,400	—	—	—
Advanced Concepts and Technology	—	—	—	—	—
Transatmospheric Research and Technology	—	—	—	—	—
Space Research and Technology	—	—	—	—	—
Safety, Reliability and Quality Assurance	—	—	—	—	—
Tracking and Data Advanced Systems	—	—	—	—	—
Total	*5,792,500*	*5,907,400*	*5,560,500*	*5,458,800*	*5,690,000*

Source: Research and Development and Science Aeronautics and Technology General Statements, Annual Budget Estimates, FY 1991–FY 2000.
Note: The appearance or disappearance of program funding for any one program listed in this table does not necessarily mean the program was new or had been eliminated. The program may have been moved to a different appropriation category during a reorganization (for example, Space Station moved to Human Spaceflight), become a subelement of another program, or become an independent program after it had been a subelement of another program.

Table 7-14A. Space Flight, Control, and Data Communications/Human Spaceflight Funding by Program: FY 1989–FY 1993 (in thousands of dollars)

Program/Fiscal Year	**1989**	**1990**	**1991**	**1992**	**1993**
Shuttle Production and Operational Capability	1,121,600	1,194,900	1,314,000	1,296,400	—
Space Transportation/Shuttle Operations	2,612,700	2,632,400	2,752,400	3,029,300	—
Space and Ground Networks, Communication and Data Systems	717,300	797,500	828,800	903,300	—
Space Shuttle	—	—	—	—	3,988,200
Expendable Launch Vehicles	—	—	229,200	—	—
Launch Services	—	—	—	155,800	—
Space Station	—	—	—	—	2,162,000
U.S.-Russian Cooperative Program	—	—	—	—	79,500
Payload and Utilization Operations	—	—	—	—	442,300
Total	*4,451,600*	*4,624,900*	*5,124,400*	*5,384,800*	*6,672,000*

Table 7-14B. Space Flight, Control, and Data Communications/Human Spaceflight Funding by Program: FY 1994–FY 1998 (in thousands of dollars)

Program/Fiscal Year	**1994**	**1995**	**1996**	**1997**	**1998**
Shuttle Production and Operational Capability	—	—	—	—	—
Space Transportation/Shuttle Operations	—	—	—	—	—
Space and Ground Networks, Communication and Data Systems	—	—	—	—	—
Space Shuttle	3,558,700	3,155,100	3,143,800	2,960,900	2,912,800
Expendable Launch Vehicles	—	—	—	—	—
Launch Services	—	—	—	—	—
Space Station	1,939,200	1,889,600	2,143,600	2,148,600	2,331,300
U.S.-Russian Cooperative Program	170,800	150,100	100,000	300,000	—
Payload and Utilization Operations	405,600	320,100	323,000	265,300	205,400
Total	*6,074,300*	*5,514,900*	*5,710,400*	*5,674,800*	*5,449,500*

Source: Space Flight Control and Data Communications and Human Spaceflight General Statements, Annual Budget Estimates.

Table 7-15. Total Procurement Award Value by Type of Contractor and Method of Procurement: FY 1989–FY 1998 (in millions of dollars)

Type of Contractor	Value of Award	Percentage Awarded
Small Business Firms	10,767.6	8.4
Large Business Firms	89,149.1	69.9
All Business Firms	99,716.7	78.2
Nonprofit Institutions	3,329.9	2.6
Educational Institutions	6,562.5	5.1
Jet Propulsion Laboratory	11,278.1	8.8
Government Agencies	5,416.0	4.2
Contractors Outside the United States	1,240.4	1.0
Total	*127,543.6*	*100.0*
Method of Procurement (Business)		
Number of Awards with Business Firms (thousands)	811.5	83.3

Table 7-16A. Value of Awards by Type of Contractor and Fiscal Year: FY 1989–FY 1993 (in millions of dollars)

Type of Contractor	FY 1989		FY 1990		FY 1991		FY 1992		FY 1993	
	Value	**Percentage**	**Value**	**Percentage**	**Value**	**Percentage**	**Value**	**Percentage**	**Value**	**Percentage**
Business Firms	8,567.6	78.8	10,071.5	80.2	10,417.3	79.2	10,716.7	79.5	10,497.9	79.8
Nonprofit Institutions	180.0	1.7	200.6	1.6	244.0	1.9	297.8	2.2	707.8	5.4
Educational Institutions	464.2	4.3	513.6	4.1	592.0	4.5	659.3	4.9	336.6	2.6
Jet Propulsion Laboratory	1,058.1	9.7	1,106.8	8.8	1,139.6	8.7	1,229.6	9.1	1,029.8	7.8
Government Agencies	543.2	5.0	610.4	4.9	693.4	5.3	498.6	3.7	508.4	3.9
Contractors Outside the United States	63.3	0.6	62.3	0.5	72.7	0.6	76.2	0.6	79.9	0.6
Total	*10,876.4*	*100.1*	*12,565.2*	*100.1*	*13,159.0*	*100.2*	*13,478.2*	*100.0*	*13,160.4*	*100.1*

Note: Numbers may not add up to 100 due to rounding.

Table 7-16B. Value of Awards by Type of Contractor and Fiscal Year: FY 1994–FY 1998 (in millions of dollars)

Type of Contractor	FY 1994		FY 1995		FY 1996		FY 1997		FY 1998	
	Value	**Percentage**	**Value**	**Percentage**	**Value**	**Percentage**	**Value**	**Percentage**	**Value**	**Percentage**
Business Firms	9,965.7	77.2	10,311.5	77.3	9,800.8	77.2	9,817.2	76.8	9,550.5	76.0
Nonprofit Institutions	311.0	2.4	311.1	2.3	287.9	2.3	383.4	3.0	406.3	3.2
Educational Institutions	730.9	5.7	814.4	6.1	745.7	5.9	807.7	6.3	898.1	7.1
Jet Propulsion Laboratory	1,093.4	8.5	1,135.0	8.5	1,188.3	9.4	1,126.2	8.8	1,171.3	9.3
Government Agencies	642.6	5.0	562.7	4.2	484.7	3.8	464.3	3.6	407.7	3.2
Contractors Outside the United States	169.5	1.3	206.7	1.5	191.8	1.5	190.7	1.5	127.3	1.0
Total	*12,913.1*	*100.1*	*13,341.4*	*99.9*	*12,699.2*	*100.1*	*12,789.5*	*100.0*	*12,561.2*	*99.80*

Note: Numbers may not add up to 100 due to rounding.

Table 7-17A. Value of Awards to Small and Large Business Firms by Fiscal Year: FY 1989–FY 1993

Type of Business	**FY 1989**		**FY 1990**		**FY 1991**		**FY 1992**		**FY 1993**	
	Value	**Percentage**	**Value**	**Percentage**	**Value**	**Percentage**	**Value**	**Percentage**	**Value**	**Percentage**
Small Business Firms	*857.3*[919]	10.0	924.3[920]	9.2	968.3[921]	9.3	1,010.6[922]	9.4	1,060.7[923]	10.1
Large Business Firms	7,710.3	90.0	9,147.2	90.8	9,449.0	90.7	9,706.1	90.6	9,437.2	89.9
Total	*8,567.6*	*100.0*	*10,071.5*	*100.0*	*10,417.3*	*100.0*	*10,716.7*	*100.0*	*10,497.9*	*100.0*

[919] Includes $184.7 million awarded to small minority firms under the authority of Section 8(a) of the Small Business Act. Also includes $51.8 million awarded through the Small Business Innovation Research (SBIR) Program.
[920] Includes $212.7 million awarded to small minority firms under the authority of Section 8(a) of the Small Business Act. Also includes $61.6 million awarded through the SBIR Program.
[921] Includes $225.6 million awarded to small minority firms under the authority of Section 8(a) of the Small Business Act. Also includes $69.3 million awarded through the SBIR Program.
[922] Includes $232.1 million awarded to small disadvantaged firms under the authority of Section 8(a) of the Small Business Act. Also includes $79.0 million awarded through the SBIR Program.
[923] Includes $232.1 million awarded to small disadvantaged firms under the authority of Section 8(a) of the Small Business Act. Also includes $79.0 million awarded through the SBIR Program.

Table 7-17B. Value of Awards to Small and Large Business Firms by Fiscal Year: FY 1994–FY 1998

Type of Business	FY 1994		FY 1995		FY 1996		FY 1997		FY 1998	
	Value	**Percentage**	**Value**	**Percentage**	**Value**	**Percentage**	**Value**	**Percentage**	**Value**	**Percentage**
Small Business Firms	1,150.2[924]	11.5	1,171.2[925]	11.4	1,162.5[926]	11.9	1,244.2[927]	12.7	1,218.3[928]	12.8
Large Business Firms	8,815.5	88.5	9,140.3	88.6	8,638.3	90.2	8,573.0	87.2	8,332.2	87.2
Total	*9,965.7*	*100.0*	*10,311.5*	*100.0*	*9,800.8*	*100.1*	*9,817.2*	*100.0*	*9,550.5*	*100.0*

[924] Includes $314.2 million awarded to small minority firms under the authority of Section 8(a) of the Small Business Act. Also includes $117.6 million awarded through the SBIR and Small Business Technology Transfer (SBTT) Programs.
[925] Includes $264.8 million awarded to small minority firms under the authority of Section 8(a) of the Small Business Act. Also includes $86.0 million awarded through the SBIR Program.
[926] Includes $342.5 million awarded to small minority firms under the authority of Section 8(a) of the Small Business Act. Also includes $127.2 million awarded through the SBIR and Small Business Technology Transfer Programs.
[927] Includes $329.2 million awarded to small minority firms under the authority of Section 8(a) of the Small Business Act. Also includes $128.3 million awarded through the SBIR and SBTT Programs.
[928] Includes $335.1 million awarded to small minority firms under the authority of Section 8(a) of the Small Business Act. Also includes $134.6 million awarded through the SBIR and SBTT Programs.

Table 7-18. Total Number of Procurement Actions by Type of Contractor: FY 1989–FY 1998 (in thousands)

Type of Contractor	**Number (thousands)**	**Percentage**
Small Business Firms	576.5	71
Large Business Firms	235	29
All Business Firms	811.5	83.3
Nonprofit Institutions	23.6	2.4
Educational Institutions	79.2	8.1
Jet Propulsion Laboratory	17.7	1.8
Government Agencies	38.8	4.0
Contractors Outside the United States	3.7	0.4
Total	*974.5*	*100.00*

Table 7-19A. Number of Procurement Actions by Type of Contractor and Fiscal Year: FY 1989–FY 1993 (actions in thousands)

Type of Contractor	**FY 1989**		**FY 1990**		**FY 1991**		**FY 1992**		**FY 1993**	
	Number	**Percentage**	**Number**	**Percentage**	**Number**	**Percentage**	**Number**	**Percentage**	**Number**	**Percentage**
Business Firms	95.1	86.9	99.5	86.3	97.5	85.6	94.8	84.8	92.8	83.7
Nonprofit Institutions	2.0	1.8	2.4	2.1	2.4	2.1	2.8	2.5	2.9	2.6
Educational Institutions	6.4	5.9	7.0	6.1	7.6	6.7	8.2	7.3	8.2	7.4
Jet Propulsion Laboratory	1.7	1.6	1.8	1.6	2.3	2.0	1.8	1.6	2.3	2.1
Government Agencies	3.8	3.5	4.1	3.6	3.8	3.3	3.8	3.4	4.3	3.9
Contractors Outside the United States	0.4	0.4	0.5	0.4	0.3	0.3	0.4	0.4	0.4	0.4
Total	*109.4*	*100.0*	*115.3*	*100.0*	*113.9*	*100.0*	*111.8*	*100.0*	*110.9*	*100.1*

Note: Percentages may not equal 100 due to rounding.

Table 7-19B. Number of Procurement Actions by Type of Contractor and Fiscal Year: FY 1994–FY 1998 (actions in thousands)

Type of Contractor	FY 1994		FY 1995		FY 1996		FY 1997		FY 1998	
	Number	Percentage	Number	Percentage	Number	Percentage	Number	Percentage	Number	Percentage
Business Firms	72.8	80.7	90.0	83.6	59.5	80.3	58.9	79.7	50.6	75.2
Nonprofit Institutions	2.3	2.5	2.6	2.4	2.0	2.7	2.0	2.7	2.2	13.4
Educational Institutions	7.6	8.4	9.8	9.1	7.5	10.1	7.9	10.7	9.0	3.3
Jet Propulsion Laboratory	3.5	3.9	1.0	0.9	0.8	1.1	1.0	1.4	1.5	2.2
Government Agencies	3.7	4.1	4.0	3.7	4.0	5.4	3.7	5.0	3.6	5.3
Contractors Outside the United States	0.3	0.3	0.3	0.3	0.3	0.4	0.4	0.5	0.4	0.6
Total	*90.2*	*99.9*	*107.7*	*100.0*	*74.1*	*100.0*	*73.9*	*100.0*	*67.3*	*100*

Note: Percentages may not equal 100 due to rounding.

Table 7-20A. Number of Procurement Actions Awarded to Small and Large Business Firms by Fiscal Year: FY 1989–FY 1993 (number in thousands)

Type of Business	FY 1989		FY 1990		FY 1991		FY 1992		FY 1993	
	Number	**Percentage**	**Number**	**Percentage**	**Number**	**Percentage**	**Number**	**Percentage**	**Number**	**Percentage**
Small Business Firms	68.9	72.5	73	73.4	70.3	72.1	68.7	72.5	67.2	72.4
Large Business Firms	26.2	27.5	26.5	26.6	27.2	27.9	26.1	27.5	25.6	27.6
Total	*95.1*	*100.0*	*99.5*	*100.0*	*97.5*	*100.0*	*94.8*	*100.0*	*92.8*	*100.0*

Table 7-20B. Number of Procurement Actions Awarded to Small and Large Business Firms by Fiscal Year: FY 1994–FY 1998 (number in thousands)

Type of Business	**FY 1994**		**FY 1995**		**FY 1996**		**FY 1997**		**FY 1998**	
	Number	**Percentage**	**Number**	**Percentage**	**Number**	**Percentage**	**Number**	**Percentage**	**Number**	**Percentage**
Small Business Firms	52.7	72.4	63.4	70.4	40.1	67.4	39.8	67.6	32.4	64.0
Large Business Firms	20.1	27.6	26.6	29.6	19.4	32.6	19.1	32.4	18.2	36.0
Total	*72.8*	*100.0*	*90*	*100.0*	*59.5*	*100.0*	*58.9*	*100.0*	*50.6*	*100.0*

Table 7-21A. Value of Awards to Business Firms by Type of Procurement and Fiscal Year: FY 1989–FY 1993 (in millions of dollars)

Type of Action	FY 1989		FY 1990		FY 1991		FY 1992		FY 1993	
	Value	Percentage	Value	Percentage	Value	Percentage	Value	Percentage	Value	Percentage
Competitive	6,995.8	80.4	8,318.4	81.5	8,169.8	77.3	8,660.9	79.6	8,635.6	81.1
Noncompetitive	1,376.3	15.8	1,338.5	13.1	782.8	7.4	780.2	7.2	699.0	6.6
Follow-on	333.4	3.8	545.4	5.4	1,610.1	15.3	1,436.2	13.2	1,314.5	12.3
Total[929]	*8,795.5*	*100.0*	*10,202.3*	*100.0*	*10,562.7*	*100.0*	*10,877.3*	*100.0*	*10,649.1*	*100.0*

[929] Does not include new contracts valued below $10,000.

