NASA

National Aeronautics and
Space Administration

Budget Estimates

FISCAL YEAR 1988

Volume I

Agency Summary

Research and Development

Space Flight, Control and Data Communications

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AGENCY SUMMARY

NATIONAL AERONAUTICS AND SPACE ADMINISTRATION

FISCAL YEAR 1988 ESTIMATES

GENERAL STATEMENT

The National Aeronautics and Space Administration conducts space and aeronautical activities for peaceful purposes and the benefit of all people. NASA's vision is to be at the forefront of advancements in aeronautics, space science, and exploration. To set our course into the 21st Century and bring this vision to reality, NASA will pursue mjor goals which represent its aspirations in aviation and space. These goals are:

-- Advancement of scientific knowledge of the planet Earth, the solar system, and the universe beyond;

-- Expansion of human presence beyond the Earth;

-- Strengthening of aeronautics research, and development of technology toward promoting U.S. leadership in civil and military aviation.

Successful pursuit of these major goals requires commitment to the following supporting goals:

-- Return the Space Shuttle to flight status and develop advanced space transportation capabilities;

-- Develop facilities and pursue science and technology needed for the Nation's space program.

The NASA FY 1988 budget recommendation of $9,481 million has been designed with these goals in mind but with concern for continued fiscal restraint. The FY 1988 budget concentrates on returning the Space Shuttle to safe and effective flight status; on moving forward toward a permanently occupied Space Station in Earth orbit; on using space capabilities for the expansion of human scientific knowledge of the Earth, solar system and the universe; on building the technology base for greater accomplishments in space in the future; and on further strengthening the technology on which our country's leadership in aeronautics and space depends.

Space program elements in FY 1988 involve:

- Space Shuttle activities concentrate on correcting the defects which have been found in the solid rocket booster design and the weaknesses identified in other elements of the system and on testing the modified system to assure that they can be safely flown. These activities are well under way and are scheduled to support a safe resumption of flight in February of **1988.** Production of an orbiter to replace the Challenger will be in progress using funds provided in FY **1987.** Implementation of the recarmendations of the Rogers' Commission to enhance our ability to sustain a safe and effective operation of the Shuttle will continue with the FY **1988** budget plan. The Shuttle manifest is being planned to meet the scientific and government program requirements, national security priorities, and commercial and international requirements consistent with administration policy.

- The FY **1988** budget provides for the buildup of Space Station developnent activities initiated with funding approved in the FY **1987** appropriation. The rate at which the buildup of these activities will occur will be somewhat reduced from last year's projection as a result of a **number** of activities undertaken during the past year. In the **summer** of **1986** the NASA Administrator directed formulation of a Task Force to re-evaluate all aspects of the Space Station design, configuration, and assembly sequence. This effort reaffirmed the validity of the basic configuration but resulted in some changes to the Space Station to make it easier to assemble and maintain. Incorporation of the results of this activity into the draft request for proposals resulted in delay of the release of these proposals for industry comment by approximately two mnths. In addition to this Task Force effort, an indepth assessment of the Space Station management structure has been completed and implementation of the recommendations is well underway. The key elements of the program are now baselined and ready to proceed. The projected cost for the Space Station in the updated configuration is currently under intensive review.

- Space Science and Applications programs are directed toward increasing our knowledge and understanding of life processes, the Earth and its space enviromnt, the planets, the Sun, the stars and the universe, as well as conducting a carefully coordinated and logically phased set of research and developnent activities. Although the Space Science program has suffered a heavy setback as a result of the Challenger accident, the importance of the approved projects remains unchanged. One of the most important scientific instrunents ever developed for astronomy, the Hubble Space Telescope, is scheduled for launch in late **1988.** The planetary program has been particulary hard hit by both the Challenger loss and the cancellation of the Shuttle-Centaur program. The Magellan, Ulysses, and Galileo missions are being refitted for launch on the Shuttle-IUS system in the **1989-1990** time period. Development continues on the Gamma Ray Observatory, the Upper Atmospheric Research Satellite and the Mars Observer Mission, all adjusted for the necessary schedule delays. The Cosmic Background Explorer, which requires a launch from Vandenberg Air Force Base, will be launched on an expendable vehicle with a delay of only nine months fran last year's plan. In addition, a number of important experiments in astrophysics, life sciences, microgravity and other scientific disciplines are being prepared for future missions on the Spacelab and a significant effort is underway to more fully define the transition of scientific experiments to the Space Station. ***An*** inportant new initiative, the Global Geospace Science program, provides for full United States participation in the international solar terrestrial physics program to obtain the measurements necessary for a new and comprehensive understanding of the interaction between the Sun and the Earth. The program will involve two United States spacecraft, two spacecraft provided by the European Space Agency and one spacecraft provided by the Japanese to fly a large complement of scientific instruments provided by all countries involved. This Space Science and Applications program, in our judgment, reflects a reasonable balance between all the inportant and highly desirable projects which could be undertaken and our ability to support those projects within reasonably constrained financial resources and is consistent with a reasonable projection of our launch capability over the next several years.

- Concern has been growing in recent years that the base of technology available for space programs is not adequate to meet the needs of the future. The FY 1988 budget begins a significant effort to strengthen the technologies in key areas where NASA has major capabilities and interest, especially in earth orbital space transportation and science. Component design and technology verification activities will be initiated in FY 1988 in the areas of: earth-to-orbit propulsion system; aeroassist orbital transfer vehicle system characteristics; multispectral sensor devices; high capacity power system; and, development of autonomous system to aid with spacecraft servicing and repair and structure assembly.

The Aeronautics program is focusing on long-term, emerging technologies aimed at maintaining United States leadership in aviation and enhancing U.S. industrial competitiveness. In FY 1988, research will focus on exploiting new capabilities in numerical simulation of flight for design of advanced aircraft and on high temperature engine materials, highly maneuverable aircraft, and high speed flight. The research activity involves fundamental aerospace disciplines in fluid and thermal physics, applied aerodynamics, propulsion, materials, human factors and information sciences. The Aeronautics program tests and verifies, through wind tunnel testing, computation modeling and flight testing, aircraft designs and promising technologies. A joint program with the DOD/Navy on oblique wing technology is underway, and is expected to result in flight tests in 1989. Activities in the Systems Technology Program will pursue the application of various aerodynamic, engine and design concepts to aircraft performance, including activities involving the Advanced Turboprop, short takeoff and landing aircraft and the Numerical Aerodynamic Simulator.

Transatmospheric research and technology efforts will accelerate the development of critical technologies that may enable a potential new class of vehicles in the future capable of flight to orbit and/or hypersonic cruise. Work will continue in the development of technology for hypersonic and transatmospheric vehicles for the National Aero-Space Plane programwith emphasis on light weight thermal structures and subsonic and supersonic propulsion. Possible opportunities in this regime include launch vehicles, hypersonic transports, and military applications.

The research, development and operational activities of the Agency are accomplished by effective cooperation of people at the NASA Centers, contractor facilities, other agencies, universities, and other locations throughout the country. The core of this team is the NASA Civil Service. Experience of the past year and planned activities have indicated that we need to strengthen program direction in a number of key areas. For this reason the budget provides for an increase of 625 people above our presently authorized strength of 21,800.

Resources Summary

The budget authority recommended for FY 1988 totals $9,481 million with estimated outlays of $9,545 million and civil service staffing level of 22,425 full-time equivalent workyears.

NATIONAL AERONAUTICS AND SPACE ADMINISTRATION

BUDGET SUMMARY
(Millions of Dollars)

	Budget Plan 1986	1987	1988
RESEARCH	2,619.3	3,127.7	3,623.2
Space Stati	200.3	420.0	767.0
Space tation apabi Development	403.9	495.5	568.6
Space Science and Applications	1,476.5	1,552.6 (2)	1,508.3
y l ization	10.6	15.7	18.3
l Use of Space	16.2	25.6	35.7
Aeronautical Research d Technology	337.3	376.0	375.0
Transatmospheric Research and logy	---	45.0	66.0
Space Reseai and Technology	151.4	171.0	250.0
Reliabi y and lity	7.6	9.2	16.2
Tracking and t Advanc Systems	15.5	17.1	18.1
SPACE FLIGHT CONTROL AND DATA	3,665.9	5,815.0	4,064.3
Shutt Production d ional Capabili	1,365.3 (1)	1,005.1	1,229.6
Replacement Orbiter	---	2,100.0	---
Space Transportation Operations	1,640.2	1,847.0	1,885.8
Space & Networks, Comm. and Data Systems	660.4	862.9	948.9
CONSTRUCTION OF FACILITIES	137.5 (1)	166.3	195.5
RESEARCH AND PROGRAM MANAGEMENT	1,341.3	1,466.5 (3)	1,598.0
S/Total Budget Requirement	7,764.0	10,575.5	9,481.0
Pay Raise and FERS (2)	---	-41.5	---
TOTAL BUDGET SUMMARY	7,764.0	10,534.0	9,481.0
OUTLAYS	7,403.5	7,887.8	9,544.8

(1) Reflects transfer in FY 1987 of $4.2 million from SFCDC (Shuttle Production and Operational Capability to CoF.

(2) This amount does not reflect the proposed FY 1987 rescission of $26 million related to termination of the Advanced Communications Technology Satellite.

(3) The source of the funding in FY 1987 for $41.5 million in R&PM to cover the impact of the pay raise and the Federal Employees Retirement System (FERS) has not been determined.

NATIONAL AERONAUTICS AND SPACE ADMINISTRATION

FISCAL YEAR 1988 ESTIMATES

SUMMARY RECONCILIATION OF APPROPRIATIONS TO BUDGET PLANS
(Millions of Dollars)

	Total	Research and Development	Space Flight Control and Data Comm.	Construction of Facilities	Research and Program Management
Fiscal Year 1986					
Appropriation PL 99-160/349........	8,087.0	2,756.8	3,828.9	139.3	1,362.0
Reduction PL 99-177................	-322.8	-118.5	-139.7	-6.0	-58.6
Transfer Between Accounts..	---	-19.0	-19.1	---	38.1
Transfer Between Accounts.	---	---	-4.2	4.2	---
Lapse.	-.2	---	---	---	-.2
Total Budget Plan...............	7,764.0	2,619.3	3,665.9	137.5	1,341.3
Fiscal Year 1987					
Budget Request.	7,694.4	3,003.1	3,069.0	181.3	1,441.0
FY 87 Portion of FY 86 Supplemental PL 99-349...........	100.0	---	100.0	---	---
Amendment..........................	272.0	29.0	274.0	-15.0	-16.0
Continuing Appropriation PL 99-591	2,467.6	95.6	2,372.0	---	---
FY 87 Pay Raise and FERS.	41.5*	---	---	---	41.5
Subtotal..........................	10,575.5	3,127.7	5,815.0	166.3	1,466.5
Adjustment	-41.5				
Total Budget Plan...............	10,534.0				
Fiscal Year 1988					
Appropriation Request/Budget Plan..	9,481.0	3,623.2	4,064.3	195.5	1,598.0

* Note: The Source of the funding in FY 1987 for $41.5 million in R&PM to cover the impact of the pay raise and the Federal Employees Retirement System (FERS) has not been determined.

RESEARCH
AND DEVELOPMENT

SUMMARY
INFORMATION

NATIONAL AERONATUTICS AND SPACE ADMINISTRATION

RESEARCH AND DEVELOPMENT

FISCAL YEAR 1988 ESTIMATES

GENERAL STATEMENT

The objectives of the National Aeronautics and Space ministration program of research and development are to extend our knowledge of the Earth, its space enviromnt, and the universe; to expand the technology for practical applications of space technology; to develop and improve manned and umnned space vehicles; and to assure continued development of the long-term aeronautics and space research and technology necessary to accomplish national goals. These objectives are achieved through the following elements:

SPACE STATION: Aprogram to develop a United States space station to continue the Nation's leadership in space and to provide for enhancement of science and applications programs and to further the commercial utilization of space while stirmlating advanced technologies.

SPACE TRANSPORTATION CAPABILITY DEVELOPMENT: A program to provide for the developnent and use of capabilities related to the Space Shuttle. The principal areas of activity in Space Transportation Capability Development are efforts related to the developnent and flight certification of the jointly developed U.S./Italy Tethered Satellite System, developnent of the Orbital Maneuvering Vehicle, development and operations of the Spacelab systems, the development and procurement of upper stages that place satellites in high altitude orbits, the engineering and technical base support at NASA centers, payload operations and support equipment, and advanced programs study and evaluation efforts.

SPACE SCIENCE AND APPLICATIONS: A program using space systems, supported by ground-based and airborne observations, (1) to conduct a broad spectrum of scientific investigations to advance our knowledge of the Earth and its space enviromnt, the Sun, the planets, interplanetary and interstellar space, the stars of our galaxy and the universe; and (2) to identify and develop the technology for the useful applications of space techniques in the areas of advanced communications satellite systems technology; mterials processing research and experimentation; and remote sensing to acquire information which will assist in the solution of Earth resources and enviromntal problems.