Table 7-21B. Value of Awards to Business Firms by Type of Procurement and Fiscal Year: FY 1994–FY 1998 (in millions of dollars)

Type of Action	FY 1994		FY 1995		FY 1996		FY 1997		FY 1998	
	Value	Percentage	Value	Percentage	Value	Percentage	Value	Percentage	Value	Percentage
Competitive	7,202.3	71.0	6,944.6	66.0	6,486.7	64.5	5,399.4	54.0	5,255.3	54.2
Noncompetitive	1,790.2	17.7	2,532.2	24.0	2,661.2	26.4	3,816.1	38.1	3,643.1	37.6
Follow-on	1,145.9	11.3	1,048.8	10.0	916.4	9.1	789.3	7.9	797.8	8.2
Total[930]	*10,138.4*	*100.0*	*10,525.6*	*100.0*	*10,064.3*	*100.0*	*10,004.8*	*100.0*	*9,696.2*	*100.0*

[930] Does not include new contracts valued below $10,000.

Table 7-22A. Value and Percentage of Direct Awards to Business Firms by Contract Type: FY 1989–FY 1993 (awards in millions)[931]

Pricing Provision	FY 1989		FY 1990		FY 1991		FY 1992		FY 1993	
	Value	Percentage	Value	Percentage	Value	Percentage	Value	Percentage	Value	Percentage
Firm-Fixed-Price	765.3	9.2	952.4	9.7	980.4	9.7	1,057.6	10.2	893.2	8.7
Incentive	1,454.1	17.5	1,443.9	14.7	362.1	3.6	371.2	3.6	256.2	2.5
Cost-Plus-Award-Fee	5,190.0	62.3	6,478.4	65.8	7,693.0	75.8	7,865.5	75.5	7,770.5	76.0
Cost-Plus-Fixed-Fee	823.3	9.9	826.8	8.4	810.8	8.0	740.3	7.1	964.8	9.4
Other[932]	96.6	1.2	141.7	1.4	302.5	3.0	384.8	3.7	337.9	3.3
Total	*8,329.3*	*100.0*	*9,843.2*	*100.0*	*10,148.8*	*100.0*	*10,419.4*	*100.0*	*10,222.6*	*100.0*

[931] Excludes smaller procurements (generally $25,000 or less) and orders under GSA Federal Supply Schedule contracts.
[932] “Other” includes fixed-price redetermination, economic price adjustment, cost-no-fee, cost-sharing, labor-hour, and time and material awards.

Table 7-22B. Value and Percentage of Direct Awards to Business Firms by Contract Type: FY 1994–FY 1998 (awards in millions)[933]

Pricing Provision	FY 1994		FY 1995		FY 1996		FY 1997		FY 1998	
	Value	Percentage	Value	Percentage	Value	Percentage	Value	Percentage	Value	Percentage
Firm-Fixed-Price	837.2	8.7	912.0	9.2	966.5	10.2	1,035.3	11.1	1,005.1	11.2
Incentive	222.5	2.3	446.9	4.5	577.4	6.1	1,700.3	18.2	1,957.4	21.8
Cost-Plus-Award-Fee	7,540.6	78.4	7,483.7	75.6	6,826.5	72.3	5,520.2	59.2	4,954.7	55.2
Cost-Plus-Fixed-Fee	696.1	7.2	666.2	6.7	629.0	6.7	572.3	6.1	529.5	5.9
Other	327.2	3.4	384.4	3.9	441.6	4.7	495.5	5.3	523.9	5.8
Total	*9,623.6*	*100.0*	*9,893.2*	*100.0*	*9,441*	*100.0*	*9,323.6*	*100.0*	*8,970.6*	*100.0*

[933] Excludes smaller procurements (generally $25,000 or less) and orders under GSA Federal Supply Schedule contracts.

Table 7-23A. Number and Percentage of Procurement Actions in Direct Awards to Business Firms by Contract Pricing: FY 1989–FY 1993

Pricing Provision	FY 1989		FY 1990		FY 1991		FY 1992		FY 1993	
	Number	Percentage	Number	Percentage	Number	Percentage	Number	Percentage	Number	Percentage
Firm-Fixed-Price	5,880	47.8	6,120	46.1	7,233	46.9	9,013	54.7	9,974	57.0
Incentive	246	2.0	208	1.6	265	1.7	151	0.9	140	0.8
Cost-Plus-Award-Fee	2,186	17.8	2,500	18.8	2,785	18.1	2,647	16.1	2,565	14.7
Cost-Plus-Fixed-Fee	3,475	28.3	4,015	30.2	4,588	29.8	4,168	25.3	4,195	24.0
Other[934]	506	4.1	435	3.3	547	3.5	496	3.0	617	3.5
Total	*12,293*	*100.0*	*13,278*	*100.0*	*15,418*	*100.0*	*16,475*	*100.0*	*17,491*	*100.0*

[934] Includes fixed-price redetermination, economic price adjustment, cost-no-fee, cost-sharing, labor-hour, and time and material awards.

Table 7-23B. Number and Percentage of Procurement Actions in Direct Awards to Business Firms by Contract Pricing: FY 1994–FY 1998

Pricing Provision	FY 1994		FY 1995		FY 1996		FY 1997		FY 1998	
	Number	Percentage	Number	Percentage	Number	Percentage	Number	Percentage	Number	Percentage
Firm-Fixed-Price	9,306	55.8	9,634	56.9	10,468	58.9	11,693	63.8	10,589	64.4
Incentive	94	0.6	338	2.0	208	1.2	302	1.6	688	4.2
Cost-Plus-Award-Fee	2,721	16.3	2,476	14.6	2,423	13.6	2,437	13.3	2,088	12.7
Cost-Plus-Fixed-Fee	3,913	23.5	3,711	21.9	3,734	21.0	3,072	16.8	2,405	14.6
Other	632	3.8	785	4.6	925	5.2	818	4.5	679	4.1
Total	*16,666*	*100.0*	*16,944*	*100.0*	*17,758*	*100.0*	*18,322*	*100.0*	*16,449*	*100.0*

Table 7-24A. Value of Prime Contract Awards by State and Percentage of Total Contracts Awarded: FY 1989–FY 1993 (number in thousands)

State	FY 1989		FY 1990		FY 1991		FY 1992		FY 1993	
	Value	Percentage	Value	Percentage	Value	Percentage	Value	Percentage	Value	Percentage
Alabama	698,959	7.7	1,121,914	10.6	1,132,872	10.3	1,232,905	10.8	1,234,764	10.9
Alaska	3,484	*	7,702	0.1	6,725	0.1	8,618	0.1	20,063	0.2
Arizona	29,008	0.3	28,028	0.3	32,393	0.3	43,651	0.4	35,734	0.3
Arkansas	190	*	197	*	343	*	407	*	519	*
California	2,727,664	30.2	3,147,758	29.7	3,100,916	28.1	3,110,769	27.2	3,083,877	27.3
Colorado	137,546	1.5	235,470	2.2	265,907	2.4	195,956	1.7	112,823	1.0
Connecticut	81,080	0.9	67,116	0.6	60,323	0.5	73,623	0.6	57,358	0.5
Delaware	2,421	*	2,216	*	3,128	*	3,212	*	2,814	*
District of Columbia	70,758	0.8	81,666	0.8	95,436	0.9	130,783	1.1	140,930	1.2
Florida	1,232,891	13.7	1,340,936	12.6	1,487,017	13.5	1,498,227	13.1	1,377,189	12.2
Georgia	22,546	0.2	16,653	0.2	17,756	0.2	13,438	0.1	25,028	0.2
Hawaii	6,337	0.1	7,204	0.1	7,434	0.1	8,420	0.1	9,882	0.1
Idaho	1,692	*	1,717	*	1,733	*	2,774	*	(424)	*
Illinois	23,989	0.3	25,226	0.2	17,417	0.2	17,118	0.1	15,954	0.1
Indiana	19,210	0.2	19,455	0.2	18,399	0.2	12,102	0.1	18,546	0.2
Iowa	13,960	0.2	5,187	0.0	10,303	0.1	11,512	0.1	7,736	0.1
Kansas	24,669	0.3	8,727	0.1	3,754	0.03	2,162	0.02	7,043	0.1
Kentucky	1,668	*	2,493	*	2,926	*	1,284	*	892	*
Louisiana	307,612	3.4	359,370	3.4	394,068	3.6	373,055	3.3	316,588	2.8
Maine	777	*	673	*	951	*	1,326	*	826	*
Maryland	753,116	8.3	802,463	7.6	895,979	8.1	953,479	8.3	1,124,045	9.9
Massachusetts	79,392	0.9	96,398	0.9	112,796	1.0	137,717	1.2	146,072	1.3
Michigan	20,693	0.2	24,234	0.2	30,904	0.3	44,058	0.4	38,598	0.3
Minnesota	7,107	0.1	7,362	0.1	6,983	0.1	5,869	0.1	5,652	0.05
Mississippi	85,353	0.9	103,907	1.0	318,588	2.9	324,116	2.8	264,228	2.3

State	FY 1989		FY 1990		FY 1991		FY 1992		FY 1993	
	Value	Percentage	Value	Percentage	Value	Percentage	Value	Percentage	Value	Percentage
Missouri	24,107	0.3	19,794	0.2	16,620	0.2	10,475	0.1	9,825	0.1
Montana	490	*	772	*	663	*	1,229	*	1,422	*
Nebraska	717	*	717	*	836	*	1,427	*	1,731	*
Nevada	818	*	976	*	1,186	*	1,600	*	953	*
New Hampshire	9,009	0.1	12,517	0.1	12,594	0.1	14,537	0.1	15,330	0.1
New Jersey	126,355	1.4	186,176	1.8	144,548	1.3	120,670	1.1	194,920	1.7
New Mexico	48,292	0.5	54,456	0.5	57,120	0.5	57,344	0.5	63,999	0.6
New York	63,381	0.7	77,776	0.7	61,196	0.6	58,447	0.5	57,349	0.5
North Carolina	12,318	0.1	12,206	0.1	10,663	0.1	11,915	0.1	10,865	0.1
North Dakota	111	*	62	*	181	*	457	*	370	*
Ohio	182,877	2.0	214,031	2.0	256,745	2.3	291,195	2.5	324,700	2.9
Oklahoma	4,503	0.05	4,041	*	5,934	0.1	7,263	0.1	7,723	0.1
Oregon	6,139	0.1	5,128	0.0	5,986	0.1	7,998	0.1	8,334	0.1
Pennsylvania	199,492	2.2	228,605	2.2	188,386	1.7	190,168	1.7	115,217	1.0
Rhode Island	2,105	*	3,018	*	2,893	*	3,549	*	4,470	*
South Carolina	2,120	*	1,202	*	1,790	*	1,609	*	3,289	*
South Dakota	554	*	432	*	694	*	802	*	1,158	*
Tennessee	29,523	0.3	29,535	0.3	36,728	0.3	33,035	0.3	40,670	0.4
Texas	1,101,607	12.2	1,250,982	11.8	1,236,002	11.2	1,290,889	11.3	1,274,392	11.3
Utah	428,591	4.7	509,201	4.8	444,878	4.0	528,606	4.6	489,237	4.3
Vermont	477	*	480	*	793	*	515	*	67	*
Virginia	357,901	4.0	371,805	3.5	432,317	3.9	504,850	4.4	537,196	4.7
Washington	26,884	0.3	68,013	0.6	39,219	0.4	38,957	0.3	33,736	0.3
West Virginia	413	*	1,526	*	4,213	0.04	10,936	0.1	34,528	0.3
Wisconsin	45,050	0.5	40,200	0.4	48,566	0.4	39,585	0.3	38,150	0.3
Wyoming	188	*	259	*	186	*	640	*	542	*
Total	*9,026,144*	*100.0*	*10,607,982*	*100.0*	*11,035,988*	*100.0*	*11,435,359*	*100.0*	*11,316,910*	*100.0*

* = Less than 0.05 percent.

Note: Excludes smaller procurements (generally $25,000 or less); also excludes awards placed through other government agencies, awards outside the United States, and actions on the JPL contracts.

Table 7-24B. Value of Prime Contract Awards by State and Percentage of Total Contracts Awarded: FY 1994–FY 1998 (number in thousands)

State	FY 1994		FY 1995		FY 1996		FY 1997		FY 1998	
	Value	Percentage	Value	Percentage	Value	Percentage	Value	Percentage	Value	Percentage
Alabama	841,145	7.8	664,756	5.9	656,030	6.2	609,665	5.6	517,542	4.9
Alaska	13,410	0.1	11,047	0.1	9,244	0.1	20,311	0.2	12,662	0.1
Arizona	68,473	0.6	76,227	0.7	71,234	0.7	56,274	0.5	57,670	0.5
Arkansas	1,468	*	1,899	*	731	*	572	*	2,271	*
California	2,405,595	22.3	2,369,156	21.1	2,133,903	20.0	1,903,616	17.6	1,894,298	17.8
Colorado	118,292	1.1	115,914	1.0	130,385	1.2	180,796	1.7	201,182	1.9
Connecticut	62,373	0.6	64,627	0.6	94,447	0.9	89,001	0.8	96,865	0.9
Delaware	3,647	*	2,874	*	2,616	*	4,748	*	3,738	*
District of Columbia	151,437	1.4	105,070	0.9	67,092	0.6	71,302	0.7	41,943	0.4
Florida	1,298,021	12.1	1,281,223	11.4	1,110,241	10.4	450,850	4.2	489,079	4.6
Georgia	31,753	0.3	31,801	0.3	26,411	0.2	25,873	0.2	23,823	0.2
Hawaii	8,792	0.1	9,422	0.1	8,640	0.1	11,446	0.1	22,830	0.2
Idaho	388	*	417	*	367	*	728	*	910	*
Illinois	15,852	0.1	19,427	0.2	19,665	0.2	18,453	0.2	15,821	0.1
Indiana	35,643	0.3	35,062	0.3	42,046	0.4	43,185	0.4	65,481	0.6
Iowa	6,700	0.1	7,871	0.1	9,031	0.1	8,314	0.1	11,269	0.1
Kansas	6,283	0.1	5,915	0.1	3,330	0.0	4,132	*	5,890	0.1
Kentucky	2,719	*	1,483	*	2,251	*	1,679	*	1,839	*
Louisiana	275,737	2.6	383,506	3.4	362,353	3.4	362,770	3.4	351,450	3.3
Maine	729	*	1,987	*	1,285	*	910	*	2,434	*
Maryland	1,122,730	10.4	1,147,542	10.2	1,159,418	10.9	1,221,856	11.3	1,150,960	10.8
Massachusetts	140,138	1.3	158,716	1.4	145,492	1.4	131,759	1.2	128,731	1.2
Michigan	26,765	0.2	33,382	0.3	24,377	0.2	31,201	0.3	33,935	0.3
Minnesota	4,889	0.05	9,552	0.1	10,521	0.1	7,109	0.1	9,720	0.1
Mississippi	196,329	1.8	139,987	1.2	129,255	1.2	137,807	1.3	159,073	1.5

State	FY 1994		FY 1995		FY 1996		FY 1997		FY 1998	
	Value	Percentage	Value	Percentage	Value	Percentage	Value	Percentage	Value	Percentage
Missouri	9,837	0.1	15,169	0.1	16,123	0.2	20,588	0.2	23,226	0.2
Montana	1,969	*	2,607	*	6,380	0.1	5,162	0.05	6,640	0.1
Nebraska	2,031	*	2,029	*	1,544	*	2,689	*	2,576	*
Nevada	680	*	2,261	*	1,707	0.02	2,680	*	2,666	*
New Hampshire	15,153	0.1	14,832	0.1	19,013	0.2	15,658	0.1	20,062	0.2
New Jersey	213,350	2.0	280,863	2.5	179,687	1.7	165,611	1.5	122,261	1.1
New Mexico	55,379	0.5	59,390	0.5	55,132	0.5	60,128	0.6	62,290	0.6
New York	45,397	0.4	48,291	0.4	44,903	0.4	50,273	0.5	56,412	0.5
North Carolina	15,873	0.1	15,712	0.1	12,498	0.1	18,689	0.2	15,171	0.1
North Dakota	524	*	759	*	941	*	1,393	*	3,124	*
Ohio	349,755	3.2	404,692	3.6	324,525	3.0	320,619	3.0	318,385	3.0
Oklahoma	8,829	0.1	7,029	0.1	9,232	0.1	6,952	0.1	10,449	0.1
Oregon	11,988	0.1	8,788	0.1	3,534	0.03	10,764	0.1	9,793	0.1
Pennsylvania	78,381	0.7	95,167	0.8	36,322	0.3	75,238	0.7	56,672	0.5
Rhode Island	4,381	*	4,519	*	2,807	0.03	3,553	*	3,733	*
South Carolina	4,728	*	3,316	*	2,757	0.03	3,644	*	2,695	*
South Dakota	2,751	*	1,675	*	1,461	*	2,828	*	3,283	*
Tennessee	24,963	0.2	21,736	0.2	22,271	0.2	22,136	0.2	22,384	0.2
Texas	2,064,289	19.2	2,495,761	22.3	2,606,413	24.5	3,640,764	33.7	3,658,466	34.4
Utah	452,152	4.2	451,922	4.0	402,349	3.8	432,334	4.0	379,121	3.6
Vermont	543	*	912	0.01	1,505	*	1,120	*	985	*
Virginia	426,269	4.0	437,858	3.9	448,075	4.2	380,425	3.5	398,506	3.7
Washington	70,162	0.7	89,915	0.8	104,123	1.0	127,665	1.2	114,422	1.1
West Virginia	29,759	0.3	29,785	0.3	29,314	0.3	28,234	0.3	38,000	0.4
Wisconsin	40,550	0.4	38,375	0.3	34,362	0.3	21,110	0.2	15,681	0.1
Wyoming	1,130	*	1,035	*	329	*	1,350	*	1,129	*
Total	*10,770,131*	*100.0*	*11,213,261*	*100.0*	*10,587,672*	*100.0*	*10,815,964*	*100.0*	*10,649,548*	*100.0*

* = Less than 0.05 percent.

Note: Excludes smaller procurements (generally $25,000 or less); also excludes awards placed through other government agencies, awards outside the United States, and actions on the JPL contracts.

Table 7-25. Distribution of Prime Contract Awards by Region: FY 1989–FY 1998

Region	1989	1990	1991	1992	1993	1994	1995	1996	1997	1998	Total
Net Value of Awards (in millions of dollars)[935]											
New England[936]	173	180	190	231	224	223	246	265	242	253	2,227
Mideast/Mid-Atlantic[937]	1,216	1,379	1,389	1,457	1,635	1,615	1,680	1,540	1,589	1,432	14,932
Southeast[938]	2,751	3,362	3,839	4,006	3,846	3,149	3,013	2,803	2,042	2,022	30,833
Plains[939]	71	42	40	33	33	33	43	44	48	59	446
Great Lakes[940]	292	323	372	404	436	469	531	445	435	449	4,156
Southwest[941]	1,183	1,338	1,332	1,399	1,382	2,197	2,638	2,742	3,764	3,789	21,764
Rocky Mountain[942]	569	747	713	729	604	574	572	541	620	589	6,258
Far West[943]	2,761	3,222	3,147	3,159	3,127	2,488	2,470	2,249	2,045	2,021	26,689
Alaska and Hawaii	10	15	14	17	30	22	20	18	31	35	212
Total	*9,026*	*10,608*	*11,036*	*11,435*	*11,317*	*10,770*	*11,213*	*10,647*	*10,816*	*10,649*	107,517
Percentage of Total											
New England	1.9	1.7	1.7	2.0	2.0	2.1	2.2	2.5	2.2	2.4	2.1
Mideast/Mid-Atlantic	13.5	13.0	12.6	12.7	14.4	15.0	15.0	14.5	14.7	13.4	13.9
Southeast	30.5	31.7	34.8	35.0	34.0	29.2	26.9	26.3	18.9	19.0	28.7
Plains	0.8	0.4	0.4	0.3	0.3	0.3	0.4	0.4	0.4	0.6	0.4
Great Lakes	3.2	3.0	3.4	3.5	3.9	4.4	4.7	4.2	4.0	4.2	3.9
Southwest	13.1	12.6	12.1	12.2	12.2	20.4	23.5	25.8	34.8	35.6	20.2
Rocky Mountain	6.3	7.0	6.5	6.4	5.3	5.3	5.1	5.1	5.7	5.5	5.8

935 Excludes smaller procurements (generally $25,000 or less); also excludes awards placed through other government agencies, awards outside the United States, and awards on the JPL contract.
936 The New England region consists of Maine, New Hampshire, Vermont, Rhode Island, Massachusetts, and Connecticut.
937 The Mideast/Mid-Atlantic region consists of New York, Pennsylvania, New Jersey, the District of Columbia, Maryland, and Delaware.
938 The Southeast region consists of West Virginia, Alabama, Virginia, Kentucky, Tennessee, North Carolina, South Carolina, Georgia, Mississippi, Louisiana, Arkansas, and Florida.
939 The Plains region consists of North Dakota, South Dakota, Minnesota, Iowa, Nebraska, Missouri, and Kansas.
940 The Great Lakes region consists of Michigan, Wisconsin, Indiana, Ohio, and Illinois.
941 The Southwest region consists of Texas, Oklahoma, New Mexico, and Arizona.
942 The Rocky Mountain region consists of Idaho, Montana, Wyoming, Utah, and Colorado.
943 The Far West region consists of Washington, Oregon, California, and Nevada.

Region	**1989**	**1990**	**1991**	**1992**	**1993**	**1994**	**1995**	**1996**	**1997**	**1998**	**Total**
Far West	30.6	30.4	28.5	27.6	27.6	23.1	22.0	21.1	18.9	19.0	24.8
Alaska and Hawaii	0.1	0.1	0.1	0.1	0.3	0.2	0.2	0.2	0.3	0.3	0.2
Total	*100.0*	*100.0*	*100.0*	*100.0*	*100.0*	*100.0*	*100.0*	*100.0*	*100.0*	*100.0*	*100.0*
Percentage Change of Prime Contract Award Value from Previous Year											
New England	14.6	4.0	5.6	21.6	–3.0	–0.4	10.3	7.7	–8.7	4.5	4.0
Mideast	22.3	13.4	0.7	4.9	12.2	–1.2	4.0	–8.3	3.2	–9.9	13.4
Southeast	25.0	22.2	14.2	4.4	–4.0	–18.1	–4.3	–7.0	–27.1	–1.0	22.2
Plains	36.5	–40.8	–4.8	–17.5	0.0	0.0	30.3	2.3	9.1	22.9	–40.8
Great Lakes	23.2	10.6	15.2	8.6	7.9	7.6	13.2	–16.2	–2.2	3.2	10.6
Southwest	20.3	13.1	–0.4	5.0	–1.2	59.0	20.1	3.9	37.3	0.7	13.1
Rocky Mountain	10.1	31.3	–4.6	2.2	–17.1	–5.0	–0.3	–5.4	14.6	–5.0	31.3
Far West	13.5	16.7	–2.3	0.4	–1.0	–20.4	–0.7	–8.9	–9.1	–1.2	16.7
Alaska and Hawaii	3.1	50.0	–6.7	21.4	76.5	–26.7	–9.1	–10.0	72.2	12.9	50.0
United States	*19.6*	*17.5*	*4.0*	*3.6*	*–1.0*	*–4.8*	*4.1*	*–5.0*	*1.6*	*–1.5*	*17.5*

Note: Excludes smaller procurements (generally $25,000 or less); also excludes awards placed through other government agencies, awards outside the United States, and awards on the JPL contracts.

Table 7-26A. Total Value and Percentage of Awards by Installation: FY 1989–FY 1993 (in millions of dollars)

Installation	FY 1989		FY 1990		FY 1991		FY 1992		FY 1993	
	Value	**Percentage**	**Value**	**Percentage**	**Value**	**Percentage**	**Value**	**Percentage**	**Value**	**Percentage**
Ames Research Center[944]	450.6	4.1	482.8	3.8	520.2	3.9	568.0	4.2	567.2	4.3
Dryden Flight Research Center	—	—	—	—	—	—	—	—	—	—
Goddard Space Flight Center	1,606.7	14.8	1,823.6	14.4	2,003.8	15.2	2,044.3	15.2	2,181.2	16.6
Johnson Space Center	2,304.0	21.2	2,760.4	22.0	2,641.9	20.1	2,686.9	19.9	2,644.4	20.1
Kennedy Space Center	1,179.5	10.8	1,275.9	10.2	1,409.7	10.7	1,484.6	11.0	1,415.4	10.8
Langley Research Center	384.0	3.5	399.7	3.2	404.6	3.1	436.0	3.2	436.1	3.3
Lewis Research Center	542.5	5.0	686.5	5.5	812.4	6.2	831.6	6.2	873.5	6.6
Marshall Space Flight Center	2,649.4	24.4	3,154.6	25.1	3,124.8	23.7	3,234.1	24.0	3,001.8	22.8
NASA Resident Office/JPL	1,063.3	9.8	1,138.5	9.1	1,173.8	8.9	1,263.7	9.4	1,068.4	8.1
Stennis Space Center	96.4	0.9	112.6	0.9	113.0	0.9	120.4	0.9	109.0	0.8
Headquarters	600.0	5.5	730.6	5.8	954.8	7.3	808.6	6.0	863.4	6.6
Total	*10,876.4*	*100.0*	*12,565.2*	*100.0*	*13,159.0*	*100.0*	*13,478.2*	*100.0*	*13,160.4*	*100*

[944] FY 1989–FY 1994: includes Dryden awards.

Table 7-26B. Total Value and Percentage of Awards by Installation: FY 1994–FY 1998 (in millions of dollars)

Installation	FY 1994		FY 1995		FY 1996		FY 1997		FY 1998	
	Value	**Percentage**	**Value**	**Percentage**	**Value**	**Percentage**	**Value**	**Percentage**	**Value**	**Percentage**
Ames Research Center	594.1	4.6	560.8	4.2	533.3	4.2	507.1	4.0	493.1	3.9
Dryden Flight Research Center	—	—	96.0	0.7	108.4	0.8	132.4	1.0	156.6	1.3
Goddard Space Flight Center	2,221.8	17.2	2,354.4	17.6	2,381.7	18.8	2,719.6	21.3	2,752.7	21.9
Johnson Space Center	1,952.4	15.1	1,754.0	13.1	3,291.7	25.9	3,998.4	31.3	3,958.4	31.5
Kennedy Space Center	1,315.0	10.2	1,257.2	9.4	1,090.8	8.6	446.3	3.5	454.7	3.6
Langley Research Center	507.0	3.9	528.9	4.0	489.3	3.9	544.7	4.3	501.4	4.0
Lewis Research Center	776.5	6.0	759.2	5.7	635.9	5.0	592.9	4.6	583.5	4.7
Marshall Space Flight Center	2,493.2	19.3	2,501.8	18.8	2,234.9	17.6	2,321.3	18.1	2,075.4	16.5
NASA Resident Office/JPL	1,118.1	8.7	1,162.9	8.7	1,211.3	9.5	1,140,1	8.9	1,192.0	9.5
Stennis Space Center	120.2	0.9	128.5	1.0	143.3	1.1	169.5	1.3	224.6	1.8
Headquarters	811.7	6.3	774.5	5.8	578.6	4.6	217.2	1.7	168.8	1.3
Space Station Program Office/Space Station Alpha	1,003.1	7.8	1,463.2	11.0	—	—	—	—	—	—
Total	*12,913.1*	*100.0*	*13,314.4*	*100.0*	*12,699.2*	*100.0*	*12,789.5*	*100.0*	*12,561.2*	*100.0*

Source: Tables 5-22, 5-27, 5-32, 5-37, 5-41, 5-46, 5-51, 5-56, 5-61, 5-66, 5-71.

Table 7-27. Ranking of NASA's Top 10 Contractors: FY 1989–FY 1998

Contractor	1989	1990	1991	1992	1993	1994	1995	1996	1997	1998
Rockwell International	1	1	1	1	1	2	2	3	—	—
Lockheed Space Operations	2	3	3	3	3	3	4	37	37	36
McDonnell Douglas	3	2	2	2	2	4	5	6	6	4
Thiokol	4	5	7	5	5	6	6	5	4	5
Martin Marietta	5	4	4	7	8	5	3	—[945]	—	—
General Electric	6	6	9	9	9	48	27	21	18	20
Rockwell Space Operations/Boeing North American	7	8	8	8	7	7	8	7	9[946]	7
Boeing Co.	8	7	5	6	4	1	1	1	1	1
Lockheed Engineering and Science	9	11	10	10	10	12	13	12[947]	5	8
Ford Aerospace	10	15	—[948]	—	—	—	—	—	—	—
Lockheed Missiles and Space	17	9	6	4	6	11	17	—	—	—
Computer Sciences Corp.	13	14	12	11	14	8	7	10	10	10
Allied-Signal Technical Services	11[949]	—	—	—	—	9	10	9	7	6
TRW Inc.	12	10	14	14	13	10	9	8	8	9
United Space Alliance	—	—	—	—	—	—	—	4[950]	2	2
Lockheed Martin Corp.	—	—	—	—	—	—	—	2	3	3

Note: During the second half of the decade, a number of companies that held NASA contracts acquired other companies, merged, and reconfigured themselves. Some legacy contracts awarded in past years to companies that "no longer existed" as independent entities may still have been in force during part of the decade.

[945] Merged with Lockheed to become Lockheed Martin, ranked no. 2 in FY 1996.
[946] Became Boeing North American.
[947] Became Lockheed Martin Engineering & Science Co.
[948] Became Loral Aerospace, was not ranked in top 10.
[949] Called AlliedSignal Aerospace.
[950] Formed from Rockwell International and Lockheed Martin Space Operations Co. in 1995.

Table 7-28. Top 50 Contractors: FY 1989 (in thousands of dollars)

Contractor/Place of Contract Performance	Rank in FY 1988	Net Value of Awards	
		Amount	Percentage
Rockwell International Corp. Downey, CA	1	1,691,857	19.75
Lockheed Space Operations Co. Kennedy Space Center, FL	2	552,297	6.45
McDonnell Douglas Corp. Huntington Beach, CA	5	506,009	5.91
Thiokol Corp. Brigham City, UT	3	419,712	4.90
Martin Marietta Corp. New Orleans, LA	4	354,973	4.14
General Electric Co. King of Prussia, PA	7	299,894	3.50
Rockwell Space Operations Inc. Houston, TX	—	286,755	3.35
Boeing Co. Marshall Space Flight Center, AL	6	235,805	2.75
Lockheed Engineering & Science Co. Houston, TX	9	216,514	2.53
Ford Aerospace Corp. Palo Alto, CA	15	196,254	2.29
USBI Booster Production Co. Huntsville, AL	8	196,037	2.29
TRW Inc. Redondo Beach, CA	13	193,362	2.26
Computer Sciences Corp. Greenbelt, MD	12	191,937	2.24
EG&G Florida Inc. Kennedy Space Center, FL	10	186,833	2.18
Boeing Computer Support Services Marshall Space Flight Center, AL	—	158,394	1.85
Bendix Field Engineering Corp.[951] Columbia, MD	—	156,021	1.82
Lockheed Missiles and Space Co. Sunnyvale, CA	14	145,071	1.69
United Technologies Corp. West Palm Beach, FL	16	133,105	1.55
International Business Machines Houston, TX	17	101,718	1.19
Grumman Aerospace Corp. Reston, VA	19	80,192	.94
Sverdrup Technology Inc. Middleburgh Heights, OH	25	65,479	.76

[951] Part of Allied-Signal since 1985.