TECHNOLOGY UTILIZATION: The program includes activities to accelerate the dissemination to both the public and the private sectors of advances achieved in NASA's research, technology, and developnent programs.

COMMERCIAL USE OF SPACE: A program to increase private sector awareness of space opportunities and encourage increased industry investment and participation in high technology, space-based research and developnent.

AERONAUTICS AND SPACE TECHNOLOGY: A program to conduct the fundamental long-term research and to develop the discipline and systems technology required to maintain United States leadership in aeronautics and space.

TRACKING AND DATA ADVANCED SYSTEM: This program includes activities to perform studies and provide for the developnent of system and techniques leading to improved tracking and data program capabilities.

NATIONAL AERONAUTICS AND SPACE ADMINISTRATION

RESEARCH AND DEVELOPMENT
FY 1988 BUDGET ESTIMATES

	1986 Actual	1987 Amended Budget	1987 Current Estimte	1988 Budget Estimte
		(Millions of Dollars)		
SPACE STATION	200.3	410.0	420.0	767.0
SPACE TRANSPORTATION CAPABILITY DEVELOPMENT	403.9	507.5	495.5	568.6
SPACE SCIENCE AND APPLICATIONS	1,476.5	1,465.0	1,552.6	1,508.3
Physics and astronomy....................	569.3	529.9	552.3	567.1
Life sciences..........................	66.1	69.7	72.2	74.6
Planetary exploration....................	353.6	374.3	358.4	307.3
Solid earth observations...............	70.9	74.1	75.6	76.8
Environmental observations...	271.6	336.9	323.9	393.8
Materials processing....................	31.0	39.4	45.4	45.9
Camunications..........................	96.4	19.5	103.5	20.5
Information systems....................	17.6	21.2	21.3	22.3
COMMERCIAL PROGRAMS	26.8	41.3	41.3	54.0
Technology Utilization.................	10.6	15.7	15.7	18.3
Commercial Use of Space.................	16.2	25.6	25.6	35.7
AERONAUTICS AND SPACE TECHNOLOGY	488.7	582.0	592.0	691.0
Aeronautical research and technology....	337.3	376.0	376.0	375.0
Transatmospheric research and technology	---	35.0	45.0	66.0
Space research and technology...........	151.4	171.0	171.0	250.0
SAFETY, RELIABILITY AND QUALITY ASSURANCE	7.6	9.2	9.2	16.2
TRACKING AND DATA ADVANCED SYSTEMS	15.5	17.1	17.1	18.1
TOTAL	2,619'.3	3,032.1	3,127.7	3,623.2

NATIONAL AERONAUTICS *AND* SPACE ADMINISTRATION
PROPOSED APPROPRIATION LANGUAGE

RESEARCH AND DEVELOPMENT *

* See Part II for additional information.

For **necessary** expenses, not otherwise provided for. including research, development, operations. services, minor construction, maintenance, repair, rehabilitation and modification of real and personal property; purchase, hire, maintenance, and operation of other than administrative *aircraft,* necessary for the conduct and support of aeronautical and space research and development activities of the National Aeronautics and Space Administration; [$3,091,700,000] *$3,623,200,000,* to remain available until September 30, [1988] *1989. (Additional authorizing legislation to be proposed.)*

Note.—Public Laws 99-500 and 99-591, section 101(g), provide funds to the extent and in the manner provided for in the conference version cl H.R. 5313, Department cl Housing and Urban Development-Independent Agencies Appropriations Act, 1987.

[*Provided*, That, notwithstanding any other provision of this joint resolution, including section 102. in addition to the funds otherwise made available in this subsection, the following amounts an made available: (1) an additional $36,000,000, to remain available until September SO. 1988, is hereby appropriated for the National Aeronautics and Space Administration, "Research and development".] *(Public Laws 99-500 and 99-591, providing appropriations for the fiscal year 1987, section 101(g).)*

NATIONAL AERONAUTICS AND SPACE ADMINISTRATION

Research and Development

Reimbursable Summary
(In thousands of dollars)

Research and Development	Budget Plan FY 1986	FY 1987	FY 1988
Space Station	54	100	---
Space Transportation Capability	206,494	110,000	117,700
Space Science and Applications	512,050	636,100	420,000
Technology Utilization	2,905	4,000	2,025
Space Research and Technology	13,703	17,000	13,686
Aeronautical Research and Technology	76,436	107,000	88,665
Energy Technology	77,915	45,000	27,151
Total	889,557	919,200	669,227

NATIONAL AERONAUTICS AND SPACE ADMINISTRATION

FISCAL YEAR 1988 ESTIMATES
DISTRIBUTION OF RESEARCH AND DEVELOPMENT BUDGET PLAN BY INSTALLATION AND FISCAL YEAR
(Thousands of Dollars)

Program		Total	Johnson Space Center	Kennedy Space Center	Marshall Space Flight Center	National Space Technology Laboratories	Goddard Space Flight Center	Jet Propulsion Laboratory	Ames Research Center	Langley Research Center	Lewis Research Center	NASA Headquarters
Space Station	1986	200,300	83,700	3,400	40,300	600	25,700	7,600	2,000	6,100	23,400	7,500
	1987	420,000	106,500	14,400	74,700	1,800	33,500	14,200	3,400	10,200	41,800	119,500
	1988	767,000	245,000	33,000	206,000	1,000	72,000	13,000	5,000	6,000	95,000	91,000
Space Transportation Capability Development	1986	403,900	110,800	56,900	195,900	7,400	2,300	1,900	500	700	18,800	8,700
	1987	495,500	108,200	36,800	287,600	8,400	3,100	1,600	1,000	500	500	47,800
	1988	568,600	116,700	56,200	344,800	8,800	1,700	1,500	1,400	600	500	36,400
Space Science and Applications	1986	1,476,500	41,490	8,021	281,706	1,090	421,282	367,234	84,997	24,195	91,596	154,889
	1987	1,552,600	50,238	7,377	266,822	1,355	441,845	401,745	90,030	17,079	98,463	177,646
	1988	1,508,300	54,835	8,628	273,415	1,317	449,291	420,043	93,756	14,131	17,050	175,834
Physics and Astronomy	1986	569,300	7,691	5,235	262,179	—	193,990	12,650	37,801	1,633	—	48,121
	1987	552,800	12,735	4,881	244,911	—	183,682	13,218	32,741	—	—	60,632
	1988	567,100	16,781	6,027	249,836	—	182,195	14,453	37,063	—	—	60,745
Life Sciences	1986	66,100	21,071	2,586	60	40	380	1,202	27,317	525	—	12,919
	1987	72,200	23,359	2,496	110	50	215	1,016	30,657	390	—	13,907
	1988	74,600	23,904	2,601	—	50	215	1,016	32,379	400	—	14,035
Planetary Exploration	1986	353,600	10,024	—	169	—	5,279	280,376	13,157	23	—	44,572
	1987	358,400	10,639	—	72	—	11,852	268,576	18,932	24	—	48,305
	1988	307,300	10,937	—	75	—	8,688	225,966	16,400	25	—	45,209
Solid Earth Observations	1986	70,900	400	200	285	760	34,778	27,175	743	—	—	6,559
	1987	75,600	100	—	300	900	37,800	28,600	700	—	—	7,200
	1988	76,800	—	—	400	900	38,200	29,200	700	—	—	7,400
Environmental Observations	1986	271,600	30	—	12,566	115	171,638	28,350	5,879	20,700	—	32,322
	1987	320,900	150	—	8,000	150	187,900	67,900	6,700	14,700	—	35,400
	1988	393,800	200	—	10,300	100	198,600	127,200	6,900	11,800	—	38,700
Materials Processing in Space	1986	31,000	2,274	—	6,447	—	—	7,199	—	1,278	7,843	5,959
	1987	47,900	3,255	—	13,429	—	—	11,407	—	1,965	11,593	6,251
	1988	45,900	3,013	—	12,804	—	—	11,052	—	1,906	10,633	6,492
Communications	1986	96,400	—	—	—	—	2,924	6,393	—	36	83,753	3,294
	1987	103,500	—	—	—	—	5,349	6,733	—	—	86,870	4,548
	1988	20,500	—	—	—	—	5,644	6,660	—	—	6,417	1,779
Information Systems	1986	17,600	—	—	—	175	12,293	3,889	100	—	—	1,143
	1987	21,300	—	—	—	255	15,047	4,295	300	—	—	1,403
	1988	22,300	—	—	—	267	15,749	4,496	314	—	—	1,474
Commercial Programs	1986	26,800	397	523	4,755	514	1,130	853	371	1,038	1,782	15,437
	1987	41,300	885	708	6,634	930	2,227	925	566	1,637	1,975	24,813
	1988	54,000	1,422	859	11,882	1,037	2,232	1,042	1,182	2,012	2,297	30,035
Technology Utilization	1986	10,580	247	473	421	278	1,090	663	203	588	488	6,129
	1987	15,700	325	708	284	820	1,337	925	286	817	805	9,393
	1988	18,300	382	859	452	737	1,232	1,042	602	672	357	11,965
Commercial Use of Space	1986	16,220	150	50	4,334	236	40	190	168	450	1,294	9,308
	1987	25,600	560	—	6,350	110	890	—	280	820	1,170	15,420
	1988	35,700	1,040	—	11,430	300	1,000	—	580	1,340	1,940	18,070
Aeronautics and Space Technology	1986	488,657	7,981	—	15,378	—	5,924	21,846	157,978	140,189	124,184	15,177
	1987	592,000	8,700	—	20,800	—	5,400	19,700	188,300	172,300	122,500	54,300
	1988	691,000	12,000	500	51,100	—	9,300	27,200	191,800	187,900	135,800	75,400
Aeronautical Research and Technology	1986	337,257	1,000	—	1,000	—	383	213	141,894	96,218	88,396	8,153
	1987	376,000	—	—	1,600	—	300	200	167,900	118,000	80,300	7,700
	1988	375,000	—	—	1,700	—	300	200	161,700	121,500	81,900	7,700
Space Research and Technology	1986	151,400	6,981	—	14,378	—	5,541	21,633	16,084	43,971	35,788	7,024
	1987	171,000	8,700	—	19,200	—	5,100	19,500	19,400	52,300	40,200	6,600
	1988	250,000	12,000	500	49,400	—	9,000	27,000	29,100	64,400	51,900	6,700
Transatmospheric Research and Technology	1986	—	—	—	—	—	—	—	—	—	—	—
	1987	45,000	—	—	—	—	—	—	1,000	2,000	2,000	40,000
	1988	66,000	—	—	—	—	—	—	1,000	2,000	2,000	61,000
Tracking and Data Acquisition	1986	15,500	—	—	—	—	4,500	10,799	7	—	—	194
	1987	17,100	—	—	—	—	5,000	12,100	—	—	—	—
	1988	18,100	—	—	—	—	5,300	12,800	—	—	—	—
Safety, Reliability and Quality Assurance	1986	7,600	345	200	402	—	780	2,431	—	745	140	2,557
	1987	9,200	265	125	314	—	1,067	2,207	—	1,147	173	3,902
	1988	16,200	1,090	100	415	—	1,485	2,350	—	1,120	185	9,455
TOTAL BUDGET PLAN	1986	2,619,257	244,713	69,044	538,441	9,604	461,616	412,663	245,853	172,967	259,902	204,454
	1987	3,127,700	274,788	59,410	656,870	12,485	492,139	452,477	283,296	202,863	265,411	427,961
	1988	3,623,200	431,047	99,287	887,612	12,154	541,308	477,935	293,138	211,763	250,832	418,124

SPACE STATION

[redacted] AND [redacted]

FISCAL YEAR 1988 ESTIMATES

BUDGET SUMMARY

OFFICE OF SPACE STATION | SPACE STATION PROGRAM

SUMMARY OF RESOURCES REQUIREMENTS

	1986 Actual	1987 Amended Budget	1987 Current Estimate	1988 Budget Estimate	r
		(Thousands of Dollars)			
Definition	190,300	250,000	250,000	---	
Utilization	(10,600)	(15,000)	(15,000)	(---)	
Advanced Development	(60,300)	(73,000)	(70,000)	(---)	
Program Management/Integration	(55,300)	(88,000)	(93,300)	(---)	
Operational Readiness	(5,200)	(17,000)	(17,000)	(---)	
System Definition	(58,900)	(57,000)	(54,700)	(---)	
Development	---	150,000	150,000	733,000	
Pressurized Modules	(---)	(---)	(40,000)	(196,500)	RD 1-4
Assembly Hardware/Subsystems	(---)	(---)	(27,000)	(204,000)	RD 1-5
Platforms and Servicing	(---)	(---)	(6,000)	(59,000)	RD 1-6
Power System	(---)	(---)	(19,000)	(88,000)	RD 1-6
Operations Capability/Utilization	(---)	(---)	(13,000)	(52,000)	RD 1-7
Management and Integration	(---)	(---)	(45,000)	(133,500)	RD 1-8
Flight Telerobotic System	10,000	10,000	20,000	22,000	RD 1-9
Operations	---	---	---	7,000	RD 1-9
Transition Definition	---	---	---	5,000	RD 1-9
Total	200,300	410,000	420,000	7[redacted]	

	1986 Actual	1987 Amended Budget	1987 Current Estimate	1988 Budget Estimate
Distribution of Program Amount by Installation:				
Johnson Space Center..................	83,700	146,800	106,500	245,000
Kennedy Space Center..................	3,400	10,200	14,400	33,000
Marshall Space Flight Center..........	40,300	37,000	74,700	206,000
National Space Technology Laboratories	600	600	1,800	1,000
Goddard Space Flight Center...........	25,700	15,000	33,500	72,000
Jet Propulsion Laboratory.............	7,600	5,900	14,200	13,000
Ames Research Center..................	2,000	1,700	3,400	5,000
Langley Research Center...............	6,100	4,600	10,200	6,000
Lewis Research Center.................	23,400	20,500	41,800	95,000
Headquarters..........................	7,500	167,700*	119,500**	91,000
Total.................................	200,300	410,000	420,000	767,000

*Development funds were shown at Headquarters pending decisions on the individual elements and related field center assignments.