Contractor/Place of Contract Performance	Rank in FY 1988	Net Value of Awards	
		Amount	Percentage
Pan American World Services Inc. Stennis Space Center, MS	20	60,074	.70
Teledyne Industries Inc. Marshall Space Flight Center, AL	23	52,407	.61
Contel Corp. Gaithersburg, MD	18	51,007	.60
Cray Research Inc. Chippewa Falls, WI	28	48,226	.56
Boeing Technical Operations Inc. Houston, TX	22	41,358	.48
Planning Research Corp. Hampton, VA	21	39,323	.46
Fairchild Industries Inc. Germantown, MD	32	37,528	.44
Aerojet General Corp. Sacramento, CA	35	37,469	.44
NSI Technology Services Corp. Moffett Field, CA	30	35,564	.42
Orbital Sciences Corp. (S) Denver, CO	29	34,800	.41
Unisys Corp. Greenbelt, MD	34	34,048	.40
Atlis Federal Services Inc. Moffett Field, CA	—	31,471	.37
Perkin Elmer Corp. Danbury, CT	27	31,388	.37
General Dynamics Corp. San Diego, CA	33	30,821	.36
BAMSI Inc. (D) Marshall Space Flight Center, AL	24	30,283	.35
Raytheon Service Co. Greenbelt, MD	26	30,098	.35
Bionetics Corp. (S) Marshall Space Flight Center, AL	56	29,914	.35
ST Systems Corp. Greenbelt, MD (S) (D)	50	29,606	.35
LTV Aerospace & Defense Co. Dallas, TX	41	25,400	.30
Grumman Data Systems Corp. Marshall Space Flight Center, AL	44	22,566	.26
Ball Corp. Boulder, CO	38	21,188	.25
Krug International Corp. Houston, TX	43	20,747	.24
Wyle Laboratories	37	18,848	.22

Contractor/Place of Contract Performance	**Rank in FY 1988**	**Net Value of Awards**	
		Amount	**Percentage**
Hampton, VA			
Air Products and Chemicals Inc. Allentown, PA	47	18,814	.22
Northrop Worldwide Aircraft Houston, TX	45	17,676	.21
Lockheed Corp. Burbank, CA	40	17,089	.20
Engineering and Economics Research (S) (D) Beltsville, MD	46	17,079	.20
Cortez III Service Corp. (S) (D) Cleveland, OH	52	16,531	.19
CAE Link Corp. Houston, TX	—	15,595	.18
Total Top 50		*7,265,137*	*84.83*
Other[952]		1,302,439	15.17
Total Awards to Business Firms		*8,567,576*	*100.00*

Note: (S) = Small business concern; (D) = Disadvantaged business.

[952] Includes remaining “top 100” list and other awards over $25,000, as well as smaller procurements of $25,000 or less.

Table 7-29. Top 50 Contractors: FY 1990 (in thousands of dollars)

Contractor/Place of Contract Performance	Rank in FY 1989	Net Value of Awards	
		Amount	Percentage
Rockwell International Corp. Downey, CA	1	1,746,840	17.34
McDonnell Douglas Corp. Huntington Beach, CA	3	850,639	8.45
Lockheed Space Operations Co. Kennedy Space Center, FL	2	583,473	5.79
Martin Marietta Corp. New Orleans, LA	5	507,292	5.04
Thiokol Corp. Brigham City, UT	4	498,437	4.95
General Electric Co. King of Prussia, PA	6	401,589	3.99
Boeing Co. Marshall Space Flight Center, AL	8	398,881	3.96
Rockwell Space Operations Inc. Houston, TX	7	308,708	3.07
Lockheed Missiles and Space Co. Marshall Space Flight Center, AL	17	293,908	2.92
TRW Inc. Redondo Beach, CA	12	241,408	2.40
Lockheed Engineering and Science Co. Houston, TX	9	233,702	2.32
USBI Booster Production Co. Huntsville, AL	11	232,860	2.31
EG&G Florida Inc. Kennedy Space Center, FL	14	191,087	1.90
Computer Sciences Corp. Greenbelt, MD	13	182,613	1.81
Ford Aerospace Corp. Palo Alto, CA	10	174,485	1.73
Boeing Computer Support Services Marshall Space Flight Center, AL	15	164,616	1.63
Bendix Field Engineering Corp. Columbia, MD	16	155,960	1.55
United Technologies Corp. West Palm Beach, FL	18	136,099	1.35
International Business Machines Houston, TX	19	101,521	1.01
Grumman Aerospace Corp. Reston, VA	20	85,637	.85
Sverdrup Technology Inc. Middleburgh Heights, OH	21	79,373	.79
Teledyne Industries Inc.	23	73,426	.73

Contractor/Place of Contract Performance	Rank in FY 1989	Net Value of Awards	
		Amount	Percentage
Marshall Space Flight Center, AL			
Contel Corp. Gaithersburg, MD	24	64,952	.64
Pan American World Services Inc. Stennis Space Center, MS	22	64,794	.64
CAE Link Corp. Houston, TX	50	53,038	.53
Fairchild Industries Inc. Germantown, MD	28	44,340	.44
Cray Research Inc. Chippewa Falls, WI	25	43,135	.43
BAMSI Inc. (D) Marshall Space Flight Center, AL	36	38,367	.38
NSI Technology Services Corp. Moffett Field, CA	30	37,597	.37
Unisys Corp. Greenbelt, MD	32	37,003	.37
Bionetics Corp. (S) Marshall Space Flight Center, AL	38	36,398	.36
Orbital Sciences Corp. (S) Denver, CO	31	34,848	.35
General Dynamics Corp. San Diego, CA	35	33,696	.33
ST Systems Corp. Greenbelt, MD (S) (D)	39	32,693	.32
Stoddard Hamilton Aircraft (S) Arlington, WA	—	32,575	.32
Sterling Software Inc. Moffett Field, CA	—	32,180	.32
Planning Research Corp. Washington, DC	27	29,732	.30
Raytheon Service Co. Greenbelt, MD	37	29,701	.29
Grumman Data Systems Corp. Marshall Space Flight Center, AL	41	27,976	.28
Cortez III Service Corp. (S) (D) Cleveland, OH	49	27,357	.27
Aerojet General Corp. Sacramento, CA	29	24,966	.25
Harris Space Systems Corp. Rockledge, FL	—	24,642	.24
Krug International Corp. Houston, TX	43	24,010	.24

Contractor/Place of Contract Performance	Rank in FY 1989	Net Value of Awards	
		Amount	Percentage
Hughes Danbury Optical Systems Danbury, CT[953]	34[954]	23,337	.23
Air Products and Chemicals Inc. Allentown, PA	45	19,558	.19
Ball Corp. Boulder, CO	42	19,465	.19
Northrop Worldwide Aircraft Houston, TX	46	19,235	.19
Lockheed Corp. Burbank, CA	47	17,880	.18
Honeywell Federal Systems Inc. Kennedy Space Center, FL	60	17,540	.17
Analex Corp. Fairview Park, OH	51	17,437	.17
Total Top 50		*8,551,006*	*84.88*
Other[955]		1,520,524	15.12
Total Awards to Business Firms		*10,071,530*	*100.00*

Note: (S) = Small business concern; (D) = Disadvantaged business.

[953] Formerly Perkin Elmer Corp.
[954] Ranking of Perkin Elmer Corp.
[955] Includes remaining "top 100" list and other awards over $25,000, as well as smaller procurements of $25,000 or less.

Table 7-30. Top 50 Contractors: FY 1991 (in thousands of dollars)

Contractor/Place of Contract Performance	Rank in FY 1990	Net Value of Awards	
		Amount	Percentage
Rockwell International Corp. Canoga Park, CA	1	1,559,634	14.97
McDonnell Douglas Corp. Huntington Beach, CA	2	1,089,205	10.45
Lockheed Space Operations Co. Kennedy Space Center, FL	3	591,449	5.68
Martin Marietta Corp. New Orleans, LA	4	571,732	5.49
Boeing Co. Marshall Space Flight Center, AL	7	468,308	4.50
Lockheed Missiles and Space Co. Iuka, MS	9	458,981	4.41
Thiokol Corp. Brigham City, UT	5	437,966	4.20
Rockwell Space Operations Inc. Houston, TX	8	343,157	3.29
General Electric Co. King of Prussia, PA	6	308,042	2.96
Lockheed Engineering and Science Co. Houston, TX	11	258,742	2.48
EG&G Florida Inc. Kennedy Space Center, FL	13	227,406	2.18
Computer Sciences Corp. Greenbelt, MD	14	207,005	1.99
USBI Booster Production Co. Huntsville, AL	12	197,660	1.90
TRW Inc. Redondo Beach, CA	10	192,015	1.84
Loral Aerospace Corp.[956] Palo Alto, CA	15[957]	185,968	1.79
Bendix Field Engineering Corp. Columbia, MD	17	175,972	1.69
Boeing Computer Support Services Marshall Space Flight Center, AL	16	158,857	1.52
United Technologies Corp. West Palm Beach, FL	18	133,380	1.28
Grumman Aerospace Corp. Reston, VA	20	99,769	.96
Sverdrup Technology Inc. Middleburgh Heights, OH	21	97,403	.93

[956] Formerly Ford Aerospace Corp.
[957] Ranking of Ford Aerospace Corp.

Contractor/Place of Contract Performance	Rank in FY 1990	Net Value of Awards	
		Amount	Percentage
Johnson Controls World Services Inc.[958] Stennis Space Center, MS	—	70,232	.67
International Business Machines Houston, TX	19	67,951	.65
Teledyne Industries Inc. Marshall Space Flight Center, AL	22	65,343	.63
BAMSI Inc. (D) Marshall Space Flight Center, AL	28	51,801	.50
Contel Corp. Gaithersburg, MD	23	49,794	.48
Cray Research Inc. Chippewa Falls, WI	27	46,800	.45
Fairchild Industries Inc. Germantown, MD	26	46,377	.45
CAE Link Corp. Houston, TX	25	45,488	.44
Harris Space Systems Corp. Rockledge, FL	42	45,163	.43
Bionetics Corp. (S) Marshall Space Flight Center, AL	31	41,069	.39
ST Systems Corp. Greenbelt, MD	34	40,748	.39
NSI Technology Services Corp. Moffett Field, CA	29	36,941	.35
PRC Inc. (S)[959] Washington, DC	37[960]	36,749	.35
Orbital Sciences Corp. (S) Denver, CO	32	36,406	.35
Raytheon Service Co. Greenbelt, MD	38	34,856	.33
Sterling Federal Systems Inc.[961] Moffett Field, CA	36[962]	34,391	.33
Unisys Corp. Greenbelt, MD	30	31,076	.30
Cortez III Service Corp. (S) (D) Cleveland, OH	40	29,076	.28
Aerojet General Corp. Sacramento, CA	41	26,222	.25
Krug International Corp.	43	25,305	.24

958 Acquired Pan American World Services Inc., ranked 24 in 1990.
959 Formerly called Planning Research Corp.
960 Ranking of Planning Research Corp.
961 Formerly Sterling Software Inc.
962 Ranking of Sterling Software Inc.

Contractor/Place of Contract Performance	Rank in FY 1990	Net Value of Awards	
		Amount	Percentage
Houston, TX			
Air Products and Chemicals Inc. Allentown, PA	45	25,183	.24
Grumman Data Systems Corp. Marshall Space Flight Center, AL	39	24,629	.24
Calspan Corp. Moffett Field, CA	59	23,563	.23
Ball Corp. Boulder, CO	46	21,950	.21
Analex Corp. Fairview Park, OH	50	21,570	.21
General Dynamics Corp. San Diego, CA	33	19,206	.18
Silicon Graphics Inc. (S) Mountain View, CA	57	19,182	.18
Ogden Logistics Services Greenbelt, MD	63	17,319	.17
Lockheed Corp. Burbank, CA	48	17,263	.17
Engineering and Economics Research (S) (D) Beltsville, MD	55	17,189	.16
Total Top 50		*8,831,493*	*84.76*
Other[963]		1,585,839	15.24
Total Awards to Business Firms		*10,417,332*	*100.00*

Note: (S) = Small Business; (D) = Disadvantaged Business.

[963] Includes remaining "top 100" list and other awards over $25,000, as well as smaller procurements of $25,000 or less.

Table 7-31. Top 50 Contractors: FY 1992 (in thousands of dollars)

Contractor/Place of Contract Performance	Rank in FY 1991	Net Value of Awards	
		Amount	Percentage
Rockwell International Corp. Canoga Park, CA	1	1,449,346	13.52
McDonnell Douglas Corp. Huntington Beach, CA	2	1,045,418	9.75
Lockheed Space Operations Co. Kennedy Space Center, FL	3	599,213	5.59
Lockheed Missiles and Space Co. Iuka, MS	6	530,153	4.95
Thiokol Corp. Brigham City, UT	7	510,292	4.76
Boeing Co. Marshall Space Flight Center, AL	5	500,115	4.67
Martin Marietta Corp. New Orleans, LA	4	444,799	4.15
Rockwell Space Operations Inc. Houston, TX	8	345,886	3.23
General Electric Co. King of Prussia, PA	9	299,400	2.79
Lockheed Engineering and Science Co. Houston, TX	10	269,905	2.52
Computer Sciences Corp. Greenbelt, MD	12	232,354	2.17
EG&G Florida Inc. Kennedy Space Center, FL	11	212,843	1.99
USBI Booster Production Co. Huntsville, AL	13	207,274	1.93
TRW Inc. Redondo Beach, CA	14	194,369	1.81
Bendix Field Engineering Corp. Columbia, MD	16	180,926	1.69
Loral Aerospace Corp. Palo Alto, CA	15	140,521	1.31
Boeing Computer Support Services Marshall Space Flight Center, AL	17	139,816	1.30
United Technologies Corp. West Palm Beach, FL	18	135,840	1.27
Sverdrup Technology Inc. Middleburgh Heights, OH	20	109,444	1.02
Grumman Aerospace Corp. Reston, VA	19	103,250	.96
Space Systems Loral Inc. San Jose, CA	—	94,944	.89
Johnson Controls World Services Inc.	21	76,139	.71

Contractor/Place of Contract Performance	Rank in FY 1991	Net Value of Awards	
		Amount	Percentage
Stennis Space Center, MS			
International Business Machines Houston, TX	22	76,085	.71
CAE Link Corp. Houston, TX	28	61,467	.57
Harris Space Systems Corp. Rockledge, FL	29	60,099	.56
BAMSI Inc. (D) Marshall Space Flight Center, AL	24	58,739	.55
Orbital Sciences Corp. (S) Denver, CO	34	55,631	.52
Teledyne Industries Inc. Marshall Space Flight Center, AL	23	53,863	.50
GTE Government Systems Inc. Gaithersburg, MD	—	49,687	.46
Ball Corp. Boulder, CO	44	49,345	.46
General Dynamics Corp. San Diego, CA	46	49,058	.46
NSI Technology Services Corp. Moffett Field, CA	32	46,947	.44
Sterling Federal Systems Inc. Moffett Field, CA	36	43,579	.41
Bionetics Corp. (S) Marshall Space Flight Center, AL	30	43,174	.40
Cray Research Inc. Chippewa Falls, WI	26	42,977	.40
PRC Inc. (S) Washington, DC	33	41,267	.39
ST Systems Corp. Greenbelt, MD	31	40,713	.38
Spacehab Corp. Washington, DC	92	37,886	.35
Metric Constructors Inc. Kennedy Space Center, FL	68	35,596	.33
Raytheon Service Co. Greenbelt, MD	35	33,847	.32
Santa Barbara Research Center Goleta, CA	63	32,367	.30
Fairchild Industries Inc. Germantown, MD	27	31,709	.30
Cortez III Service Corp. (S) (D) Cleveland, OH	38	31,283	.29
Analex Corp.	45	27,475	.26

Contractor/Place of Contract Performance	Rank in FY 1991	Net Value of Awards	
		Amount	Percentage
Fairview Park, OH			
Aerojet General Corp. Sacramento, CA	39	26,949	.25
Science Application International Corp. San Diego, CA	51	26,658	.25
Calspan Corp. Moffett Field, CA	43	26,286	.25
Krug International Corp. Houston, TX	40	24,892	.23
Northrop Worldwide Aircraft Houston, TX	52	22,208	.21
Air Products and Chemicals Inc. Allentown, PA	41	21,438	.20
Total Top 50		*8,973,472*	*83.73*
Other[964]		1,743,271	16.27
Total Awards to Business Firms		*10,716,743*	*100.00*

Note: (S) = Small business; (D) = Disadvantaged business.

[964] Includes remaining “top 100” list and other awards over $25,000, as well as smaller procurements of $25,000 or less.

Table 7-32. Top 50 Contractors: FY 1993 (in thousands of dollars)

Contractor/Place of Contract Performance	Rank in FY 1992	Net Value of Awards	
		Amount	Percentage
Rockwell International Corp. Canoga Park, CA	1	1,491,394	14.21
McDonnell Douglas Corp. Huntington Beach, CA	2	996,765	9.49
Lockheed Space Operations Co. Kennedy Space Center, FL	3	589,888	5.62
Boeing Co. Marshall Space Flight Center, AL	6	502,005	4.78
Thiokol Corp. Brigham City, UT	5	478,842	4.56
Lockheed Missiles and Space Co. Marshall Space Flight Center, AL	4	429,548	4.09
Rockwell Space Operations, Inc. Houston, TX	8	351,155	3.34
Martin Marietta Corp. New Orleans, LA	7	324,583	3.09
General Electric Co. Princeton, NJ	9	286,393	2.73
Lockheed Engineering and Science Co. Houston, TX	10	256,247	2.44
AlliedSignal Technical Services[965] Greenbelt, MD	84[966]	231,412	2.20
EG&G Florida, Inc. Kennedy Space Center, FL	12	221,435	2.11
TRW Inc. Redondo Beach, CA	14	217,706	2.07
Computer Sciences Corp. Greenbelt, MD	11	194,588	1.85
USBI Booster Production Co. Huntsville, AL	13	177,287	1.69
Grumman Aerospace Corp. Reston, VA	20	162,895	1.55
Boeing Computer Support Services Marshall Space Flight Center, AL	17	155,085	1.48
Loral Aerospace Corp. Houston, TX	16	136,852	1.30
Sverdrup Technology Inc. Middleburgh Heights, OH	19	106,520	1.01

[965] Allied-Signal adopted the name AlliedSignal in 1993 to reinforce a one-company image and signify the full integration of all of its businesses. “Our History,” Honeywell, *http://www.honeywell.com/sites/honeywell/ourhistory.htm* (accessed May 8, 2007).

[966] Ranking refers to AlliedSignal Inc. with place of performance in Tempe, AZ.

Contractor/Place of Contract Performance	Rank in FY 1992	Net Value of Awards	
		Amount	Percentage
United Technologies Corp. West Palm Beach, FL	18	96,540	.92
Space Systems Loral Inc. San Jose, CA	21	76,964	.73
Johnson Controls World Service Stennis Space Center, MS	22	67,057	.64
CAE Link Corp. Houston, TX	24	65,485	.62
Harris Space Systems Corp. Rockledge, FL	25	63,130	.60
Orbital Sciences Corp. Dulles, VA	27	61,740	.59
Sterling Federal Systems Inc. Moffett Field, CA	33	58,025	.55
BAMSI Inc. (D) Marshall Space Flight Center, AL	26	57,304	.55
Teledyne Industries Inc. Marshall Space Flight Center, AL	28	56,406	.54
International Business Machines Houston, TX	23	54,805	.52
GTE Government Systems Corp. Gaithersburg, MD	29	54,414	.52
Hughes Applied Information Systems Inc. Greenbelt, MD	—	52,795	.50
Spacehab Inc. (S) Washington, DC	38	49,808	.47
Santa Barbara Research Center Goleta, CA	41	47,559	.45
Cray Research Inc. Chippewa Falls, WI	35	47,105	.45
Ball Corp Boulder, CO	30	46,479	.44
Bionetics Corp Marshall Space Flight Center, AL	34	45,679	.44
Raytheon Service Co. Annapolis Junction, MD	40	44,202	.42
NSI Technology Services Corp. Greenbelt, MD	32	37,018	.35
PRC Inc. Washington, DC	36	35,282	.34
Hughes STX Corp. Greenbelt, MD	—	34,589	.33
Cortez III Service Corp. (D) Cleveland, OH	43	32,135	.31

Contractor/Place of Contract Performance	Rank in FY 1992	Net Value of Awards	
		Amount	Percentage
Swales & Associates Inc. (S) Greenbelt, MD	52	29,861	.28
Calspan Corp. Moffett Field, CA	47	28,432	.27
Krug Life Sciences Inc. Houston, TX	48	27,778	.26
Science Application International Corp. San Diego, CA	46	26,847	.26
General Electric UTC JV Evendale, OH	82	25,070	.24
Martin Marietta Services Houston, TX	—	23,588	.22
General Dynamics Corp. San Diego, CA	31	22,817	.22
Unisys Government Systems Inc. Hampton, VA	55	22,652	.22
Jackson & Tull Inc. (S) (D) Greenbelt, MD	60	22,494	.21
Total Top 50		*8,724,660*	*83.07*
Other[967]		1,773,252	16.93
Total Awards to Business Firms		*10,497,912*	*100.00*

Note: (S) = Small business; (D) = Disadvantaged business.

[967] Includes remaining “top 100” list and other awards over $25,000, as well as smaller procurements of $25,000 or less.

Table 7-33. Top 50 Contractors: FY 1994 (in thousands of dollars)

Contractor/Place of Contract Performance	**Rank in FY 1993**	**Net Value of Awards**	
		Amount	**Percentage**
Boeing Co. Houston, TX	4	1,142,113	11.46
Rockwell International Corp. Downey, CA	1	1,088,574	10.92
Lockheed Space Operations Co. Kennedy Space Center, FL	3	571,533	5.74
McDonnell Douglas Corp. Huntington Beach, CA	2	565,401	5.67
Martin Marietta Corp. New Orleans, LA	8	497,603	4.99
Thiokol Corp. Brigham City, UT	5	430,643	4.32
Rockwell Space Operations Inc. Houston, TX	7	338,005	3.39
Computer Sciences Corp. Greenbelt, MD	14	254,842	2.56
AlliedSignal Technical Services Greenbelt, MD	11	247,341	2.48
TRW Inc. Redondo Beach, CA	13	234,643	2.35
Lockheed Missiles & Space Co. Iuka, MS	6	222,364	2.23
Lockheed Engineering & Science Co. Houston, TX	10	216,145	2.17
EG&G Florida Inc. Kennedy Space Center, FL	12	200,046	2.01
USBI Booster Production Co. Huntsville, AL	15	155,908	1.56
United Technologies Corp. West Palm Beach, FL	20	118,967	1.19
Loral Aerospace Corp. Houston, TX	18	118,921	1.19
Grumman Aerospace Corp. Houston, TX	16	111,347	1.12
Space Systems Loral Inc. San Jose, CA	21	90,845	.91
Boeing Computer Support Services Marshall Space Flight, AL	17	83,993	.84
Santa Barbara Research Corp. Goleta, CA	33	82,015	.82
General Dynamics Corp. San Diego, CA	48	77,912	.78
Johnson Controls World Services	22	69,554	.70

Contractor/Place of Contract Performance	Rank in FY 1993	Net Value of Awards	
		Amount	Percentage
Stennis Space Center, MS			
Sverdrup Technology Inc. Stennis Space Center, MS	19	66,220	.66
International Business Machines Houston, TX	29	63,853	.64
Teledyne Industries Inc. Marshall Space Flight Center, AL	28	62,679	.63
BAMSI Inc. (D) Marshall Space Flight Center, AL	27	57,963	.58
Spacehab Inc. (S) Washington, DC	32	56,260	.56
Hughes STX Corp. Greenbelt, MD	40	54,056	.54
Sterling Federal Systems Inc. Moffett Field, CA	26	51,640	.52
Hughes Applied Information Systems Inc. Greenbelt, MD	31	50,723	.51
Ball Corp. Boulder, CO	35	47,046	.47
Martin Marietta Services Inc. Houston, TX	47	46,083	.46
Harris Space Systems Corp. Rockledge, FL	24	44,688	.45
CAE Link Corp. Houston, TX	23	39,503	.40
NYMA Inc. (S) (D) Cleveland, OH	—	38,519	.39
Bionetics Corp. Marshall Space Flight Center, AL	36	38,496	.39
PRC Inc. Washington, DC	39	38,067	.38
Raytheon Service Co. Annapolis Junction, MD	37	36,108	.36
Jackson & Tull Inc. (S) (D) Greenbelt, MD	50	35,409	.36
Calspan Corp. Moffett Field, CA	43	31,938	.32
General Electric Co. Evendale, OH	9[968]	31,707	.32
Krug Life Sciences Inc. Houston, TX	44	31,434	.32
NSI Technology Services Corp. Greenbelt, MD	38	31,188	.31

[968] Place of performance in 1993 listed as Princeton, NJ.

Contractor/Place of Contract Performance	Rank in FY 1993	Net Value of Awards	
		Amount	Percentage
Swales & Associates Inc. (S) Greenbelt, MD	42	30,192	.30
Cortez III Service Corp. (D) Cleveland, OH	41	28,699	.29
Science Application International Corp. Hampton, VA	45	28,281	.28
Cray Research Inc. Chippewa Falls, WI	48	28,273	.28
General Electric UTC JV Evendale, OH	46	28,143	.28
Aerojet General Corp. Azusa, CA	61	27,619	.28
Martin Marietta Technologies Littleton, CO	—	25,830	.26
Total Top 50		*8,069,332*	*80.94*
Other[969]		1,896,325	19.06
Total Awards to Business Firms		*9,965,657*	*100.0*

Note: (S) = Small business; (D) = Disadvantaged business.

[969] Includes remaining “top 100” list and other awards over $25,000, as well as smaller procurements of $25,000 or less.

Table 7-34. Top 50 Contractors: FY 1995 (in thousands of dollars)

Contractor[970]	Rank in FY 1994	Net Value of Awards	
		Amount	Percentage
Boeing Co.	1	1,441,977	13.98
Rockwell International Corp.	2	1,022,151	9.91
Martin Marietta Corp.	5	737,403	7.15
Lockheed Space Operations Co.	3	558,447	5.42
McDonnell Douglas Corp.	4	468,094	4.54
Thiokol Corp.	6	39,978	4.27
Computer Sciences Corp.	8	311,114	3.02
Rockwell Space Operations Inc.	7	306,153	2.97
TRW Inc.	10	288,202	2.80
AlliedSignal Technical Services	9	231,100	2.24
EG&G Florida Inc.	13	182,595	1.77
USBI Booster Production Co.	14	171,643	1.66
Lockheed Engineering & Science Co.	12	164,257	1.59
Loral Aerospace Corp.	16	163,582	1.59
United Technologies Corp.	15	158,564	1.54
Santa Barbara Research Corp.	20	93,761	.91
Lockheed Missiles and Space Co.	11	93,325	.91
Boeing Commercial Airplane Group	51	88,641	.86
Hughes Information Technology Corp.	—	87,065	.84
Grumman Aerospace Corp.	17	65,571	.64
Johnson Controls World Services	22	65,296	.63
BAMSI Inc. (D)	26	65,018	.63
Space Systems Loral Inc.	18	64,620	.63
Teledyne Industries Inc.	25	60,834	.59
General Dynamics Corp.	21	58,474	.57
CAE Link Corp.	34	52,164	.51
General Electric Co.	41	51,010	.49
Martin Marietta Services Inc.	32	50,935	.49
Sterling Federal Systems Inc.	29	49,228	.48
Hughes STX Corp.	28	47,789	.46
Hughes Applied Information Systems Inc.	30	47,030	.46
Ball Corp.	31	43,956	.43
Science Application International Corp.	46	42,908	.42
Krug Life Sciences Inc.	42	40,991	.40
Aerojet General Corp.	49	39,617	.38
Cortez III Service Corp.	45	38,198	.37
Spacehab Inc. (S)	27	37,724	.37
NYMA Inc. (S) (D)	35	36,782	.36

[970] NASA stopped noting the contract place of performance in the FY 1995 procurement report.

Contractor[970]	**Rank in FY 1994**	**Net Value of Awards**	
		Amount	**Percentage**
Bionetics Corp.	36	36,111	.35
Raytheon Service Co.	38	34,539	.34
Swales & Associates Inc. (S)	44	33,269	.32
General Electric UTC JV	48	32,712	.32
NSI Technology Services Corp.	43	32,187	.31
Sverdrup Technology Inc.	23	32,027	.31
CTA Inc.	—	31,734	.31
I Net Inc. (D)	55	31,181	.30
Cray Research Inc.	47	28,952	.28
AlliedSignal Inc.	73	28,141	.27
Unisys Corp.	54	28,002	.27
Silicon Graphics Inc.	61	27,059	.26
Total Top 50		*7,942,111*	*80.92*
Other[971]		2,369,380	19.08
Total Awards to Business Firms		*10,311,491*	*100.00*

Note: (S) = Small business; (D) = Disadvantaged business.

[971] Includes remaining “top 100” list and other awards over $25,000, as well as smaller procurements of $25,000 or less.

Table 7-35. Top 50 Contractors: FY 1996 (in thousands of dollars)

Contractor[972]	**Rank in FY 1995**	**Net Value of Awards**	
		Amount	**Percentage**
Boeing Co.	1	1,607,774	16.40
Lockheed Martin Corp.	3[973]	833,387	8.50
Rockwell International Corp.	2	756,319	7.72
United Space Alliance[974]	—	544,424	5.55
Thiokol Corp.	6	396,184	4.04
McDonnell Douglas Corp.	5	388,587	3.96
Rockwell Space Operations Inc.	8	292,423	2.98
TRW Inc.	9	287,339	2.93
AlliedSignal Technical Services	10	285,084	2.91
Computer Sciences Corp.	7	213,543	2.18
EG&G Florida Inc.	11	175,147	1.79
Lockheed Martin Engineering & Science Co.[975]	13	165,571	1.69
United Technologies Corp.	15	162,456	1.66
Lockheed Martin Aerospace Corp.	—	160,630	1.64
USBI Booster Production Co.	12	157,096	1.60
Hughes Aircraft Co.	32	152,864	1.56
Hughes Information Technology Corp.	19	133,486	1.36
Boeing Commercial Airplane Group	18	83,045	.85
Johnson Controls World Services	21	68,806	.70
BAMSI Inc. (D)	22	59,322	.61
General Electric Co.	27	58,383	.60
Grumman Aerospace Corp.	20	57,729	.59
Orbital Sciences Corp.	56	56,204	.57
Sterling Software U.S. Inc.[976]	29	55,433	.57
Santa Barbara Research Center[977]	16	53,707	.55
Space Systems Loral Inc.	23	50,018	.51
Ball Aerospace and Technology Corp.[978]	31	47,347	.48
Hughes STX Corp.	30	46,966	.48
Cortez III Service Corp.	36	45,527	.46
Spacehab Inc. (S)	37	44,831	.46
Hughes Training Inc.	—	43,629	.45
Calspan Corp.	70	39,939	.41
Raytheon Service Co.	40	39,508	.40

[972] NASA stopped noting the contract place of performance in the FY 1995 procurement report.
[973] Ranking is for Martin Marietta Corp. Lockheed and Martin Marietta merged in 1995.
[974] A limited liability company (LLC) formed from and owned equally by Rockwell International and Lockheed Martin.
[975] Formerly Lockheed Engineering and Science Co.
[976] Formerly Sterling Federal Systems Inc.
[977] Formerly Santa Barbara Research Corp.
[978] Formerly Ball Corp.