**Includes Headquarters and the Program Office programs.

OBJECTIVES AND STATUS

The Space Station will provide a unique capability to enhance the Nation's space science and applications program, and to further the commercial utilization of space while stirmlating advanced technologies. Development of the U.S. permanently manned Space Station, as directed by President Reagan, will follow a deliberately-paced program plan which will permit us to mintain the pre-eminence in space our Nation has attained through various manned and umned programs.

The U.S. Space Station will be a multi-purpose, national facility, providing a pemnent human presence in space to conduct essential scientific and technical research, to support unique commercial activities, and to perform operational tasks more efficiently in space. International participation with the U.S. Space Station program has been encouraged by the President. Canada, member states of the European Space Agency (ESA), and Japan have responded enthusiastically. Memoranda of Understanding (MOU) for the definition and preliminary design phase were executed with Canada, ESA, and Japan in the spring of 1985 concurrent with the initiation of the NASA definition contracts. These international partners have undertaken parallel definition and preliminary design studies to identify Space Station elements that each of them may consider for developnt. Negotiations for the developnt phase of the program are currently underway with our current international partners.

The Space Station will be designed to permit the system to evolve, as warranted over time, to provide greater user utility and operational capabilities. Its manned and unmanned elements will be designed to facilitate on-orbit maintainability/restorability, operational autonomy, human productivity, and simplified user interfaces. Implicit in these objectives is the recognized need to optimize man/machine systems in space via automation, robotics, and artificial intelligence technologies. During the definition period, NASA conducted trade studies to evaluate various subsystems changes to the Space Station options. The baseline configuration has been selected and is commonly known as the "dual keel" configuration. It is from this baseline, which was derived using the findings of the preliminary design and definition studies, as well as the advanced technology work, that the detailed design will begin in late FY 1987.

The Station and its platform will be placed and maintained in low-Earth orbit by the Space Transportation System, thereby building upon the previous national investment in space.

The definition and preliminary design phase will continue through FY 1987 and will provide the technical and progrmtic plan for the Space Station developnt program, including the completion of the detailed definition and preliminary design, the analysis and integration of national and international user community requirements, and the advanced developnt of technology options. A continuing emphasis on user requirements and operations will be maintained as the engineering design evolves through subsystem advanced developnt and testing in dedicated test beds.

CHANGES FROM FY 1987 BUDGET ESTIMATE

The FY 1987 budget estimate of $410.0 million was increased in the Congressional review process by $10.0 million to $420.0 million. Congressional direction required that the additional $10 million be added for work on the Flight Telerobotic System. The definition phase was rebalanced by deferring some planned flight experiments due to the loss of flight capability, by decreasing the systems definition funding due to the withdrawal by a definition contractor, and by increasing the program management/integration funding in anticipation of bringing on the program support contractor.

BASIS OF FY 1988 ESTIMATE

The FY 1988 budget provides for the buildup of Space Station developnent activities initiated with funding approved in the FY 1987 appropriation. The rate at which the buildup of these activities will occur will be somewhat reduced fran last year's projection as a result of the configuration review and changes and the resulting delay of the request for proposals release. In addition to this effort, an indepth assessment of the Space Station management structure has been completed and implementation of the recommendations is well underway. The key elements of the program are now baselined and ready to proceed. The projected cost for the Space Station in the updated configuration is currently under intensive review. The FY 1988 distribution of the development funds are tentative pending the final result of the cost review.

DEVELOPMENT

The development phase, which will begin in FY 1987, includes the prime contractor effort on the work packages, which will provide the major hardware components, as well as supporting development activities such as the systems engineering and integration (SE&I), the program's Technical and Management Information System (TMIS) and Software Support Environment (SSE), and the evolvement of operational planning including user accommodations and interfaces.

Pressurized Modules

The design and development activities of the hardware elements and systems will be initiated in FY 1987. In FY 1988, the prime activities will commence with program requirements reviews (PRR) for the pressurized modules and related elements. The PRR's will update the program to include those management decisions and design changes which occurred as a result of contact negotiations and source evaluation board activities. PRR's are scheduled to begin three mnths after contract start date. Near the end of FY 1988, program design reviews (PDR) will be conducted for hardware elements and systems including the structure for the modules (laboratory, habitation and logistics) and resource nodes: the outfitting of the modules; the environmental control and life support system: the manned systems and the internal components of the thermal control system and audio/video system; and related launch package integration activities. These PDR's will provide an evaluation of the current design approach of the work packages, taking into consideration the interfaces with other elements of the program including those being developed by our international partners. Successful carpletion of the PDR's will result in the authorization to proceed with detailed design in accordance with the reviewed design approach and interface requirements.

Those efforts beginning in FY 1987 that provide capabilities for independent assessments of contracted work that develop necessary in-house capabilities required to accomplish development responsibilities will continue. These activities include the mintenance of data magement activities to provide for transfer of data between the work packages, contractors, and other parties involved in the developnent process; the developnent of tools and analyses that will provide independent assessment capabilities in areas such as commonality and man/system integration effectiveness. Also, work in the materials area relative to hardware responsibilities of developing the modules for the Station will continue. The work in this area involves the establishment of a mterials data base that will serve as a resource during the design and developnent of the Station's hardware elements. Efforts will also be undertaken in the international integration area to ensure the compatability of the international hardware with the Space Station.

Assembly Hardware/Subsystems

The developnent efforts which were initiated in FY 1987 in this area will continue to concentrate on carpleting the design of the hardware elements as well as the various subsystem and related activities including: the truss; the mbile base for the mbile servicing center; the outfitting of the airlocks and nodes; the external thermal control; extravehicular activity; data management; communications and tracking; guidance, navigation, and control; propulsion; and related launch package integration activities.

In FY 1988, the prim activities will commence with PRR's for the assembly hardware/subsystems areas. The PRR's will update the program to include those management decisions and design changes which occurred as a result of contract negotiations and source evaluation board actions. These PRR's are scheduled to begin three months after the contract start date. The PDR, which is currently planned for the end of FY 1988, will be conducted using the data developed by the contractors as well as that data available fran the in-house activities supporting those efforts and will allow for the evaluation of the design approach planned for the interfaces.

Continued work in the outfitting of facilities being prepared for Station will provide capabilities to conduct tests of the advanced technology to be utilized in the developnent of the Station. Designing the outfitting of the resource nodes, a recent configuration change, will commence as well as the designing and outfitting of the airlocks and the interfaces with the extravehicular activity system. The identification of requirements for each subsystem will continue and trade studies will be conducted to assure that proper interfaces are mintained with the additional hardware being developed by other NASA centers as well as the international partners. For example, examination of various design alternatives of distributed processing architectures for the guidance, navigation and control subsystem will be continued. The technology work required to provide the information for a possible new space suit will progress to enable a timely decision about the design of that suit.

Platform and Servicing

The platform and servicing responsibilities include the developnt and production of two unmanned platform, one multi-purpose servicing facility, the payload accmdation equipnent (PAE) and the coarse pointing system. The platform, one co-orbiting and one polar, will be used for scientific research and Earth and astronomical observations. The servicing facility will be positioned on the Station structure and will provide maximum access for servicing payloads and free-flyers. The PAE is attached to the structure and will provide for the munting of various scientific instrunents. Electrical power and other utilities are provided to the payloads through the PAE. The coarse pointing systems are provided for payload instrunents requiring a high degree of pointing accuracy typically instruments for observing Earth and celestial bodies.

The initial design and developnt activities initiated in FY 1987 will continue in FY 1988. Currently planned for three mnths after the contract start date, the PRR will update the program to include those management decisions and design changes which occurred as a result of contract negotiations, and source evaluation board actions. The major thrust of the developnent activities will be to ensure that the requirements, design, configuration, and interfaces of the platform, servicing bay, and attached payload accommodations are defined and identified in sufficient detail to support the PDR, which is currently planned for the end of FY 1988. This review will result in the authorization to proceed with further design in accordance with the reviewed design approach and interface requirements. Specifications will be baselined, procurement activities will accelerate, and the technology developnt effort, associated with the platform thermal and data management system will continue. Emphasis will also be placed upon maintaining an effective interface with potential users of the Station, thus ensuring that their requirements are adequately accomnodated. Prime contractor activities will be augmented by extensive in-house efforts in mterials testing and evaluation, system engineering and integration, product assurance and parts evaluation, and transportation planning. The acquisition of the unique test equipment, payload interface simulators, and other related equipment required to implement and support these in-house efforts will also begin in FY 1988.

Power System

The Space Station will utilize a 20 kHz hybrid power system, with 87.5 kw of power produced by photovoltaic arrays and solar dynamic converters. The polar and co-orbiting platform will have photovoltaic arrays for power production and batteries for energy storage. The space Station power system requirements include the design, development, and production of electrical power system hardware and software, the integration, assembly, and checkout of power module elements, the provision of support equipnent to other work packages, support to Space Station systems engineering and integration, and launch package integration of power module elements.

The power system effort is directed toward the production of photovoltaic (PV) and solar dynamic (SD) modules, common components for the polar and co-orbiting platform power systems, a power management and distribution subsystem (PMAD) and components, and flight, application and ground support software. Flight, applications, ground support, and test software for the PV and SD modules, the PMAD subsystem, and the platform power systems will be designed, produced, and tested.

The prime contractor's efforts will be directed toward baselining specifications and commencing initial design and purchase activities. Pdditional activities will include outfitting test cells in preparation for energy storage tests, and preparations for photovoltaic array, PMAD and materials tests.

In FY 1988, the prime activities will commence with program requirements reviews (PRR) for the power system elements. The PRR's will update the program to include those management decisions and design changes which occurred as a result of contract negotiations, source evaluation board actions, etc. PRR's are scheduled to begin three mnths after the contract start date. During FY 1988, procurement activities will increase, and qualification, fabrication, and testing of some of the W components will be conducted. Software design and developnent will also be initiated.

Toward the end of the fiscal year the preliminary design reviews (PDR) for the power system elements will be held. These are held in support of the program PDR, and are intended to ensure that the design approaches and configurations interface properly. The program PDR will result in the authorization to proceed with further design in accordance with the reviewed design approach and interface requirements. Pdditional activities will essentially be an extension of those activities which commenced in FY 1987, with energy storage, thermal cycle, and power distribution and management tests to be conducted. The Power Systems Facility will be outfitted, and project control and delegated systems engineering and integration activities will be increased.

operations Capability/Utilization

Operational capability development efforts include the detailed design and developnent of the hardware and software necessary to outfit the operational facilities, exclusive of those item which are provided under the Constitution of Facilities appropriation. Outfitting of the Space Station Support Center, the Space Station training facilities, and the launch site ground processing facilities are representative of this type of development effort. Another supporting developnent activity is in the utilization area. This effort builds upon the utilization activity conducted during definition. It includes the develapnent of procedures, tools and equipent to integrate the user fully into the design and operation of the flight and ground systems of the Space Station. User requirements and user selection processes will also be developed.

Management and Integration

Systems engineering and integration (SE&I) activities will be managed by the newly established Program Office with support fran the program support contractor (PSC). Some effort will be distributed at each major center involved in the Space Station program. The proposals received in response to the request for proposal for the program support contractor are anticipated and a selection is scheduled for the mid-1987 time frame. These efforts include the developnent of integrated engineering models of the Station, the continuation of trade studies on resource allocation by element, the allocation of requirements among program elements, and the establishment of design requirements. Key system level schedules and documentation will be expanded and maintained, systems level assembly and check out logic will be refined, and systems level verification requirements and procedures will be established.

Data management and information systems efforts include the Technical and Management Information System (TMIS) and the Software Support Environment (SSE) which are the initial elements of the Space Station Information System. TMIS is an integrated system of technical and management processes, automatic data processing hardware and software, communications networks, and procedures supporting the design and developnent, as well as the operations of the Space Station. Award of the TMIS develapnent contract: is expected in mid-FY 1987 and the first increment of the system is scheduled to be in place by the end of FY 1987 to support the early developnent efforts of the program. The system will be designed incrementally to allow for advances in state-of-the-art technologies. This approach will also allow for requirements to be accommodated as they become known in lieu of replacement of obsolete hardware, software, and processes. The SSE will provide the infrastructure for the developnent of common applications software required for flight and ground systems. Planned activities include the completion of the requirements analysis effort, the completion of the software production facility preliminary design document, the completion of the facility contract end item list, and bringing the facility on-line to support the preliminary and critical design reviews.

Safety, reliability, and quality assurance activities will be emphasised for developnent and operations. Early emphasis will be on the developnent of criteria to perform critical reviews of station design for safety issues at the black box and system level, application of the criteria to assess the safety of the proposed design during the preliminary design review, and establishment of quality assurance standards. Program support activities will provide management, technical, and institutional support franthe individual centers necessary to sustain the developnent activities of the Space Station.

FLIGHT TELEROBOTIC SYSTEM

The Flight Telerobotic System (FTS) will be a highly automated telerobotic device capable of precise mnipulations in space. It will operate with a mix of remote and supervisory controls by astronauts and will be used to assist in assembly and servicing operations. The FTS will improve the efficiency and safety of Space Station related operations. Initially intended for relatively simple tasks, the FTS capabilities will evolve over time to accommodate increasingly sophisticated operations for wide application in space as well as the technology application on the ground.

The FTS program is structured to provide a flight telerobotic system with phased capabilities based on assembly, servicing, and maintenance needs, to support the Station launch and operations schedules. In FY 1987, a definition and preliminary design effort with multiple contracts will be pursued. Work was also begun on the design of both the flight and ground systems that will support the FTS program and the definition of requirements for the flight demonstration. The integration of NASA-developed technology fran the Office of Aeronautics and Space Technology is being reviewed for possible FTS applications.

In FY 1988, the definition and preliminary design contracts will continue. These contracts will culminate in the selection of a preliminary design for the FTS which will be developed by a single contractor. Work will continue in the design of the flight and ground systems and the requirements definition for the flight demonstration. Current plans are to have it available for flight on the second assembly launch of the Space Station. A Shuttle flight demonstration of the FTS will precede the second assembly launch and will be conducted in the early 1990's.

OPERATIONS DEFINITION

Operations definition funding begins in FY 1988 and builds on the work initiated in the definition phase of the program. It includes a variety of operations-oriented study activities that are required to support the developnent of flight hardware and operational facilities. The key FY 1988 operations activities will be in the integrated logistics arena. Logistics requirements rmst be defined early in the developnt phase and factored into the work package and KSC detailed design and developnt efforts to ensure an efficient design and reasonable life cycle costs. Other activities in FY 1988 include studies of automation and robotics applications for operations, and other studies that m y be recommended by the Space Station Operations Task Force.

TRANSITION DEFINITION

In order to assure that the initial Station design will facilitate evolution to greater capacities and capabilities to accommodate users, transition definition efforts rmst be conducted in parallel with the developnt phase. With a start in FY 1988, the transition definition program will provide the minimum lead time required to demonstrate major new technologies prior to being incorporated into the Space Station System, thereby avoiding decisions based on conceptual studies with no substantive engineering data as support.

The transition definition initiative encompasses evolution and transition technology definition studies. The definition studies: include mission and system analyses to define Station evolution requirements; operations analyses to establish growth modes that will optimize user accommodations; and technology forecasts that will enable upgrades to increase the efficiency and productivity of the Station. The studies will provide a knowledge base to allow the Space Station Program to respond to new requirements as they develop as well as to enhance accommodations of current user requirements.

SPACE
TRANSPORTATION
CAPABILITY
DEVELOPMENT

RESEARCH AND DEVELOPMENT

FISCAL YEAR 1988 ESTIMATES

BUDGET SUMMARY

OFFICE OF SPACE FLIGHT — **SPACE TRANSPORTATION CAPABILITY DEVELOPMENT PROGRAM**

SUMMARY OF RESOURCES REQUIREMENTS

	1986 Actual	1987 Amended Budget	1987 Current Estimte	1988 Budget Estimte	Page Number
	(Thousands of Dollars)				
Spacelab	78.000	68.800	73.900	73.500	RD 2-6
Upper stages	122.000	202.100	160.500	159.700	RD 2-9
Engineering and technical base	109.700	119.900	133.400	139.800	RD 2-11
Payload operations and support equipment	54.800	44.500	44.500	83.400	RD 2-13
Advanced programs	19.400	16.600	27.600	24.900	RD 2-15
Tethered satellite system	15.000	10.600	10.600	7.300	RD 2-17
Orbital maneuvering vehicle	5.000	45.000	45.000	80.000	RD 2-18
Total	403.900	507,500	495,500	568.600	

Distribution of Program hunts By Installation

	1986 Actual	1987 Amended Budget	1987 Current Estimte	1988 Budget Estimte
Johnson Space Center	110,800	103.200	108.200	116.700
Kennedy Space Center	56,900	34.600	36.800	56.200
Marshall Space Flight Center	195,900	264.100	287.600	344.800
National Space Technology Laboratories	7,400	8.400	8.400	8.800
Goddard Space Flight Center	2,300	3.100	3.100	1.700
Jet Propulsion Laboratory	1,900	1.600	1.600	1.500
Langley Research Center	700	500	500	600
Lewis Research Center	18,800	14.200	500	500
Ames Research Center	500	1.000	1.000	1.400
Headquarters	8.700	76.800	47.800	36.400
Total	403.900	507.500	495.500	568.600

OFFICE OF SPACE FLIGHT

SPACE TRANSPORTATION PROGRAM

PROGRAM OBJECTIVES AND JUSTIFICATION

The principle areas of activity in space Transportation Capability Development include the Spacelab; the Upper Stages required to place satellites in high altitude orbits: the Engineering and Technical Base support at the manned space flight centers: Payload operations and Support Equipment for accommodating NASA payloads: Advanced Programs study and evaluation efforts: the development and first flight of the United States/Italian Tethered Satellite System: and the developnent of the Orbital Maneuvering Vehicle.

Spacelab is a major element of the Space Transportation System (STS) that provides a versatile, reusable laboratory which is flown to and from Earth orbit in the orbiter cargo bay. The develapnent program which has been carried out jointly by NASA and the European Space Agency (ESA) continues With the procurement of hardware for the Hitchhiker System, the Spacelab Pallet System, the Space Technology Experiment Platform and the lay-in of spares to support the flight program. Operational missions for the next few flights include a number of Spacelab module and Spacelab Pallet System missions.

Upper Stages are required to deploy payloads to orbits and trajectories not attainable by the Shuttle alone. The program provides for procurement of stages for NASA missions, for technical monitoring and management activities for government and commercial Upper Stages, and a solid rocket mtor integrity program to establish an engineering data base for solid stage components.

The Engineering and Technical Base provides the core capability for the engineering, scientific and technical support required at the Johnson Space Center (JSC), the Kennedy Space Center (KSC), the Marshall Space Flight Center (MSFC), and the National Space Technology Laboratories (NSTL) for research and development activities.

The Payload Operations and Support Equipment program develops and places into operational status the ground and flight systems necessary to support the STS payloads during pre-launch processing, on-orbit mission operations and, when appropriate, post-landing processing. Included within this program area are the STS support services for NASA payloads, satellite servicing tools and techniques development, flight demonstrations and multi-mission payload support equipment.

The Advanced Programs effort identifies potential future space initiatives and provides technical as well as progrmtic data for their definition and evaluation. Activity is focused on six major areas: advanced missions, satellite services, spacecraft systems, advanced transportation systems, crew system, and generic space system capabilities. Advanced developnent activities are conducted to provide a basis for obtaining significant performance and reliability improvements and reducing future program risks and developnent costs through the effective use of new technology. Extensive studies are being conducted jointly with DOD on future launch vehicle requirements.

The Tethered Satellite System (TSS), a joint Italian/United States development effort, will provide a new reuseable capability for conducting space experiments and unique tethered applications in regions remote from the Shuttle orbiter. The objectives of the initial TSS mission are twofold: (1) to verify the controlled deployment, operation, and retrieval of the TSS, and (2) to quantify the interaction between the satellite/tether and space plasma in the presence of a current drawn through the tether.

The development of the Orbital Maneuvering Vehicle, initiated in 1986, will provide a capability for payload delivery, retrieval, and servicing beyond the reach of the Space Shuttle or the Space Station.

OBJECTIVES AND STATUS

The first Spacelab reimbursable flight, Deutchland-1 (D-1), was successfully flown during the first quarter of FY 1986 and the first GSFC Spacelab Hitchhiker was successfully flown in the second quarter of FY 1986. In FY 1986, preparations were completed for the Spacelab Astro-1 mission that was scheduled for March 1986. This mission would have been the first Igloo Pallet Configuration of the Spacelab Pallet System (SPS). This mission has been rescheduled for the first quarter of 1989.

The balance of the hardware for the Dedicated Discipline Laboratory, the Spacelab Pallet System, the Space Technology Experiment Platform, and the Hitchhiker system is being procured.

In Upper Stages the comnercially developed Payload Assist Modules (PAM) provide low cost transportation from the Shuttle's low Earth orbit. The Delta class PAM-D is capable of injecting up to 2,750 pound payloads into geosynchronous transfer orbit. The PAM-DII is capable of placing a 4,100 pound payload into geosynchronous transfer orbit and was used for the first time in launching an RCA payload for STS 61B in November 1985. The Atlas-Centaur class PAM-A is capable of inserting 4,400 pound payloads into the same orbit and was system-qualified in late 1984. Forty PAM's have been launched on the Delta, Atlas, and Space Shuttle. There have been 20 consecutive successful PAM missions.

The Inertial Upper Stage (IUS) was developed under a DOD contract to provide the capability to place payloads of up to 5,000 pounds into geosynchronous orbit. The FY 1988 Budget includes funds for production, launch, flight support, and integration costs for vehicles to accommodate the TDRS C, D, E and F missions, and the Galileo, Ulysses (including a PAM-S vehicle), and Magellan planetary missions.

The Transfer Orbit Stage (TOS) is a three-axis stabilized perigee stage that is being comnercially developed by the Orbital Sciences Corporation for use in the Shuttle or on Titan. It will have the capability of placing 6,000 to 13,000 pounds into geosynchronous transfer orbit. The Apogee Maneuvering Stage (AMS) is a three-axis stabilized liquid propellant apogee stage which has completed preliminary design and is under consideration for commercial development by Orbital Sciences Corporation for use in the Shuttle. It will have the capability to place 5,200 pound payloads into geosynchronous transfer orbits when used alone or 6,500 pounds into geosynchronous orbit when combined with a TOS. Production of a TOS vehicle for the Mars Observer mission and an AMS for the Global Geospace Science mission is included in the FY 1988 budget.

The Solid Rocket Motor Integrity Program objectives are to provide confidence in existing flight systems, and to generate an urgently needed engineering data base for design, analysis, and testing of solid rocket mtor components. The 19 contracts in 11 states have made excellent progress in determining root causes of persistent problems plaguing mtor nozzles and the results are contributing to the Shuttle Solid Rocket Motor redesign effort. Investigation of other motor components in addition to the nozzle is being considered.

In Payload Operations and Support Equipment, payload integration support and payload-related hardware are developed and furnished for NASA payloads. Multi-mission payload support equipment is developed and procured including fiber optic cabling and equipment for communication links between the payload procesing facilities, standard sets of wire harnesses for interconnection of mixed cargoes in the orbiter payload bay, and payload display and controls in the orbiter vehicle crew cabin.

The Advanced Programs effort is focused on six major areas--advanced missions, satellite services, spacecraft systems, advanced transportation systems, crew systems, and generic space system capabilities. Advanced planning and analysis efforts will be increasingly focused on long range manned mission options in and beyond Earth orbit. Satellite servicing systems will continue definition and advanced developent work in remote and proximity operations. Continued efforts will be made in the areas of platform systems and servicing and advanced tether applications. Advanced transportation concepts will be studied, including orbit transfer vehicles (OTV's), propellant management, advanced launch vehicles, and advanced STS analytical tools. The joint NASA/DOD studies of future launch vehicle requirements will be continued. Systems supporting human presence in space as well as generic work in space structures, orbital debris management and retrieval, and artificial intelligence applications will be investigated.