Contractor[972]	**Rank in FY 1995**	**Net Value of Awards**	
		Amount	**Percentage**
Teledyne Industries Inc.	24	35,988	.37
Aerojet General Corp.	35	35,439	.36
Lockheed Martin Services Inc.[979]	28	35,262	.36
Lockheed Space Operations Co.	—	33,825	.35
Jackson & Tull Inc. (S) (D)	54	33,683	.34
Swales & Associates Inc. (S)	41	33,450	.34
NYMA Inc. (S) (D)	38	31,787	.32
Cray Research Inc.	47	31,677	.32
Silicon Graphics Inc.	50	30,925	.32
Science Application International Corp.	33	30,426	.31
Krug Life Sciences Inc.	34	30,387	.31
General Electric UTC JV	42	29,900	.31
CTA Inc.	45	28,331	.29
Dyncorp	60	28,319	.29
Johnson Engineering Corp. (S)	58	28,058	.29
Government Micro Resources (S) (D)	68	27,989	.29
Sverdrup Technology Inc.	44	26,500	.27
Total Top 50		*8,094,654*	*82.6*
Other[980]		1,706,165	17.4
Total Awards to Business Firms		*9,800,819*	*100.00*

Note: (S) = Small business; (D) = Disadvantaged business.

[979] Formerly Martin Marietta Services Inc.
[980] Includes remaining "top 100" list and other awards over $25,000, as well as smaller procurements of $25,000 or less.

Table 7-36. Top 50 Contractors: FY 1997 (in thousands of dollars)

Contractor	Rank in FY 1996	Net Value of Awards	
		Amount	Percentage
Boeing Co.	1	1,661,705	16.93
United Space Alliance LLC	4	1,314,367	13.39
Lockheed Martin Corp.	2	1,048,698	10.68
Thiokol Corp.	5	424,393	4.32
Lockheed Martin Engineering and Science Co.	12	376,179	3.83
McDonnell Douglas Corp.	6	354,079	3.61
AlliedSignal Technical Services	9	333,172	3.39
TRW Inc.	8	281,349	2.87
Boeing North American Inc.[981]	7[982]	236,587	2.41
Computer Sciences Corp.	10	162,853	1.66
EG&G Florida Inc.	11	156,106	1.59
Hughes Aircraft Co.	16	153,403	1.56
USBI Booster Production Co.	15	146,863	1.50
United Technologies Corp.	13	139,537	1.42
Hughes Information Technology Corp.	17	117,003	1.19
Boeing Commercial Airplane Group	18	90,341	.92
Lockheed Martin Aerospace Corp.	14	71,763	.73
General Electric Co.	21	68,664	.70
Swales & Associates Inc. (S)	39	67,815	.69
Johnson Controls World Services	19	62,370	.64
Science Applications International Corp.	43	57,631	.59
BAMSI Inc. (D)	20	55,233	.56
Ball Aerospace & Technology Corp.	27	51,802	.53
Silicon Graphics Inc.	42	51,437	.52
Grumman Aerospace Corp.	22	46,579	.47
Cortez III Service Corp. (D)	29	44,190	.45
Hughes Training Inc.	31	43,016	.44
Hughes STX Corp.	28	41,210	.42
Santa Barbara Research Center	25	40,677	.41
Aerojet General Corp.	35	39,157	.40
NYMA Inc. (S) (D)	40	38,515	.39
Johnson Engineering Corp. (S)	48	35,680	.36
ITT Corp.	53	35,129	.36
Sterling Software U.S. Inc.	24	33,015	.34
Government Micro Resources (S) (D)	49	32,767	.33
Wang Government Services Inc. (D)	—	30,772	.31
Lockheed Space Operations Co.	37	27,106	.28

[981] Boeing North American acquired a facility at Seal Beach from North American Rockwell in 1996.
[982] Ranking is for Rockwell Space Operations Inc.

Contractor	Rank in FY 1996	Net Value of Awards	
		Amount	Percentage
Sverdrup Technology Inc.	50	26,767	.27
Spacehab Inc. (S)	30	26,284	.27
Unisys Corp.	52	25,741	.26
Raytheon Service Co.	32	24,918	.25
Space Systems Loral	26	24,670	.25
NSI Technology Service Corp.	56	24,464	.25
Calspan Corp.	32	24,304	.25
Jackson & Tull Inc. (S) (D)	38	23,010	.23
Bionetics Corp.	51	20,615	.21
EG&G Langley Inc.	58	20,218	.21
Orbital Sciences Corp.	23	19,449	.20
Micro Craft Inc. (S)	61	19,163	.20
General Electric UTC JV	45	19,025	.19
Total Top 50		*8,269,791*	*84.23*
Other[983]		1,547,366	15.77
Total Awards to Business Firms		*9,817,157*	*100.00*

Note: (S) = Small business; (D) = Disadvantaged business.

[983] Includes remaining "top 100" list and other awards over $25,000, as well as smaller procurements of $25,000 or less.

Table 7-37. Top 50 Contractors: FY 1998 (in thousands of dollars)

Contractor	Rank in FY 1997	Net Value of Awards	
		Amount	Percentage
Boeing Co.	1	1,487,934	15.58
United Space Alliance LLC	2	1,480,306	15.50
Lockheed Martin Corp.	3	982,011	10.28
McDonnell Douglas Corp.	6	420,438	4.40
Thiokol Corp.	4	363,770	3.81
AlliedSignal Technical Services	7	275,252	2.88
Boeing North American Inc.	9	260,760	2.73
Lockheed Martin Engineering and Science Co.	5	226,872	2.38
TRW Inc.	8	223,926	2.34
Computer Sciences Corp.	10	176,521	1.85
EG&G Florida Inc.	11	149,677	1.57
Hughes Aircraft Co.	12	107,701	1.13
Lockheed Martin Aerospace Corp.	17	94,399	.99
Hughes Information Technology Corp.	15	91,891	.96
United Technologies Corp.	14	90,975	.95
Boeing Commercial Airplane Group	16	86,279	.90
Science Applications International Corp.	21	78,136	.82
Ball Aerospace and Technology Corp.	23	69,418	.73
Johnson Controls World Services	20	63,241	.66
General Electric Co.	18	62,170	.65
USBI Booster Production Co.	13	61,134	.64
Orbital Sciences Corp.	48	57,374	.60
ITT Corp.	33	56,979	.60
Hamilton Standard Space Systems	85	55,307	.58
Johnson Engineering Corp. (S)	32	54,009	.57
Hughes STX Corp.	28	51,949	.54
Hughes Training Inc.	27	44,939	.47
Wyle Laboratories	90	42,476	.44
Cortez III Service Corp. (D)	26	41,493	.43
Grumman Aerospace Corp.	25	40,595	.43
Swales & Associates Inc. (S)	19	37,690	.39
Santa Barbara Research Center	29	37,205	.39
Aerojet General Corp.	30	36,618	.38
Dynacs Engineering Co. Inc. (S) (D)	—	36,579	.38
BRSP Inc.	56	36,233	.38
Lockheed Space Operations Co.	37	35,853	.38
Spacehab Inc. (S)	38	33,437	.35
EG&G Alabama	—	31,689	.33
Space Systems Loral Inc.	42	31,046	.33

Contractor	Rank in FY 1997	Net Value of Awards	
		Amount	Percentage
General Electric UTC JV Unisys Corp.	50	30,849	.32
Sverdrup Technology Inc.	38	28,965	.30
Silicon Graphics Inc.	24	28,915	.30
Sterling Software U.S. Inc.	34	28,293	.30
Calspan Corp.	44	28,119	.29
Jackson & Tull Inc. (S) (D)	45	27,648	.29
NYMA Inc. (S) (D)	31	26,456	.28
Scientific & Commercial Systems (S) (D)	76	25,771	.27
Micro Craft Inc. (S)	49	24,849	.26
NSI Technology Service Corp.	43	23,804	.25
Government Micro Resources (S) (D)	35	23,082	.24
Total Top 50		*7,911,033*	*82.82*
Other[984]		1,639,467	17.18
Total Awards to Business Firms		*9,550,500*	*100.00*

Note: (S) = Small business; (D) = Disadvantaged business.

[984] Includes remaining “top 100” list and other awards over $25,000, as well as smaller procurements of $25,000 or less.

Table 7-38. Top 50 Educational and Nonprofit Institutions: FY 1989 (in thousands of dollars)

Contractor/Place of Contract Performance	Rank in FY 1988	Net Value of Awards	
		Amount	Percentage
Stanford University Stanford, CA	1	41,785	6.49
Association of Universities for Research in Astronomy (N) Baltimore, MD	2	27,318	4.24
University of California–Berkeley Berkeley, CA	6	24,560	3.81
Universities Space Research (N) Greenbelt, MD	4	23,404	3.63
MITRE Corp. (N) Houston, TX	52	20,345	3.16
Massachusetts Institute of Technology Cambridge, MA	5	19,425	3.02
New Mexico State University, Las Cruces Palestine, TX	3	19,348	3.00
Southwest Research Institute (N) San Antonio, TX	11	18,289	2.84
University of Arizona Tucson, AZ	8	16,209	2.52
Smithsonian Institution (N) Cambridge, MA	10	15,890	2.47
National Academy of Sciences (N) Washington, DC	7	13,698	2.13
Charles Stark Draper Lab Inc. (N) Cambridge, MA	12	13,465	2.09
University of Colorado–Boulder Boulder, CO	9	13,283	2.06
University of Maryland–College Park College Park, MD	13	12,995	2.02
University of Iowa Iowa City, IA	20	12,427	1.93
University of California–San Diego La Jolla, CA	17	12,058	1.87
University of Michigan–Ann Arbor Ann Arbor, MI	16	12,030	1.87
University of Alabama–Huntsville Huntsville, AL	14	11,427	1.77
University of Wisconsin–Madison Madison, WI	15	9,441	1.47
Pennsylvania State University–University Park University Park, PA	23	8,166	1.27

Contractor/Place of Contract Performance	Rank in FY 1988	Net Value of Awards	
		Amount	Percentage
California Institute of Technology[985] Pasadena, CA	18	7,757	1.20
Case Western Reserve University Cleveland, OH	19	6,775	1.05
University of Texas–Austin Austin, TX	29	6,612	1.03
University of Chicago Chicago, IL	24	6,445	1.00
University of California–Los Angeles Los Angeles, CA	22	6,141	.95
University of Hawaii Honolulu, HI	21	6,095	.95
Old Dominion University Norfolk, VA	32	5,613	.87
Ohio State University Columbus, OH	34	5,391	.84
Cornell University Ithaca, NY	36	5,301	.82
University of Southern California Los Angeles, CA	30	5,288	.82
University of Houston–Clear Lake Houston, TX	26	5,192	.81
University of New Hampshire Durham, NH	25	4,896	.76
Johns Hopkins University Baltimore, MD	33	4,484	.70
Texas A&M University El Paso, TX	37	4,447	.69
Harvard University Cambridge, MA	27	4,400	.68
Battelle Memorial Institute (N) Columbus, OH	48	4,107	.64
Virginia Polytechnic Institute Blacksburg, VA	38	4,058	.63
University of Washington Seattle, WA	28	4,043	.63
Columbia University New York, NY	31	3,944	.61
San Jose State University Moffett Field, CA	43	3,812	.59
Research Triangle Institute Research Triangle, Park, NC	61	3,710	.58

[985] Excludes the Jet Propulsion Laboratory.

Contractor/Place of Contract Performance	Rank in FY 1988	Net Value of Awards	
		Amount	Percentage
Carnegie Mellon University Pittsburgh, PA	56	3,697	.57
North Carolina State University Raleigh, NC	—	3,647	.57
University of Illinois–Urbana Urbana, IL	49	3,608	.56
Hampton City (N) Hampton, VA	39	3,580	.56
Princeton University Princeton, NJ	41	3,481	.54
Oklahoma State University Stillwater, OK	42	3,465	.54
Georgia Institute of Technology Atlanta, GA	45	3,418	.53
University of Alaska–Fairbanks Fairbanks, AK	44	3,383	.53
University of Virginia Charlottesville, VA	53	3,314	.51
Total Top 50		*485,667*	*75.42*
Other[986]		159,551	24.58
Total Awards to Educational and Nonprofit Institutions		*644,218*	*100.00*

Note: (N) = Nonprofit institution.

[986] Includes remaining “top 100” list and other awards over $25,000, as well as smaller procurements of $25,000 or less.

Table 7-39. Top 50 Educational and Nonprofit Institutions: FY 1990 (in thousands of dollars)

Contractor/Place of Contract Performance	Rank in FY 1989	Net Value of Awards	
		Amount	Percentage
Stanford University Stanford, CA	1	49,144	6.88
Association of Universities for Research in Astronomy (N) Baltimore, MD	2	31,592	4.42
Smithsonian Institution (N) Cambridge, MA	10	26,465	3.71
Universities Space Research (N) Greenbelt, MD	4	24,099	3.37
MITRE Corp. (N) Houston, TX	5	22,805	3.19
Massachusetts Institute of Technology Cambridge, MA	6	21,242	2.97
University of California–Berkeley Berkeley, CA	3	19,403	2.72
University of Arizona Tucson, AZ	9	18,887	2.64
University of Maryland–College Park College Park, MD	14	17,920	2.51
New Mexico State University, Las Cruces Palestine, TX	7	16,455	2.30
University of Alabama–Huntsville Huntsville, AL	18	15,818	2.21
Charles Stark Draper Lab Inc. (N) Cambridge, MA	12	13,622	1.91
University of Colorado–Boulder Boulder, CO	13	12,717	1.78
University of California–San Diego La Jolla, CA	16	12,688	1.78
University of Wisconsin–Madison Madison, WI	19	12,458	1.74
Southwest Research Institute (N) San Antonio, TX	8	11,775	1.65
National Academy of Sciences (N) Washington, DC	11	10,894	1.53
University of Michigan–Ann Arbor Ann Arbor, MI	17	10,420	1.46
California Institute of Technology[987] Pasadena, CA	21	9,632	1.35
University of New Hampshire Durham, NH	32	8,384	1.17

[987] Excludes the Jet Propulsion Laboratory.

Contractor/Place of Contract Performance	Rank in FY 1989	Net Value of Awards	
		Amount	Percentage
Pennsylvania State University–University Park University Park, PA	20	7,872	1.10
University of Alaska–Fairbanks Fairbanks, AK	49	7,681	1.08
Case Western Reserve University Cleveland, OH	22	7,573	1.06
University of Houston–Clear Lake Houston, TX	31	7,400	1.04
University of California–Los Angeles Los Angeles, CA	25	7,337	1.03
University of Washington Seattle, WA	38	7,151	1.00
University of Hawaii Honolulu, HI	26	6,880	.96
University of Texas–Austin Austin, TX	23	6,785	.95
University of Chicago Chicago, IL	24	6,244	.87
Cornell University Ithaca, NY	29	5,968	.84
Battelle Memorial Institute (N) Columbus, OH	36	5,566	.78
Columbia University New York, NY	39	5,500	.77
University of Southern California Los Angeles, CA	30	5,453	.76
San Jose State University Moffett Field, CA	40	5,175	.72
University of Virginia Charlottesville, VA	50	5,054	.71
University of Houston Houston, TX	51	4,919	.69
Johns Hopkins University Baltimore, MD	33	4,918	.69
Ohio State University Columbus, OH	28	4,638	.65
Old Dominion University Norfolk, VA	27	4,279	.60
University of Iowa Iowa City, IA	15	4,149	.58
Princeton University Princeton, NJ	46	4,123	.58
Virginia Polytechnic Institute Blacksburg, VA	37	4,120	.58

Contractor/Place of Contract Performance	Rank in FY 1989	Net Value of Awards	
		Amount	Percentage
University of Illinois–Urbana Urbana, IL	44	3,974	.56
North Carolina State University Raleigh, NC	43	3,951	.55
Georgia Institute of Technology Atlanta, GA	48	3,908	.55
Harvard University Cambridge, MA	35	3,884	.54
American Institute of Aeronautics and Astronautics (N) New York, NY	60	3,844	.54
SETI Institute (N) Moffett Field, CA	64	3,648	.51
Hampton City (N) Hampton, VA	45	3,491	.49
SRI International Corp. (N) Menlo Park, CA	67	3,447	.48
Total Top 50		*525,352*	*73.55*
Other[988]		188,814	26.45
Total Awards to Educational and Nonprofit Institutions		*714,166*	*100.00*

Note: (N) = Nonprofit institution.