The Tethered Satellite System (TSS) hardware developnent was initiated in FY 1984 following the completion of an advanced developent phase initiated in FY 1983. Systems definition studies were canpleted in FY 1985. Comprehensive design and requirements validation: procurement of long lead time flight hardware elements and tooling; systems development and integration, and deployer manufacturing and integration will continue through FY 1989. The Italians started satellite and core equipment developent in FY 1984 and a cooperative first flight is presently scheduled for 1990.

The Orbital Maneuvering Vehicle (OMV) canpleted early study and feasibility efforts in FY 1985. FY 1986 was devoted to phase C/D RFP/SEB activities. The Administrator selected TRW as the OMV contractor and negotiations were completed in EY 1986. TRW was given authority to proceed on October 1, 1986, with contract award in December 1986. The OMV will be a reusable, remotely operated propulsion vehicle with the capabilty to deliver, retrieve and service payloads and spacecraft deployed at a wide range of altitudes and inclinations. Based on current planning, this capability will be available for use With the STS in 1991.

BASIS OF FY 1988 FUNDING REQUIREMENT

SPACELAB

	1986 Actual	1987 Amended Budget	1987 Current Estimate	1988 Budget Estimate
		(Thousands of Dollars)		
Development	18,200	21,100	21,100	14,400
Operations	59,800	47,700	52,800	59,100
Total	78,000	68,800	73,900	73,500

OBJECTIVES AND STATUS

The Spacelab is a versatile facility designed for installation in the cargo bay of the orbiter which affords scientists the opportunity to conduct scientific experiments in the unique environment of space. The reusable Spacelab system enhances the advancement of scientific research by serving as both an observatory and laboratory in space. Ten European nations, including nine members of the European Space Agency (ESA), have participated in this joint development program with NASA. ESA designed, developed, produced, and delivered the first Spacelab components; consisting of a pressurized module and unpressurized pallet segments, igloo, command and data management subsystem, environmental control subsystem, power distribution systems, instrument pointing subsystem (IPS), and much of the ground support equipment and software for both flight and ground operations.

Additional hardware to complete the Spacelab system is in the Spacelab development budget, including such major elements as the crew ground support equipment, hardware modifications, system recertification and a training simulator. Support software and procedures development, testing, and training activities not provided by ESA, which are required to demonstrate the operational capability of Spacelab, are also included in NASA's funding. NASA has procured an additional Spacelab unit fran ESA under terms of the ESA/NASA Memorandum of Understanding and the Intergovernment Agreement. Additional Spacelab hardware including the initial lay-in of spare hardware is being procured fran European sources.

NASA is developing two principal versions of the Spacelab Pallet System (SPS). One will support missions requiring the igloo and pallet in a mixed cargo configuration like the Astro series; the other version will support missions that do not require use of the igloo such as the Space Technology Experiment Platform (STEP) and the Tethered Satellite System. Development of the Hitchhiker system is near canpletion.

The Spacelab operations budget includes mission planning, mission integration, and flight and ground operations. This includes integration of the flight hardware and software, mission independent crew training, system operations support, payload operations control support, logistical support and sustaining engineering.

The first Spacelab reimbursable flight, Deutschland-1 (D-1), was flown during the first quarter of FY 1986. Astro-1, planned for observation of Halley's comet, was delayed to FY 1989 due to the January 1986 Shuttle accident. The initial flight of the Goddard Space Flight Center Hitchhiker (E-1) took place in the first quarter of FY 1986.

In addition to these missions, analytical and physical integration, configuration management and software development for future flights will be conducted. Procurement of spares for both NASA-developed hardware and for hardware developed by U.S. companies under contract with ESA will continue throughout FY 1987. Operation of the depot maintenance program for U.S.-provided and European-supplied hardware and the procurement of replenishment spares will continue in FY 1987.

CHANGES FROM 1987 BUDGET ESTIMATE

The aperations increase of $5.1 million is due to the delay in anticipated receipts of reimbursements consistent with the Shuttle flight delays following the Challenger accident.

BASIS OF FY 1988 ESTIMATE

The FY 1988 development funds are required to complete the Hitchhiker and STEP programs, complete the lay-in of both U.S. and European source spares, and to make the necessary hardware and GSE modifications and upgrades for return-to-flight recertifications as recommended by the Rogers' Commission, in preparation for re-flight in 1989.

The FY 1988 operations program reflects significant restructuring and resheduling of Spacelab missions resulting fran the Challenger accident. Funds are required to support payload operations and to continue payload integration support, mission itdependent training, and logistic support in preparation for launch of the Astro-1 mission and the Materials Science Laboratory (MSL-3 and MSL-4) and two to three Hitchhiker systems in FY 1989 and the first Spacelab Life Science Laboratory (SLS-1), the International Microgravity Laboratory (IML-1), MSL-5, and four Hitchhiker systems in FY 1990. The support for these missions includes analytical integration, configuration management, hardware integration and software development and integration. Funding is also included to operate and maintain the MSFC and JSC Payload Operations Control Centers (POCC) required to support the Spacelab manifest. Spacelab operations also provides for replenishment spares, the operation of the depot for United States and European hardware and software, and sustaining engineering of all hardware and software.

The FY 1988 request also reflects significant program restructuring and rescheduling of Spacelab missions resulting from the standdown of the Shuttle. The current program provides for launching one to two major Spacelab missions per year beginning in 1989 as compared to three to four missions planned previously.

In addition to these NASA missions Spacelab reimbursable missions are scheduled to support DOD, Germany (D-2) and Japan (J).

BASIS OF FY 1988 FUNDING REQUIREMENT

UPPER STAGES

	1986 Actual	1987 Amended Budget	1987 Current Estimate	1988 Budget Estimate
		(Thousands of Dollars)		
Development...........................	17,000	21,200	14,200	17,100
Procurement and operations............	105,000	180,900	146,300	142,600
Total...............................	122,000	202,100	160,500	159,700

OBJECTIVES AND STATUS

The STS upper stages are required to deploy Shuttle-launched payloads to orbits not attainable by the Shuttle alone. The Inertial Upper Stage (IUS), and the commercially developed Payload Assist Modules (PAM-A, PAM-D and PAM-DII) are currently available for use on the STS. Several other upper stages now being commercially developed, including the Transfer Orbit Stage (TOS), will become available for use with the STS.

The IUS was developed under a DOD contract to provide the capability to place payloads of up to 5,000 pounds into geosynchronous orbit. The first IUS was successfully launched in October 1982 on a Titan 34-D booster. The first IUS/STS launch in April 1983 carried the TDRS-1 spacecraft. The IUS failed to operate nominally during the second stage boost. The IUS anomalies were resolved by joint USAF/NASA action, and the DOD/NASA/Industry Anomaly Investigating Team determined that the IUS was again ready for flight. The IUS operated nominally when deployed fran STS-51C in January 1985. The second IUS/TDRS was lost during the Challenger accident. Four IUS vehicles were procured by NASA for launch of the initial four Tracking and Data Relay Satellite System spacecraft: the first three were funded through the TDRSS contract while the fourth is funded under this budget element.

The objective of the PAM program is to provide low cost transportation fran the Shuttle's low Earth orbit to geosynchronous transfer orbit. The Delta class PAM-D is capable of injecting up to 2,750 pound payloads into geosynchronous transfer orbit. The PAM-DII was developed commercially and is capable of injecting 4,100 pound payloads into geosynchronous transfer orbit. Its first mission, on STS-61B in November 1985, deployed an RCA satellite. The Atlas-Centaur class (PAM-A) is capable of inserting 4,400 pound payloads into the same orbit. PAM's are being developed commercially, but NASA monitors the development and production to assure that the PAM is technically adequate and will be available when needed. Forty PAM's have been launched on the Delta, Atlas, and Shuttle with 20 consecutive successes.

TOS is a three-axis stabilized perigee stage that is being developed commercially by the Orbital Sciences Corporation for use with the Shuttle. It will have the capability to place 6,000 to 13,000 pounds into geosynchronous transfer orbit. A TOS vehicle is being procured for the Mars Observer mission and FY 1987 funding is included to procure a second TOS for the ACTS mission. The Apogee Maneuvering Stage (AMS) is a three-axis stabilized liquid propellant apogee stage that has completed preliminary design with development under consideration for initiation in 1987. The AMS will also be developed commercially by the Orbital Sciences Corporation for use with the Shuttle. It will have the capability to place a 5200 pound payload into geosynchronous transfer orbit when used alone or 6500 pounds into geosynchronous orbit when combined with TOS. The Global Geospace Science mission will require three Pam-D and one AMS class upper stages.

The solid rocket motor integrity program was initiated in FY 1984 to establish an urgently needed engineering data base for use of composite materials in upper stage motor nozzles, to minimize risk to planned missions and to restore user confidence in U.S. launch systems. Underlying root causes of persistent problems in motor nozzles have been identified and required data is being generated. Motor testing will be conducted to verify analyses and create an engineering data base. The results of this program are contributing to the redesign of the Shuttle Solid Rocket Motor.

CHANGES FROM FY 1987 BUDGET ESTIMATE

The reduction of $41.6 million reflects a delay in the IUS and TOS upper stages procurement activities as a result of extensive reviews of vehicle options for the planetary missions, reduced requirements for NASA funding for termination cost related to the STS/Centaur, and a reduction in the scope of the RL-10 engine product improvement program.

BASIS OF FY 1988 ESTIMATE

Production and operations funds in FY 1988 are required to continue production of three IUS's and one PAM-S vehicle to support the Galileo, Ulysses and Magellan missions, and upper stages for the Mars Observer, TDRSS-E and TDRSS-F Missions. Monitoring of the PAM-D, PAM-DII and TOS program will continue. Funds are also required to support continuation of the solid rocket motor integrity program. Consistent with the FY 1987 recission request submitted by the President, funding for the upper stage for ACTS has not been provided in FY 1988. Funding starts in FY 1988 on four upper stages, three PAM-D class and one AMS class, for the Global Geospace Science Missions.

BASIS OF FY 1988 FUNDING REQUIREMENT

ENGINEERING AND TECHNICAL BASE

	1986 Actual	1987 Amended Budget	1987 Current Estimate	1988 Budget Estimate
		(Thousands of Dollars)		
Research and test support.............	44,200	53,900	67,400	72,500
Data systems and flight support..	21,500	22,600	22,600	26,100
Operations support....................	40,100	38,600	38,600	36,100
Launch systems support................	3,900	4,800	4,800	5,100
Total............................. .	109,700	119,900	133,400	139,800

OBJECTIVES AND STATUS

The Engineering and Technical Base (ETB) provides the core capability. required to sustain an engineering and developent base for various NASA program at the manned space flight centers. Additional center program support requirements above the core level are funded by the benefitting programs, such as Shuttle Operations and Shuttle Production and Capability Development. The centers involved are the Johnson Space Center (JSC), the Kennedy Space Center (KSC), the Marshall space Flight Center (MSFC), and the National Space Technology Laboratories (NSTL).

The core level of support varies fran center to center due to programmatic and institutional differences. At JSC, the core level requirement is that one shift of operations be mintained in the engineering and development laboratories and the White Sands Test Facility. Safety, reliability and quality assurance areas are also supported by the ETB core. The core level for the central computer canplex is established as a two-shift operation. The funding for center operations base support is split between the ETB and Shuttle Operations budget elements in accordance with the principle that ETB will provide the core level and the benefitting program is responsible for funding additional support requirements. At KSC, due to its operational character, the core level provides for future studies and *ground* systems research and development. ETB funds at MSFC provide for multi-program support activities, including technical labs and facilities, reliability and quality assurance, computational and communications Services, and at NSTL for facilities operations, including security.

CHANGES FROM FY 1987 BUDGET ESTIMATE

The total funding for the ETB has increased in FY 1987 reflecting the augmentation and consolidation of safety reliability and quality assurance activities at the centers engaged in manned flight programs.

BASIS OF FY 1988 ESTIMATE

The requested funding for the ETB in FY 1988 provides for a continuation of the FY 1987 level of support for institutional research and development facilities and services at the centers.

In research and test support, effort will be continued to provide increased computation capabilities at MSFC for engineering and science projects through the acquisition of a Class VI computer system. This capability is required for the solution of more complex main engine three-dimensional dynamics modeling problem and for canplex structural analyses. At JSC, the requested funding will provide for a five-day, one-shift operation for the engineering and development laboratories, such as the Electronic Systems Test Laboratory and the Thermal Test Area. Safety, reliability and quality assurance activities will also be provided.

Data systems and flight support provide a core level of support based on a five-day, two-shift operation of the central computer complex at JSC. Any additional requirements are the responsibility of the benefiting program.

Operations support funding provides for the maintenance of technical facilities and equipment, chemical cleaning, engineering design, technical documentation and analysis, telecommunications, component fabrication, photographic support, and logistics support. Examples of specific services to be provided in FY 1988 include: (1) operation and maintenance of specialized electrical and cryogenic systems, and maintenance of test area cranes: (2) operation of shops to do metal refurbishing, anodizing, plating, stripping, and etching of selected items of in-house hardware; (3) engineering, installation, operation, and maintenance of closed circuit fixed and mobile television required for the support and surveillance of tests: (4) photographic services, including still and motion picture processing, and audio-visual mission support; (5) fabrication of models, breadboards, and selected item of flight hardware; (6) technical documentation services, telecommunications, and graphics: (7) technical services in support of center operations including receipt, storage, and issue of research and development supplies and equipment and transportation services; and (8) management services in support of center operations, including data management, microfilming, and preparation of technical documentation. In addition, FY 1988 funds will provide a basic level of institutional support at NSTL for continuing main engine testing activities.

In launch systems support, funds are required to continue work in the develoPent of beneficial application of new technology to the solution of operational problem and development of improved operational capabilities for launch site hardware, ground processing and support systems.

BASIS OF FY 1988 FUNDING REQUIREMENT

PAYLOAD OPERATIONS AND SUPPORT EQUIPMENT

	1986 Actual	1987 Amended Budget	1987 Current Estimate	1988 Budget Estimate
		(Thousands of Dollars)		
Payload operations....................	46,500	37,000	37,000	68,300
Payload support equipment.............	8,300	7,500	7,500	15,100
Total............................	54,800	44,500	44,500	83,400

OBJECTIVES AND STATUS

The Payload Operations and Support Equipment objectives are to centralize the provisioning of payload services, both unique and common, which are required beyond the basic standard services for NASA missions, and to provide multi-mission support equipment in support of payload operations. Payload operations provides unique hardware, analyses, and launch site support services to support STS missions. Payload support equipment funds the developnent and acquisition of multi-mission reusable ground support equipent required for a wide range of payloads. This includes test equipent required to checkout payload-to-orbiter interfaces at KSC, mixed cargo hardware such as standard cable harnesses, and displays and controls related to payload bay operations.

BASIS OF FY 1988 ESTIMATE

Payload operations funding is required to furnish continued payload services for currently scheduled NASA launches. As a result of the Challenger accident and the decision to cancel the Centaur program for planetary launches there have been major changes in payload itegration requirements. Major NASA payloads receiving support during this year include Hubble Space Telescope, Galileo, Ulysses, Magellan, Astro, and Tracking and Data Relay Satellite (TDRS). The change to IUS upper stages for the planetary launches of Galileo, Ulysses and Magellan require substantial new integration. The significant change in launch dates for all NASA payloads will require a thorough reassessment. of the paylaod integration into the Shuttle. Efforts will continue to provide the means to maintain and repair satellites on-orbit by developing a series of tools, aids, and techniques, and to demonstrate capabilities and methods of improving the efficiency of on-orbit operations. These demonstrations will provide the experience necessary for realization of the Shuttle's potential for satellite servicing missions and on-orbit assembly functions.

Payload support equipment estimates reflect the requirement to modify and upgrade selected pyload integration facilities for safer, more efficient operations. FY 1988 funding for multi-mission payload support equipment is required for developnent testing an3 delivery of pyload common communication equipment (PCCE) to accommodate required payload data transmission, and initial spares provisioning for cargo integration test equipment (CITE) an3 PCCE. Funds for fiber optic cabling and an upgraded operational intercom system in the industrial area at KSC are included in this budget to provide increased reliability and quality of data transmission'among cargo facilities. Multi-mission payload support equipment funding also includes orbiter/payload interface hardware for groups of payloads; cargo bay cabling; modified aft flight deck panels; and, associated display and controls.

BASIS OF FY 1988 FUNDING REQUIREMENT

ADVANCED PROGRAMS

	1986 Actual	1987 Amended Budget	1987 Current Estimate	1988 Budget Estimate
		(Thousands of Dollars)		
Advanced programs......................	19,400	16,600	27,600	24,900

OBJECTIVES AND STATUS

Advanced Program's principal objectives are to conduct mission requirements analyses, conceptual system definition, detailed system definition, and advanced and supporting developments to acquire the technical and programmatic data for the evaluation of new space flight initiatives. Future space program and systems requirements, configurations, costs, and capabilities are identified to provide the basis for development decisions on new space flight systems. Past program efforts have provided such information for new major Agency programs and systems including Apollo, Skylab, the Space Transportation System and Space Station. Subsystem studies and advanced and supporting development efforts are conducted to demonstrate the required performance and reliability. Improvements to reduce future system program cost and schedule risks while increasing performance will also be investigated.

In FY 1987, the Advanced Programs effort is focused in six major areas--advanced missions, satellite services, spacecraft Systems, advanced transportation systems, crew systems, and generic space system capabilities. Definition studies as well as advanced development efforts are being continued in the areas of satellite servicing systems, manned extravehicular activity, spacecraft and platform resupply, mintenance and repair, rendezvous and proximity operations, satellite maintenance and repair in low and geostationary Earth orbit, and autonomous capabilities. In spacecraft systems, definition activities continue for free flying and tethered space platforms in low and geostationary orbits operating frun the Shuttle. Advanced transportation studies are focused on study of potential future reusable orbit transfer vehicles (OTV), space-based operations of OTV's, canpetitive aeroassist braking techniques for OTV, Shuttle-derived launch vehicle concepts, propellant scavenging, and aft cargo carrier concepts. Crew systems efforts will focus on definition and advanced development related to future space flight systems. Generic space system capabilities will include studies related to space debris. Preliminary definition and ground simulation evaluations of assembly and construction operations for large space systems and orbital structures will be pursued.

NASA, in conjunction with the DOD, is investigating future space transportation and operational support requirements including heavy lift launch capability and associated advanced technology. These studies were initiated during **FY 1986** to identify the necessary requirements and supporting technologies for future space transportation systems. Studies, definition, and a limited amount of advanced developnent effort will be devoted to key subsystems for a Shuttle-derived Heavy Lift Launch Vehicle (HLLV). Preliminary studies have already been initiated for engines, precision recovery devices, propulsion/avionics modules, advanced structures, avionics and other contributory technologies.

The objective of efforts to be initiated in the advanced manned mission area will be the planning and analysis of potential follow-on programs to exploit the STS and the Space Station. Integrated program options involving law Earth orbit, geostationary orbit, lunar and planetary missions will be investigated, with the multi-year purpose to develop goals, planning information, and infrastructure requirements.

CHANGES FROM FY 1987 BUDGET ESTIMATE

Advanced program funding was increased in FY **1987** by **$11.0** million to continue the joint **NASA/DOD** studies on future launch vehicle requirements.

BASIS OF FY 1988 ESTIMATE

In FY **1988**, mjor emphasis will be placed on system concept definition and key advanced technology in crew systems, geostationary Earth orbital umnned platforms, reusable OTV's, new capability mission kits for orbital rmneuvering vehicles, future tethered systems applications, satellite servicing systems near and remote from the orbiter, and second generation shuttles. A major goal continues to be the conceptual definition of the systems architecture and space elenents needed for space operations over the next twenty years.

The satellite servicing program element will continue to explore effective rmnned servicing concepts to extend STS operational capability for Earth orbit support of spacecraft, platforms, and constellation aggregates. The spacecraft systems program element will focus on geostationary platform capability, definition and delineation of critical mechanisms, and designs which require advanced developnent efforts. Detailed engineering systems analysis will be continued to determine the efficiency of future tethered platform applications. Second generation shuttle concept studies and advanced developments will continue. In the crew systems area, new life support system concepts and advanced developments will continue focusing on post-Space Station era manned missions. Also, in the crew systems area, new capabilities for EVA will be pursued. Generic studies regarding orbital debris, large structures, and system applications will be continued. Advanced manned missions beyond the Space Station will continue to be studied with expanded scope and increased depth. Studies will be conducted to identify potential lunar/Mars missions and their potential demands on the STS.

BASIS OF FY 1988 FUNDING REQUIREMENT

TETHERED SATELLITE SYSTEM

	1986 Actual	1987 Amended Budget	1987 Current Estimate	1988 Budget Estimate
		(Thousands of Dollars)		
Tethered satellite system............	15,000	10,600	10,600	7,300

OBJECTIVES AND STATUS

The developanent of a Tethered Satellite System (TSS) will provide a new reuseable facility for conducting space experiments at distances up to 100 kilometers frun the Shuttle orbiter while being held in a fixed position relative to the orbiter. A number of significant scientific and engineering objectives can be uniquely undertaken with a TSS facility such as the observation of important atmospheric processes occurring within the lower themsphere, new observations of crustal geomagnetic phenawna, and entirely new electrodynamic experiments interacting with the space plasma. This is being undertaken as a cooperative development program with the Italian government. Formal signing by representatives of both governments of a Memorandum of Understanding took place in March 1984.

The United States is responsible for overall program management, overall systems engineering and integration, Orbiter integration, ground and flight operations, ard developnent of the deployment mechanism. The U.S. effort was initiated in 1984. The Italians are responsible for the design and development of the satellite, and the European instruments being flown on the joint missions. They initiated their developanent efforts in 1984.

BASIS OF FY 1988 ESTIMATE

The FY 1988 funding of $7.3 million reflects a phase down of the hardware design and development consistant with a delay in the engineering verification flight from 1988 to 1990 caused by the Challenger accident. Current plans call for completion of hardware assembly in FY 1987 and delay in system qualification until FY 1989. Contractor manpower levels will be minimized consistent with Scienoe and Italian interface requirements. Late FY 1988 will see the start of preparations for completion of deployer qualification efforts. Mission Operation Planning and Dynamic Simulations of on-orbit tethered satellite operations are planned to continue throughout FY 1988.

BASIS OF FY 1988 FUNDING REQUIREMENT

ORBITAL MANEUVERING VEHICLE

	1986 Actual	1987 Amended Budget	1987 Current Estimate	1988 Budget Estimate
		(Thousands of Dollars)		
Orbital maneuvering vehicle..	5,000	45,000	45,000	80,000

OBJECTIVES AND STATUS

The Orbital Maneuvering Vehicle (OMV) will provide a new STS reusable extension capability for conducting orbital operations with spacecraft and payloads beyond the practical operational accessibility limits of the baseline STS. By means of direct m-in-the-loop control, the spacebaseble reusable OMV, operating as far as 1200 nautical. miles altitude above the orbiter, will provide delivery, maneuvering, and retrieval of satellite payloads to and from altitudes or inclinations beyond the existing STS capability; reboost of satellite to original operational altitudes or higher; delivery of multiple payloads to different orbital altitudes and inclinations in a single flight; and safe deorbit of satellites which have completed their useful life. It will be designed to serve the Space Station as well and to accommodate the add-on of future "mission kits" as needed to support more advanced missions such as the servicing of satellites and platform and the retrieval of space debris which could represent an orbital hazard to all future space missions. TRW was competitively selected and is now under contract to develop the OMV.

BASIS FOR FY 1988 ESTIMATE

The funds provided in FY 1988 will be used to continue OMV hardware design and development and fabrication of test and flight hardware. The preliminary design review will be held early in FY 1988 and long lead procurements will be initiated. The planned first flight for the OMV is late 1991.