[988] Includes remaining “top 100” list and other awards over $25,000, as well as smaller procurements of $25,000 or less.

Table 7-40. Top 50 Educational and Nonprofit Institutions: FY 1991 (in thousands of dollars)

Contractor/Place of Contract Performance	Rank in FY 1990	Net Value of Awards	
		Amount	Percentage
Stanford University Stanford, CA	1	55,016	6.59
Association of Universities for Research in Astronomy (N) Baltimore, MD	2	47,355	5.67
Smithsonian Institution (N) Cambridge, MA	3	31,395	3.76
Universities Space Research (N) Greenbelt, MD	4	28,261	3.38
Massachusetts Institute of Technology Cambridge, MA	6	25,535	3.06
MITRE Corp. (N) Houston, TX	5	23,453	2.81
University of Maryland–College Park College Park, MD	9	22,333	2.67
New Mexico State University, Las Cruces Palestine, TX	10	21,177	2.54
University of California–Berkeley Berkeley, CA	7	20,306	2.43
University of Alabama–Huntsville Huntsville, AL	11	17,371	2.08
University of Colorado–Boulder Boulder, CO	13	16,520	1.98
Charles Stark Draper Lab Inc. (N) Cambridge, MA	12	15,973	1.91
University of California–San Diego La Jolla, CA	14	15,950	1.91
University of Arizona Tucson, AZ	8	15,300	1.83
National Academy of Sciences (N) Washington, DC	17	13,423	1.61
University of Michigan–Ann Arbor Ann Arbor, MI	18	12,573	1.51
University of Wisconsin–Madison Madison, WI	15	11,987	1.44
California Institute of Technology[989] Pasadena, CA	19	11,701	1.40
Southwest Research Institute (N) San Antonio, TX	16	11,096	1.33
University of Tennessee Calspan Center for Space Transportation and Applied Research (CSTAR) (N)	—	10,745	1.29

[989] Excludes the Jet Propulsion Laboratory.

Contractor/Place of Contract Performance	Rank in FY 1990	Net Value of Awards	
		Amount	Percentage
Tullahoma, TN			
Pennsylvania State University–University Park University Park, PA	21	10,646	1.27
Saginaw Valley State University University Center, MI	59	10,100	1.21
University of Iowa Iowa City, IA	40	8,624	1.03
University of New Hampshire Durham, NH	20	8,354	1.00
University of California–Los Angeles Los Angeles, CA	25	7,801	.93
University of Washington Seattle, WA	26	7,680	.92
Case Western Reserve University Cleveland, OH	23	7,627	.91
Harvard University Cambridge, MA	46	7,451	.89
University of Hawaii Honolulu, HI	27	7,113	.85
University of Texas–Austin Austin, TX	28	7,031	.84
SETI Institute (N) Moffett Field, CA	48	6,833	.82
University of Houston Houston, TX	36	6,755	.81
University of Alaska–Fairbanks Fairbanks, AK	22	6,725	.81
University of Houston–Clear Lake Houston, TX	24	6,723	.80
Columbia University New York, NY	32	6,480	.78
Cornell University Ithaca, NY	30	5,995	.72
Johns Hopkins University Baltimore, MD	37	5,958	.71
University of Chicago Chicago, IL	29	5,939	.71
Ohio State University Columbus, OH	38	5,593	.67
University of Alabama–Birmingham Birmingham, AL	55	5,369	.64
Battelle Memorial Institute (N) Columbus, OH	31	5,284	.63
Texas A&M University	51	5,235	.63

Contractor/Place of Contract Performance	Rank in FY 1990	Net Value of Awards	
		Amount	Percentage
College Station, TX			
Georgia Institute of Technology Atlanta, GA	45	5,170	.62
Oklahoma State University Stillwater, OK	60	5,024	.60
University of Virginia Charlottesville, VA	35	4,969	.59
San Jose State University Moffett Field, CA	34	4,851	.58
Virginia Polytechnic Institute Blacksburg, VA	42	4,822	.58
Old Dominion University Norfolk, VA	39	4,297	.51
Princeton University Princeton, NJ	41	4,132	.49
University of California–Santa Barbara Santa Barbara, CA	65	3,908	.47
Total Top 50		*619,959*	*74.22*
Other[990]		216,011	25.78
Total Awards to Educational and Nonprofit Institutions		*835,970*	*100.00*

Note: (N) = Nonprofit institution.

[990] Includes remaining “top 100” list and other awards over $25,000, as well as smaller procurements of $25,000 or less.

Table 7-41. Top 50 Educational and Nonprofit Institutions: FY 1992 (in thousands of dollars)

Contractor/Place of Contract Performance	Rank in FY 1991	Net Value of Awards	
		Amount	Percentage
Stanford University Stanford, CA	1	53,963	5.64
Association of Universities for Research in Astronomy (N) Baltimore, MD	2	47,539	4.97
Smithsonian Institution (N) Cambridge, MA	3	38,293	4.00
Massachusetts Institute of Technology Cambridge, MA	5	37,085	3.88
Universities Space Research (N) Greenbelt, MD	4	31,908	3.33
University of California–Berkeley Berkeley, CA	9	24,497	2.56
Center for International Earth Science Information Network (CIESIN) (N) Ann Arbor, MI		23,815	2.49
MITRE Corp. (N) Houston, TX	6	21,026	2.20
University of California–San Diego La Jolla, CA	13	20,950	2.19
University of Maryland–College Park College Park, MD	7	20,935	2.19
University of Arizona Tucson, AZ	14	18,994	1.99
University of Colorado–Boulder Boulder, CO	11	18,919	1.98
University of Tennessee Calspan Center for Space Transportation and Applied Research (CSTAR) (N) Tullahoma, TN	20	18,750	1.96
National Academy of Sciences (N) Washington, DC	15	17,852	1.87
University of Alabama–Huntsville Huntsville, AL	10	16,578	1.73
Charles Stark Draper Lab Inc. (N) Cambridge, MA	12	16,561	1.73
New Mexico State University, Las Cruces Palestine, TX	8	16,491	1.72
University of Wisconsin–Madison Madison, WI	17	13,888	1.45
Pennsylvania State University–University Park University Park, PA	21	12,687	1.33
University of Michigan–Ann Arbor Ann Arbor, MI	16	11,899	1.24

Contractor/Place of Contract Performance	Rank in FY 1991	Net Value of Awards	
		Amount	Percentage
California Institute of Technology[991] Pasadena, CA	18	11,477	1.20
Utah State University Logan, UT	—	11,437	1.20
University of New Hampshire Durham, NH	24	10,102	1.06
University of Iowa Iowa City, IA	23	9,381	.98
Southwest Research Institute (N) San Antonio, TX	19	9,145	.96
University of Washington Seattle, WA	26	9,113	.95
Cornell University Ithaca, NY	36	8,726	.91
SETI Institute (N) Moffett Field, CA	31	8,573	.90
University of Alaska–Fairbanks Fairbanks, AK	33	8,552	.89
University of California–Los Angeles Los Angeles, CA	25	8,330	.87
University of Texas–Austin Austin, TX	30	8,127	.85
Johns Hopkins University Baltimore, MD	37	8,027	.84
San Jose State University Moffett Field, CA	46	7,752	.81
University of Hawaii Honolulu, HI	29	7,631	.80
University of Virginia Charlottesville, VA	45	7,344	.77
Case Western Reserve University Cleveland, OH	27	7,081	.74
Wheeling Jesuit College Wheeling, WV	64	6,956	.73
University of Houston Houston, TX	32	6,918	.72
University of Chicago Chicago, IL	38	6,474	.68
Columbia University New York, NY	35	6,416	.67
University of Houston–Clear Lake Houston, TX	34	6,307	.66

[991] Excludes the Jet Propulsion Laboratory.

Contractor/Place of Contract Performance	Rank in FY 1991	Net Value of Awards	
		Amount	**Percentage**
Oklahoma State University Stillwater, OK	44	6,182	.65
Battelle Memorial Institute (N) Columbus, OH	41	5,980	.63
Ohio Aerospace Institute (N) Brookpark, OH	69	5,747	.60
Texas A&M University College Station, TX	42	5,656	.59
Harvard University Cambridge, MA	28	5,258	.55
Princeton University Princeton, NJ	49	5,207	.54
Auburn University Auburn, AL	58	5,104	.53
Carnegie Mellon University Pittsburgh, PA	60	4,775	.50
University of California–Santa Barbara Santa Barbara, CA	50	4,685	.49
Total Top 50		*705,093*	*73.72*
Other[992]		251,992	26.28
Total Awards to Educational and Nonprofit Institutions		*957,085*	*100.00*

Note: (N) = Nonprofit institution.

992 Includes remaining “top 100” list and other awards over $25,000, as well as smaller procurements of $25,000 or less.

Table 7-42. Top 50 Educational and Nonprofit Institutions: FY 1993 (in thousands of dollars)

Contractor/Place of Contract Performance	Rank in FY 1992	Net Value of Awards	
		Amount	Percentage
Stanford University Stanford, CA	1	55,897	5.35
Association of Universities for Research in Astronomy (N) Baltimore, MD	2	54,795	5.25
Smithsonian Institution (N) Cambridge, MA	3	42,233	4.04
Massachusetts Institute of Technology Cambridge, MA	4	39,165	3.75
Universities Space Research (N) Greenbelt, MD	5	31,035	2.97
University of Tennessee Calspan Center for Space Transportation and Applied Research (CSTAR) (N) Tullahoma, TN	13	23,817	2.28
Wheeling Jesuit College Wheeling, WV	37	23,559	2.26
University of California–Berkeley Berkeley, CA	6	22,853	2.19
New Mexico State University, Las Cruces Palestine, TX	17	21,749	2.08
University of Arizona Tucson, AZ	11	21,718	2.08
MITRE Corp. (N) Houston, TX	8	21,543	2.06
University of Alaska–Fairbanks Fairbanks, AK	29	20,063	1.92
Christopher Columbus Center Development (N) Baltimore, MD	—	20,000	1.92
CIESIN (Center for International Earth Science Information Network) (N) Ann Arbor, MI	7	18,975	1.82
University of Maryland–College Park College Park, MD	10	17,643	1.69
University of Colorado–Boulder Boulder, CO	12	17,285	1.66
Charles Stark Draper Lab Inc. (N) Cambridge, MA	16	16,723	1.60
University of California–San Diego La Jolla, CA	9	16,307	1.56
National Academy of Sciences (N) Washington, DC	14	15,767	1.51
University of Alabama–Huntsville Huntsville, AL	15	14,939	1.43

Contractor/Place of Contract Performance	Rank in FY 1992	Net Value of Awards	
		Amount	Percentage
California Institute of Technology[993] Pasadena, CA	21	14,111	1.35
Pennsylvania State University–University Park University Park, PA	19	13,619	1.31
University of Michigan–Ann Arbor Ann Arbor, MI	20	11,353	1.09
University of Wisconsin–Madison Madison, WI	18	11,099	1.06
University of New Hampshire Durham, NH	23	10,463	1.00
West Virginia University Morgantown, WV	65	10,395	1.00
Johns Hopkins University Baltimore, MD	32	10,235	.98
University of Texas–Austin Austin, TX	31	9,687	.93
University of Washington Seattle, WA	26	9,612	.92
University of Hawaii Honolulu, HI	34	9,353	.90
University of California–Los Angeles Los Angeles, CA	30	9,086	.87
University of Virginia Charlottesville, VA	35	8,526	.82
Cornell University Ithaca, NY	27	8,035	.77
Southwest Research Institute (N) San Antonio, TX	25	7,685	.74
Ohio Aerospace Institute (N) Brookpark, OH	44	7,676	.74
SETI Institute (N) Moffett Field, CA	28	7,664	.73
Georgia Institute of Technology Atlanta, GA	62	7,491	.72
San Jose State University Moffett Field, CA	33	7,190	.69
Oklahoma State University Stillwater, OK	42	7,125	.68
Battelle Memorial Institute (N) Columbus, OH	43	7,063	.68
University of Houston Houston, TX	38	6,847	.66

[993] Excludes the Jet Propulsion Laboratory.

Contractor/Place of Contract Performance	Rank in FY 1992	Net Value of Awards	
		Amount	Percentage
Columbia University New York, NY	39	6,730	.64
Case Western Reserve University Cleveland, OH	36	6,711	.64
Texas A&M University College Station, TX	45	6,567	.63
Harvard University Cambridge, MA	46	6,526	.63
University of Chicago Chicago, IL	39	6,436	.62
University of Houston–Clear Lake Houston, TX	41	5,930	.57
University of Iowa Iowa City, IA	24	5,485	.53
Old Dominion University Norfolk, VA	57	5,364	.51
University of Southern California Los Angeles, CA	66	4,739	.45
Total Top 50		*764,869*	*73.28*
Other[994]		279,596	26.72
Total Awards to Educational and Nonprofit Institutions		*1,044,465*	*100.00*

Note: (N) = Nonprofit institution.

[994] Includes remaining “top 100” list and other awards over $25,000, as well as smaller procurements of $25,000 or less.

Table 7-43. Top 50 Educational and Nonprofit Institutions: FY 1994 (in thousands of dollars)

Contractor/Place of Contract Performance	Rank in FY 1993	Net Value of Awards	
		Amount	Percentage
Association of Universities in Research in Astronomy (N) Baltimore, MD	1	60,127	5.77
Stanford University Stanford, CA	2	57,027	5.47
University of Arizona Tucson, AZ	10	48,232	4.63
Massachusetts Institute of Technology Cambridge, MA	4	39,297	3.77
Universities Space Research (N) Greenbelt, MD	5	38,442	3.69
Smithsonian Institution (N) Cambridge, MA	3	37,574	3.61
California Institute of Technology[995] Pasadena, CA	21	28,529	2.74
National Academy of Sciences (N) Washington, DC	19	25,200	2.42
University of California–Berkeley Berkeley, CA	8	24,840	2.38
University of Maryland–College Park College Park, MD	15	19,441	1.87
Battelle Memorial Institute (N) Columbus, OH	40	19,434	1.87
Wheeling Jesuit College Wheeling, WV	7	19,348	1.86
New Mexico State University, Las Cruces Palestine, TX	9	18,076	1.73
University of Colorado–Boulder Boulder, CO	16	17,136	1.64
Charles Stark Draper Lab Inc. (N) Cambridge, MA	17	14,027	1.35
University of California–San Diego La Jolla, CA	18	13,130	1.26
University of Alaska–Fairbanks Fairbanks, AK	12	13,091	1.26
University of Wisconsin–Madison Madison, WI	24	12,740	1.22
University of Alabama–Huntsville Huntsville, AL	20	12,511	1.20
Pennsylvania State University–University Park University Park, PA	22	12,442	1.19

[995] Excludes the Jet Propulsion Laboratory.