SPACE SCIENCE
AND APPLICATIONS

NATIONAL AERONAUTICS AND SPACE ADMINISTRATION

FISCAL YEAR 1988 ESTIMATES

RESEARCH AND DEVELOPMENT BUDGET PLAN FOR SPACE SCIENCE AND APPLICATIONS PROGRAMS

	Budget Plan			
		1987		1988
Program	1986 Actual	Amended Budget	Current Estimate	Budget Estimate
Physics and astronomy..................	569,300	529,900	552,800	567,100
Life sciences.........................	66,100	69,700	72,200	74,600
Planetary exploration..................	353,600	374,300	358,400	307,300
Solid earth observations..............	70,900	74,100	75,600	76,800
Environmental observations............	271,600	336,900	320,900	393,800
Materials processing in space.........	31,000	39,400	47,900	45,900
Communications........................	96,400	19,500	103,500	20,500
Information systems	17,600	21,200	21,300	22,300
Total..............................	1,476,500	1,465,000	1,552,600	1,508,300

PHYSICS AND
ASTRONOMY

RESEARCH AND DEVELOPMENT

FISCAL YEAR 1988 ESTIMATES

BUDGET SUMMARY

OFFICE OF SPACE SCIENCE AND APPLICATIONS — **PHYSICS AND ASTRONOMY PROGRAM**

SUMMARY OF RESOURCES REQUIREMENTS

	1986 Actual	1987 Amended Budget	1987 Current Estimate	1988 Budget Estimate	Page Number
		(Thousands of Dollars)			
Hubble space telescope development....	125.800	95.900	101.300	98.400	RD 3-5
Gamma ray observatory development.....	85.300	51.500	50.500	49.100	RD 3-7
Spacelab/Space Station payload development and mission management..........	89.400	84.600	90.100	95.400	RD 3-9
Explorer development..................	48.200	56.700	56.700	60.300	RD 3-12
Mission operation and data analysis...	111.700	125.700	125.700	128.100	RD 3-16
Research and analysis.................	49.000	51.100	53.400	60.100	RD 3-18
Suborbital program....................	59.900	64.400	75.100	75.700	RD 3-21
Total..............................	569.300	529.900	552.800	567.100	

Distribution of Program Amount by Installation

	1986 Actual	1987 Amended Budget	1987 Current Estimate	1988 Budget Estimate
Johnson Space Center..................	7.691	8.700	12.735	16.781
Kennedy Space Center..................	5.235	5.600	4.881	6.027
Marshall Space Flight Center..........	262.179	235.800	244.911	249.836
Goddard Space Flight Center...........	193.990	167.900	183.682	182.195
Jet Propulsion Laboratory.............	12.650	17.400	13.218	14.453
Ames Research Center..................	37.801	40.600	32.741	37.063
Langley Research Center...............	1.633	---	---	---
Headquarters..........................	48.121	53.900	60.632	60.745
Total..............................	569.300	529.900	552.800	567.100

PROGRAM OBJECTIVES AND JUSTIFICATION

The objectives of the Physics and Astronomy program are to increase understanding of the origin and evolution of the universe, the fundamental laws of physics, and the formation of stars and planets. The objects under study include the most distant clusters and galaxies, stars and structures in nearby galaxies, and the interstellar medium in our galaxy. The most unusual and exotic phenomena exhibited as quasars, black holes, neutron stars, and pulsars are of particular interest. We also include our own Sun, with its multitude of time varying phenomena at all scales of spacial resolution. Space research allows observations in wavelength regions, such as the infrared, ultraviolet, or x-rays and gamma-rays, which are absorbed by the earth's atmosphere; or in the visible region, where ground based work is limited by atmospheric distorting effects. We also couple these observations to those of cosmic ray particles, which have their origin in energetic acceleration processes occurring in sites such as solar flares and supernovae.

The objectives of the program are accomplished with a mixture of large, complex free flying space missions, less complex Explorer spacecraft, Shuttle/Spacelab flights, retrievable Spartans, and suborbital opportunities. The latter include balloons, aircraft, and sounding rocket flights. In the future, the Space Station will provide an opportunity for both attached payloads and major free-flying observatories requiring assembly, maintenance, and refurbishment on-orbit. The entire program rests on a solid basis of supporting research and technology, data analysis, and theory.

Research teams involved in this program are located at universities, industrial laboratories, NASA field centers, and other government laboratories. The scientific information obtained and the technology developed in this program are made available to the scientific communities and the general public for application to the advancement of scientific knowledge, education and technology.

The Physics and Astronomy missions undertaken to date have been extraordinarily successful. Recently, these include the High Energy Astronomical Observatories (HEAO, 1977-1979), the International Ultraviolet Explorer (IUE, 1978), the Solar Maximum Mission (SMM, 1980) and the Infrared Astronomy Satellite (IRAS, 1983). The IUE and the SMM are still operating, and new scientific results are continually emerging from these, as well as the high quality data sets archived from the HEAO's and the IRAS.

The Hubble Space Telescope, to be launched by the Space Shuttle in late 1988, will provide an international spaceborne astronomical observatory capable of measuring objects appreciably fainter and more distant than those accessible from the ground, since it will be above the turbulent and absorbant atmosphere. This telescope will be able to resolve special features by a factor of ten better than the typical ground based optical telescope, and will observe the universe at approximately seven times the distances now possible. This means some 350 times the volume of the present universe will be available for study. This increased capability will allow us to address such basic questions as the origin, evolution, and disposition of galaxies, quasars, clusters, and stars, thus allowing us to significantly increase our understanding of both the early and present universe; its beginning and end.

The Gamma Ray Observatory (GRO) mission will be launched by the Space Shuttle in 1990. This mission will measure gamma rays, which are produced by the most energetic and exotic fundamental physical processes occurring in nature. Instruments on this mission will provide unique information on phenomena occurring in quasars, active galaxies, black holes, neutron stars, supernovae, and the nature of the mysterious cosmic gamma-ray bursts.

Definition studies of the advanced technology will continue on the other observatories, i.e. the Advanced X-Ray Facility *(AXAF)* and the Space Infrared Telescope Facility (SIRTF). The *AXAF* will provide a capability some 10 times more sensitive than the HEAO-2 to understand the multi-million degree thermal and non-thermal processes which occur in quasars, clusters of galaxies, supernovae remnants, binary stellar systems involving compact objects, and stellar corona. Many of these objects are end points of cosmic evolutionary cycles. SIRTF, on the other hand, will measure phenomena associated with the beginning of an evolutionary cycle. This includes cosmic dust, cool interstellar material, star formation, and proto-planetary nebulae in both our galaxy and the most distant ones.

The Explorer program, since the inception of the U.S. space program, has been the means for fast-turnaround scientific space missions. The Physics and Astronomy Explorers have been extremely successful. The IUE, a U.S./ESA endeavor has recently shown that our galaxy has a halo of gas at over a million degrees, while the IRAS, a joint U.S./U.K./Netherlands project, has detected and cataloged over 300,000 sources on the sky, and has shown star formation in other galaxies is a more prelevant and important activity than previously thought. At least one quasar has been shown to have its dominant energy release in the infrared spectral region. Since the IRAS completed operations in late 1983, these discoveries have come from analysis of archival data, and many more results can be expected.

Two major Explorer missions are now under development: the Cosmic Background Explorer (COBE) and the Extreme Ultraviolet Explorer (EWE). A third mission, the X-ray Timing Explorer (XTE) is under definition. In addition, a U.S. instrument is being developed for inclusion on the Roentgen Satellite (ROSAT), being built by the Federal Republic of Germany. A Cosmic Ray Isotope Experiment (CRIE) is also being developed along with the Combined Released and Radiation Effects (CRRES) experiment for flight in 1992 on a Department of Defense spacecraft. Finally, we have concluded the selection of a U.S. team who will participate in the Japanese Solar-A mission (an explorer mission previously called the High Energy Solar Physics Mission, HESP). Solar-A will be launched in 1991 to study the Sun during the upcoming solar maximum.

The Astrophysics involvement in the Shuttle/Spacelab program will continue, with the flight of the Astro-1, a set of ultra-violet and soft x-ray telescopes and spectrometers, scheduled for 1989. The Astro-1, whose first flight, scheduled to observe Comet Halley in March 1986, was cancelled due to the Challenger accident, will investigate the interstellar medium by following up on discoveries made with the IUE. Many of the investigations originally scheduled for Shuttle/Spacelab opportunities, such as Cosmic-Ray Nuclei Experiment (CRNE), the Heavy Nuclei Collector (HNC), the Shuttle High Energy Astrophysics Lab (SHEAL), and the Spartan program have been cancelled, deferred or rescoped as a consequence of the loss of the Challenger.

During the shuttle recovery period, suborbital observation from balloons, sounding rockets, and high-flying aircraft will take on increased significance. This enhanced effort will provide observations and instrument development opportunities for research groups. Furthermore, activities in the Research and Analysis (R&A) and the Mission Operations and Data Analysis (MO&DA) areas will also be augmented in order to maintain this vital research base in Physics and Astronomy.

BASIS OF FY 1988 FUNDING REQUIREMENT

HUBBLE SPACE TELESCOPE DEVELOPMENT

	1986 Actual	1987 Amended Budget	1987 Current Estimate	1988 Budget Estimate
		(Thousands of Dollars)		
Spacecraft...........................	111,900	82,900	87,600	85,000
Experiments..........................	13,900	13,000	13,700	13,400
Total............................	125,800	95,900	101,300	98,400
Mission operations and data analysis..	(83,900)	(90,600)	(92,000)	(93,700)
Space transportation system operations	(10,200)	(22,500)	(22,500)	(60,800)

OBJECTIVES AND STATUS

The Hubble Space Telescope will make a major contribution to understanding the stars and galaxies, the nature and behavior of the gas and dust between them, and the broad question of the origin and scale of the universe. The Hubble Space Telescope will operate in space above the atmospheric veil surrounding the Earth, increasing dramatically the volume of space accessible for observations. With its significant improvements in resolution and precision in light sensitivity and in wavelength coverage, the Hubble Space Telescope will permit scientists to conduct investigations that could never be carried out with ground-based observatories limited by the obscuring and distorting effects of the Earth's atmosphere.

The Hubble Space Telescope will enhance the ability of astronomers to study radiation in the visible and ultraviolet regions of the spectrum. It will be more sensitive than ground-based telescopes and will allow the objects under study to be recorded in greater detail. It will make possible unique observations of objects so remote that the light will have taken many billions of years to reach the Earth. As a result, we will be able to look farther into the distant past of our universe than ever before. The Hubble Space Telescope will also contribute significantly to the study of the early state of stars and the formation of solar systems, as well as the observatlon of such highly-evolved objects as supernova remnants and white dwarf stars. With the Hubble Space Telescope, we may be able to determine the nature of quasars and the processes by which they emit such enormous amounts of energy; it may also be possible to determine whether some nearby stars have planetary systems.

The Hubble Space Telescope will be an automated observatory, delivered into orbit by the Space Shuttle. Data from its scientific instruments will be transmitted to Earth via the Tracking and Data Relay Satellite System. The Hubble Space Telescope design will permit on-orbit maintenance and repair, and/or retrieval by the Space Shuttle for return to Earth for required refurbishment and then relaunch by the Space Shuttle.

During FY 1986, the Hubble Space Telescope (HST) Program completed the series of comprehensive functional and environmental tests that had begun in FY 1985. The test series culminated in a highly successful thermal/vacuum test, which verified performance of the spacecraft, the science instruments, and the HST ground system under simulated orbital conditions. The results of these tests indicate that the flight and ground support elements of the HST system will meet or exceed the scientific performance objectives. The HST was on schedule for an October 1986 launch until the Challenger accident forced a replanning of the program to meet a launch date of November 1988.

After the completion of the thermal/vacuum testing, the scientific and engineering manpower assigned to the HST Program was reduced to the minimum cadre needed to retain the critical skills and knowledge required to sustain the program through FY 1987. During the first half of FY 1987, this reduced level of effort will be used to bring the spacecraft to a final state of launch readiness and to complete functional verification of the ground system, whose development has been stretched out to permit the inclusion of measures to increase the on-orbit efficiency of the HST and provide capabilities originally scheduled for the post-launch period. After a systems validation test, the spacecraft will be retained in environmentally-controlled storage until reactivated for pre-ship preparations. In addition, the program will participate in a Failure Modes and Effects Analysis/Critical Item List re-review as required by the Space Transportation System.

CHANGES FROM FY 1987 AMENDED BUDGET

The increase of $5.4 million is required for work related to the Space Telescope interfaces in connection with review of the Failure Modes and Effects Analysis and the Critical Items List and other Shuttle safety review requirements.

BASIS OF FY 1988 ESTIMATE

The FY 1988 funding level *is* required to maintain the irreplaceable skilled experts who have hands-on experience with the spacecraft. During FY 1988, the HST Program will be performing additional safety and spacecraft review work as a consequence of the shuttle accident, as well as returning to the program manning levels needed to support pre-ship functional testing of the HST system, transporting the spacecraft to Kennedy Space Center, and conducting launch preparations and operations at KSC.

BASIS OF FY 1988 FUNDING REQUIREMENT

GAMMA RAY OBSERVATORY DEVELOPMENT

	1986 Actual	1987 Amended Budget	1987 Current Estimate	1988 Budget Estimate
		(Thousands of Dollars)		
Spacecraft...........................	57,700	35,500	34,500	34,100
Experiments and ground operations.....	27,600	16,000	16,000	15,000
Total.............................	85,300	51,500	50,500	49,100
Space transportation system operations	(200)	(9,000)	(9,000)	(23,400)

OBJECTIVES AND STATUS

The Gamma Ray Observatory (GRO) has as its objective the measurement of the highest energy electromagnetic radiation emitted from sources in the cosmos. This spectral region represents one of the last frontiers in astronomy to be studied at high sensitivity. Because of their extreme energy, gamma-rays are produced by the most energetic and intriguing phenomena occurring in the universe: phenomena occurring in the central energy source region of quasars, in supernovae, near black holes, and on the surface of neutron stars. Gamma-rays provide the unique direct signature of all nuclear processes which occur in astrophysics: the synthesis of elements, cosmic rays interacting in the interstellar medium, and transformations involving the fundamental particles of physics. The GRO will provide new information on phenomena ranging from the enigmatic, and yet unidentified, cosmic gamma-ray bursts, to the diffuse gamma-ray sky background, whose origin must have cosmological significance.