Contractor/Place of Contract Performance	Rank in FY 1993	Net Value of Awards	
		Amount	Percentage
MITRE Corp. (N) Houston, TX	11	11,993	1.15
Johns Hopkins University Baltimore, MD	27	11,621	1.12
University of Michigan–Ann Arbor Ann Arbor, MI	23	10,669	1.02
University of Utah Salt Lake City, UT	—	10,228	.98
University of Texas–Austin Austin, TX	28	9,450	.91
University of Washington Seattle, WA	29	9,077	.87
University of Hawaii Honolulu, HI	30	8,612	.83
University of New Hampshire Durham, NH	25	8,593	.82
University of California–Los Angeles Los Angeles, CA	31	8,482	.80
University of Tennessee Calspan CSTAR (N) Tullahoma, TN	6	8,214	.79
Oklahoma State University Stillwater, OK	39	7,886	.76
State of Maryland (N) Baltimore, MD	—	6,558	.63
Ohio Aerospace Institute (N) Brook Park, OH	35	6,514	.63
Harvard University Cambridge, MA	45	6,474	.62
University of Houston Houston, TX	41	6,188	.59
Columbia University New York, NY	42	6,082	.58
CIESIN (N) Ann Arbor, MI	14	5,880	.56
Case Western Reserve University Cleveland, OH	43	5,766	.55
Cornell University Ithaca, NY	33	5,703	.55
San Jose State University Moffett Field, CA	38	5,544	.53
Old Dominion University Norfolk, VA	49	5,292	.51
Georgia Institute of Technology Atlanta, GA	37	5,202	.50

Contractor/Place of Contract Performance	Rank in FY 1993	Net Value of Awards	
		Amount	Percentage
Southwest Research Institute (N) San Antonio, TX	34	4,898	.47
University of Alabama–Birmingham Birmingham, AL	51	4,894	.47
Ohio State University Columbus, OH	53	4,761	.46
Carnegie Mellon University Pittsburgh, PA	59	4,677	.45
University of Iowa Iowa City, IA	48	4,568	.44
Princeton University Princeton, NJ	56	4,556	.44
University of Chicago Chicago, IL	46	4,535	.44
Virginia Polytechnic Institute Blacksburg, VA	55	4,463	.43
Total Top 50		*738,024*	*70.83*
Other[996]		303,899	29.62
Total Awards to Educational and Nonprofit Institutions		*1,041,923*	*100.00*

Note: (N) = Nonprofit institution.

[996] Includes remaining “top 100” list and other awards over $25,000, as well as smaller procurements of $25,000 or less.

Table 7-44. Top 50 Educational and Nonprofit Institutions: FY 1995 (in thousands of dollars)

Contractor[997]	**Rank in FY 1994**	**Net Value of Awards**	
		Amount	**Percentage**
Association of Universities for Research in Astronomy (AURA)[998] (N)	1	61,198	5.44
Stanford University	2	58,333	5.18
Smithsonian Institution (N)	6	47,570	4.23
Massachusetts Institute of Technology	4	46,660	4.15
Universities Space Research Association (N)	5	37,493	3.33
University of Arizona	3	36,468	3.24
California Institute of Technology[999]	7	30,740	2.73
University of California–Berkeley	9	24,346	2.16
University of Alabama–Huntsville	19	24,001	2.13
University of Maryland–College Park	10	22,206	1.97
National Academy of Sciences (N)	8	22,148	1.97
New Mexico State University	13	20,259	1.80
Johns Hopkins University	22	19,587	1.74
University of Colorado–Boulder	14	18,004	1.60
Wheeling Jesuit College	12	17,990	1.60
Ohio Aerospace Institute (N)	33	15,949	1.42
University of Michigan–Ann Arbor	23	13,561	1.20
University of California–San Diego	16	13,320	1.18
Southwest Research Institute (N)	43	12,908	1.15
University of Wisconsin–Madison	18	12,903	1.15
University of Washington	26	12,132	1.08
University of Alaska–Fairbanks	17	11,045	.98
Pennsylvania State University–University Park	20	10,594	.94
University of Texas–Austin	25	9,992	.89
University of New Hampshire	28	9,916	.88
University of California–Los Angeles	29	9,376	.83
Georgia Institute of Technology	42	9,000	.80
Battelle Memorial Institute (N)	11	8,914	.79
University of Hawaii	27	8,707	.77
University of Alabama–Birmingham	44	8,221	.73
University Corporation for Atmospheric Research (UCAR) (N)	56	7,860	.70
Charles Stark Draper Labs (N)	15	7,636	.68
Harvard University	34	7,490	.66
Columbia University	36	7,422	.66

[997] The Annual Procurement Report stopped listing the contractor's place of performance in the FY 1995 report.
[998] Listed as "Assn Univ Research & Astronomy" in FY 1995 Annual Procurement Report.
[999] Excludes Jet Propulsion Laboratory awards.

Contractor[997]	**Rank in FY 1994**	**Net Value of Awards**	
		Amount	**Percentage**
Ohio State University	45	7,236	.64
Delta College	—	6,825	.61
University of Virginia	53	6,349	.56
Oklahoma State University	31	6,251	.56
University of Utah	24	6,228	.55
University of Florida	52	6,170	.55
Texas A&M University	51	5,895	.52
University of Chicago	49	5,868	.52
Cornell University	39	5,518	.49
SETI Institute (N)	57	5,458	.49
Research Triangle Institute (N)	83	5,430	.48
University of Houston	35	5,362	.48
Old Dominion University	41	5,337	.48
San Jose State University	40	5,134	.46
Princeton University	48	5,070	.45
CIESIN (N)	36	5,066	.45
Total Top 50		*777,146*	*69.05*
Other[1000]		348,302	30.95
Total Awards to Educational and Nonprofit Institutions		*1,125,448*	*100.00*

Note: (N) = Nonprofit institution.

[1000] Includes remaining "top 100" list and other awards over $25,000, as well as smaller procurements of $25,000 or less.

Table 7-45. Top 50 Educational and Nonprofit Institutions: FY 1996 (in thousands of dollars)

Contractor	Rank in FY 1995	Net Value of Awards	
		Amount	Percentage
Stanford University	2	72,785	7.04
Johns Hopkins University	13	60,748	5.88
Association of Universities for Research in Astronomy (AURA) (N)	1	55,272	5.35
Smithsonian Institution (N)	3	45,998	4.45
Massachusetts Institute of Technology	4	37,883	3.67
Universities Space Research Association (N)	5	31,425	3.04
California Institute of Technology[1001]	7	25,098	2.43
University of Arizona	6	21,700	2.10
New Mexico State University	12	19,596	1.90
National Academy of Sciences (N)	11	19,013	1.84
University of California–Berkeley	8	18,444	1.78
University of Maryland–College Park	10	18,337	1.77
Wheeling Jesuit College	15	17,567	1.70
University of Colorado–Boulder	14	16,335	1.58
Amtech Inc. California (N)	—	16,051	1.55
University of Alabama–Huntsville	9	14,534	1.41
University Corporation for Atmospheric Research (UCAR) (N)	31	12,589	1.22
University of New Hampshire	25	11,654	1.13
University of Michigan–Ann Arbor	17	11,322	1.10
University of Wisconsin–Madison	20	10,937	1.06
University of Alabama–Birmingham	30	10,460	1.01
University of California–San Diego	18	10,131	0.98
Harvard University	33	9,693	0.94
University of California–Los Angeles	26	9,532	0.92
Pennsylvania State University–University Park	23	9,356	0.91
University of Alaska–Fairbanks	22	9,194	0.89
University of Washington	21	8,973	0.87
University of Texas–Austin	24	8,017	0.78
Oklahoma State University	38	7,799	0.75
University of Hawaii	29	7,674	0.74
University of Houston	46	7,519	0.73
Charles Stark Draper Labs (N)	32	6,801	0.66
University of Iowa	53	6,739	0.65
Georgia Institute of Technology	27	6,414	0.62
Cornell University	43	5,817	0.56
Southwest Research Institute (N)	19	5,786	0.56

[1001] Excludes Jet Propulsion Laboratory awards.

Contractor	Rank in FY 1995	Net Value of Awards	
		Amount	Percentage
Rotorcraft Industry Technical Association (N)	—	5,748	0.56
Ohio Aerospace Institute (N)	16	5,273	0.51
University of Virginia	37	5,188	0.50
Ohio State University	35	4,940	0.48
University of Florida	40	4,900	0.47
Columbia University	34	4,835	0.47
University of Chicago	42	4,787	0.46
Research Triangle Institute (N)	45	4,326	0.42
Princeton University	49	4,234	0.41
San Jose State University	48	4,125	0.40
University of California–Santa Barbara	55	4,093	0.40
Research and Development Institute (N)	—	4,050	0.39
Florida A&M Institute	66	3,989	0.39
University of Southern California	60	3,978	0.38
Total Top 50		*731,659*	*70.79*
Other[1002]		301,941	29.21
Total Awards to Educational and Nonprofit Institutions		*1,033,600*[1003]	*100.00*

Note: (N) = Nonprofit institution.

[1002] Includes remaining "top 100" list and other awards over $25,000, as well as smaller procurements of $25,000 or less.

[1003] The total awards to educational and nonprofit institutions as shown in the list of 100 educational and nonprofit institutions on page 26 of the FY 1996 Annual Procurement Report were printed incorrectly (amounts shown in the FY 1995 table were copied). The correct amounts, as provided elsewhere in the FY 1996 procurement report, are listed in the above table.

Table 7-46. Top 50 Educational and Nonprofit Institutions: FY 1997 (in thousands of dollars)

Contractor/Place of Contract Performance	Rank in FY 1996	Net Value of Awards	
		Amount	Percentage
Stanford University	1	72,541	6.09
Universities Space Research Association (N)	—	72,217	6.06
Association of Universities for Research in Astronomy (AURA) (N)	3	64,903	5.45
Johns Hopkins University	2	49,834	4.18
University of Colorado–Boulder	14	41,986	3.53
Smithsonian Institution (N)	4	39,649	3.33
Massachusetts Institute of Technology	5	34,242	2.88
Southwest Research Institute (N)	36	26,955	2.26
University of Maryland–College Park	12	25,234	2.12
Amtech Inc. California (N)	15	23,841	2.00
California Institute of Technology[1004]	6	19,979	1.68
University of California–Berkeley	11	19,775	1.66
National Academy of Sciences (N)	10	19,641	1.65
University of Arizona	8	18,067	1.52
New Mexico State University	9	15,922	1.34
University of Alabama–Huntsville	16	15,397	1.29
University of Alaska–Fairbanks	26	14,542	1.22
University of California–San Diego	22	13,364	1.12
Wheeling Jesuit College	13	11,756	.99
Pennsylvania State University–University Park	25	11,248	.94
University of Michigan–Ann Arbor	19	10,619	.89
Columbia University	42	10,371	.87
Rotorcraft Industry Technical Association (N)	38	10,139	.85
University of Alabama–Birmingham	21	10,020	.84
University of Washington	27	9,314	.78
University of California–Los Angeles	24	9,157	.77
University of Wisconsin–Madison	20	8,577	.72
Harvard University	23	8,543	.72
University of Hawaii	30	7,909	.66
Hampton University	63	7,492	.63
Research Triangle Institute (N)	44	7,259	.61
Princeton University	45	6,312	.53
University of New Hampshire	18	6,302	.53
University of Texas–Austin	28	6,222	.52
Georgia Institute of Technology	34	6,221	.52
Utah State University	69	5,939	.50
Alaska Aerospace Development Corp. (N)	—	5,681	.48

[1004] Excludes Jet Propulsion Laboratory awards.

Contractor/Place of Contract Performance	Rank in FY 1996	Net Value of Awards	
		Amount	Percentage
Virginia Polytechnic Institute	66	5,615	.47
University of California–Santa Barbara	47	5,591	.47
Oregon State University	53	5,342	.45
Baylor College of Medicine	—	5,092	.43
Oklahoma State University	29	5,089	.43
Carnegie Mellon University	55	5,084	.43
University of California–Riverside	58	4,991	.42
Cornell University	35	4,944	.42
University of Iowa	33	4,912	.41
SETI Institute (N)	64	4,820	.40
University of Florida	41	4,804	.40
Boston University	68	4,800	.40
Ohio Aerospace Institute (N)	38	4,733	.40
Total Top 50		*812,987*	*68.26*
Other[1005]		378,109	31.74
Total Awards to Educational and Nonprofit Institutions		*1,191,096*	*100.00*

Note: (N) = Nonprofit institution.

[1005] Includes remaining “top 100” list and other awards over $25,000, as well as smaller procurements of $25,000 or less.

Table 7-47. Top 50 Educational and Nonprofit Institutions: FY 1998 (in thousands of dollars)

Contractor/Place of Contract Performance	Rank in FY 1997	Net Value of Awards	
		Amount	Percentage
Johns Hopkins University	4	90,762	6.96
Stanford University	1	70,501	5.40
Association of Universities for Research in Astronomy (AURA) (N)	3	69,973	5.36
Universities Space Research Association (N)	2	68,235	5.23
University of Colorado–Boulder	5	46,098	3.53
Smithsonian Institution (N)	6	40,124	3.08
University of Maryland–College Park	9	35,630	2.73
American Technology Alliances (N)		30,573	2.34
Massachusetts Institute of Technology	7	28,874	2.21
University of California–Berkeley	12	28,654	2.20
Southwest Research Institute (N)	8	27,008	2.07
New Mexico State University	15	26,312	2.02
California Institute of Technology[1006]	11	19,897	1.53
University of Arizona	14	18,380	1.41
Wheeling Jesuit College	19	15,519	1.19
University of Alabama–Huntsville	16	15,273	1.17
Baylor College of Medicine	41	13,670	1.05
University of Alabama–Birmingham	24	12,906	.99
Columbia University	22	11,532	.88
California Association for Research in Astronomy (N)	—	11,018	.84
University of Washington	25	10,941	.84
University of California–Los Angeles	26	10,836	.83
University of Wisconsin–Madison	27	10,680	.82
University of Hawaii	29	10,492	.80
Utah State University	36	10,478	.80
University of California–San Diego	18	10,319	.79
Pennsylvania State University–University Park	20	10,077	.77
University of Alaska–Fairbanks	17	10,044	.77
University of New Hampshire	33	9,145	.70
University of Texas–Austin	34	8,593	.66
Rotorcraft Industry Technical Association (N)	23	8,316	.64
American Museum of Natural History (N)	—	8,183	.63
University of Iowa	46	8,095	.62
Battelle Memorial Institute (N)	59	7,844	.60
Charles Stark Draper Labs (N)	55	7,271	.56
University of California–Santa Barbara	39	7,227	.55

[1006] Excludes the Jet Propulsion Laboratory.

Contractor/Place of Contract Performance	**Rank in FY 1997**	**Net Value of Awards**	
		Amount	**Percentage**
University of Virginia	78	7,189	.55
Oklahoma State University	42	6,971	.53
National Academy of Sciences (N)	14	6,630	.51
University of New Mexico	65	6,452	.49
Georgia Institute of Technology	35	6,199	.48
Ohio Aerospace Institute (N)	50	6,145	.47
San Bernardino County Support Schools (N)	—	6,000	.46
Ohio State University	52	5,936	.46
Princeton University	32	5,898	.45
Hampton University	30	5,778	.44
SETI Institute (N)	—	5,730	.44
Mississippi Research Consortium (N)	68	5,621	.43
University of Michigan–Ann Arbor	21	5,465	.42
Florida A&M University	64	5,431	.42
Total Top 50		*914,925*	*70.12*
Other[1007]		389,480	29.88
Total Awards to Educational and Nonprofit Institutions		*1,304,405*	*100.00*

Note: (N) = Nonprofit institution.

[1007] Includes remaining "top 100" list and other awards over $25,000, as well as smaller procurements of $25,000 or less.