The GRO science and instrumentation rests on a foundation of exploratory investigations and developments from previous spacecraft, such as the Small Astronomy Satellite-2 (SAS-2, 1972), the High Energy Astronomical Observatories (HEAO's 1 and 3, 1977 and 1979), and the European COS-B (1975). A community of astronomers and physicists has built up both the data analysis experience and developed the theoretical concepts to complete the infrastructure required for a successful space mission. Scientific involvement in the GRO cuts across university, government and industry. The international involvement, with a complete Principle Investigator team based in Europe, is extensive.

The low flux of cosmic gamma-rays, their penetrating nature, and the high background produced by cosmic-ray interactions all dictate large and massive instruments to be flown in space for extended periods of time. The four complementary instruments selected for the GRO represent a quantum jump in sensitivity, spectral range, and spectral, spacial, and temporal resolution over any previous missions or instruments in these energy ranges. GRO, scheduled for launch on the space shuttle in 1990, is designed to be pointed at fixed directions in space for hours or weeks to obtain the long exposures required. The orbit selected allows possible refueling through the STS or reboost by the Orbital Maneuvering Vehicle (OMV) to obtain an extended lifetime.

In FY 1986, the detailed design of the spacecraft primary structure was completed at TRW, the prime contractor, and manufacturing and assembly of the structure was initiated. In addition, fabrication and assembly of instrument hardware was continued.

In FY 1987, instrument calibration and testing will continue. Assembly of the spacecraft structure will be completed, electronic manufacturing will continue, and all government furnished property subsystems for GRO will be delivered.

CHANGES FROM FY 1987 AMENDED BUDGET

The decrease in the FY 1987 estimate reflects a general reduction.

BASIS OF FY 1988 ESTIMATE

FY 1988 funding is required for completion of the spacecraft modal survey and static load testing. In addition, the fabrication and testing of the spacecraft attitude control and power system electronics will be completed. The development of the GRO mission operations and data systems will be continued and the implementation of the payload operations control center (POCC) for GRO will be completed. Funding is also required for final testing, calibration and shipment of all four science instruments to the spacecraft contractor for the beginning of spacecraft integration and testing.

BASIS OF FY 1988 FUNDING REQUIREMENT

SPACELAB/SPACE STATION PAYLOAD DEVELOPMENT AND MISSION MANAGEMENT

	1986 Actual	1987 Amended Budget	1987 Current Estimate	1988 Budget Estimate
		(Thousands of Dollars)		
Spacelab/Space Station Payload Development and mission management..	89,400	84,600	90,100	95,400
(Shuttle/Spacelab development and mission management).......	(89,400)	(84,600)	(74,600)	75,400)
(Space Station Integration Planning)..	(---)	(---)	(15,500)	(20,000)

OBJECTIVES AND STATUS

A primary objective of the Spacelab Payload Development and Mission Management program is to develop instruments used for Shuttle/space flight investigations in the disciplines of physics and astronomy on board the Space Shuttle or Spacelab carriers. These science payloads include sounding rocket class experiments for flight on the Space Shuttle.

A second objective is to initiate the necessary planning, definition and development of payloads and missions as the Office of Space Science and Applications begins its preparations as a future major user of the Space Station complex. This new focus includes the study definition of integration and operational requirements of potential Space Station payloads and missions, in anticipation of the new, integrated methods of conducting scientific research which the Space Station will offer.

Another major objective is to manage the mission planning, integration, and execution of all NASA Spacelab and attached payloads. This includes system management and engineering development of flight support equipment and software; development of certain interface hardware; payload specialist training and support; integration of the science payloads with the Spacelab system; payload flight operations; data dissemination to experimenters, and initial analysis of flight data from physics and astronomy science payloads. Similar mission management activities will be carried out for Space Station payloads as the they enter the development phase and interface requirements become well defined.

Instruments are currently under development for several Shuttle/Spacelab missions with primary emphasis on physics and astronomy. Each of these instruments is typically developed by a principal investigator to carry out a specific scientific investigation; several instruments with closely allied or compatible objectives will generally be flown as an integrated mission. In many cases, the principal investigator heads a team of coinvestigators. Investigators are generally members of the university community, but may also represent government or industry reseach facilities, or foreign cooperative research activities.

Development is essentially complete for the three ultraviolet telescopes and two wide-field cameras to be flown on the Astro-1 mission. This mission is designed to conduct investigations in ultraviolet imaging, spectrophotometry, and polarimetry at very high resolution. It will be able to observe a broad range of objects, from nearby comets and planets to the most distant quasars. This mission is scheduled for flight in early 1989.

Work is proceeding on instruments for the Shuttle High Energy Astrophysics Lab (SHEAL). This mission, planned for flight in 1992, will study the diffuse x-ray background and measure x-ray spectra of point and extended sources.

Mission management activities are continuing on several other space science and applications missions, such as the Atmospheric Laboratory for Applications and Science (ATLAS). The first of this series will fly in early 1991. The mission will incorporate a large number of instruments designed to study the complex relationships of solar irradiance, atmospheric composition and changes, and the near-earth plasma environment. Other examples include flight of an imaging radar in the early 1990's; a series of Spacelab Life Science missions (SLS), the first scheduled for launch in December 1989; a joint microgravity mission with the Japanese (SL-J); a series of cooperative International Microgravity Laboratories (IML's); and flight of the ongoing series of Materials Science Laboratories (MSL's). Mission management activities also support other (non-OSSA) payloads. For example, the Space Station heat pipe advanced radiator element experiment payload will test a heat rejection system with high potential for future spaceborne applications.

CHANGES FROM FY 1987 AMENDED BUDGET

The FY 1987 amended budget is increased a net amount of $5.5 million. As a result of Congressional direction, this includes a $15.5 million increase to fund preliminary definition and planning activities for payloads to be flown on the Space Station. Initial activities include definition of science requirements, work on science operations concepts, and initiation of payload definition and design, including necessary support for science selection processes. This increase is offset by a reduction of $10.0 million in Shuttle/Spacelab Payload Development and Mission Management. This reduction reflects deferral of planned activities due to the delay in shuttle launches.

BASIS OF FY 1988 ESTIMATE

Mission management of ongoing Spacelab missions will continue in FY 1988. For non-physics and astronomy missions, such as the Spacelab Life Sciences missions (SLS) and the International Microgravity Lab (IML), this includes all spacelab efforts except instrument development and data analysis. Development of instruments will continue for the Space Plasma Lab as well as for the Shuttle High Energy Astrophysics Lab. For the Astro-1 mission, final integration and test activities will resume, in preparation for a planned flight in early 1989. FY 1988 funding will support the continued develoment of low-cost sounding rocket class payloads which will be flown on the Space Shuttle to provide more flight opportunities for the science community.

In addition, FY 1988 funding is required to continue ongoing Space Station payload development and planning activities. FY 1988 funding will support continued early definition, design and development activities for payloads selected for early Space Station flights. Other planning activities will address concerns or issues that typically cut across OSSA disciplines, and will include continued science operations concept development, information systems concept and architecture studies, servicing studies, platform utilization studies as well as other special systems engineering and integration support studies.

BASIS OF FY 1988 FUNDING REQUIREMENT

EXPLORER DEVELOPMENT

	1986 Actual	1987 Amended Budget	1987 Current Estimate	1988 Budget Estimate
		(Thousands of Dollars)		
Cosmic background explorer.............	24,700	16,700	31,500	16,000
Extreme ultraviolet explorer...........	13,700	32,400	14,700	31,400
Roentgen satellite experiments.........	2,200	1,500	2,700	2,500
Combined release and radiation effects satellite............................	3,300	2,200	2,200	2,200
Heavy nuclei collector.................	1,700	1,300	---	---
Other exlorers.........................	2,600	2,600	2,600	2,800
Solar-A (formerly HESP)................	---	---	3,000	5,400
Total................................	48,200	56,700	56,700	60,300
Mission operations and data analysis...	(17,200)	(23,100)	(21,400)	(22,400)

OBJECTIVES AND STATUS

Investigations selected for Explorers are usually of an exploratory or survey nature, or have focused specific objectives not requiring the capabilities of a major observatory. Past Explorers have discovered radiation trapped within the Earth's magnetic field, investigated the solar wind and its interaction with the Earth, studied upper atmosphere dynamics and chemistry, mapped our galaxy in radio waves and gamma-rays, and determined the properties of the interstellar medium through ultra-violet obgervations.

Recent Explorers have performed active plasma experiments on the magnetosphere, made in-situ measurements of the comet Giacobinni-Zinner, and completed the first high sensitivity, all sky survey in the infrared, discovering over 300,000 sources.

Explorers under development will study the properties of the cosmic microwave background which is important for understanding the early universe and cosmology, survey the sky in the extreme-ultraviolet for the first time, and measure time variable phenomena in x-ray sources. These data elements have proven to be some of the most important signatures of the nature of these phenomena.

The Explorer program also provides a means of implementing instruments on "target of opportunity" missions, such as those involving international collaboration, or other Federal agencies.

Solar-terrestrial and atmospheric Explorers provide a means for conducting studies of the Earth's near space environment. The International Sun Earth Explorer (ISEE-1977), International Cometary Explorer (ICE-1978), Dynamics Explorer (DE-1981), and Advanced Magnetic Particle Trace Experiment (AMPTE-1984), have provided data on plasmas and fields, near the earth and throughout the interplanetary medium. The ISEE and ICE data sets have directly confirmed, by in-situ observation, magnetic merging in space plasmas, as well as several plasma wave instabilities and kinetic effects which cannot be reproduced in the laboratory. The ICE encounter with Comet Giacobinni-Zinner and the AMPTE artificial comet releases late in 1985 prepared the Halley armada for their historic encounters. The IMP-8 satellite, now almost 13 years old, is the only exising monitor for the solar wind as a plasma input to the geospace environment, and provides a near-earth baseline for missions to the other planets.

Astrophysics explorers have been the principal means for conducting the first sky surveys in the gamma ray, x-ray, ultraviolet, infrared, and low frequency radio regions of the electromagnetic spectrum. The IUE (1978) is still operating, and has shown that our Galaxy has an extended hot halo, that the local interstellar medium is much more transparent and less homogeneous than expected, and determined the spectra of hundreds of hot stars which are losing mass. The IRAS (1983), in nearly a year of operation, performed a complete sky survey over the 10-100 micron region, locating over 300,000 sources. A major discovery is a dust ring around a nearby star, Vega, which is believed to be a proto-planetary nebula. IRAS has also catalogued many new asteroids, discovered properties of star-forming regions in ours as well as external galaxies, and has provided new data on energetics and processes in active galaxies, including quasars.

A number of small or cooperative activities are also included in the Explorer budget. The Heavy Nuclei Collector (HNC), which consists of an array of passive cosmic ray detectors developed for inclusion on the Long Duration Exposure Facility (LDEF), has been cancelled due to budgetary and launch opportunity constraints. Scheduled for launch in 1987 on a Scout expendable launch vehicle, is the San Marco-D mission. A cooperative effort with Italy, this project will include a group of U.S. experiments to study the relationship between solar activity and meteorological phenomena on the Earth. The Cosmic-Ray Isotope Experiment (CRIE) is to be completed for inclusion in the Combined Release and Radiation Effects Satellite (CRRES), an Air Force Mission now scheduled for 1992. The CRRES will also release trace chemicals, whose transport in the magnetosphere can be observed from ground and airborne-based instruments.

In FY 1986, a new cooperative mission called Solar-A (formerly High Energy Solar Mission, HESP), was initiated with the Japanese. Solar-A will be launched in 1991 to study the Sun during the upcoming solar maximum. The U.S. has selected an instrument for this spacecraft, which will relate energetic solar phenomena and dynamic coronal structures seen in hard and soft x-rays to the topology of evolving solar magnetic fields. This will be the first simultaneous observations of these phenomena from space.

In FY 1987, development continues on the Cosmic Background Explorer (COBE), the Extreme Ultraviolet Explorer (EWE), and on the X-ray imaging instrument to be flown on the German Roentgen Satellite (ROSAT). COBE will carry out a definitive, all-sky exploration of the infrared background radiation of the universe between the wavelengths of a micrometer and 9.6 millimeters. Because COBE requires a polar orbit, and the opening of the West Coast Shuttle launch facility has been postponed, the decision was made to launch the COBE spacecraft on a Delta expendable launch vehicle in early 1989, a slip of 9 months from the original launch date of July 1988. Funding in FY 1987 will be used to continue development and testing of the three COBE instruments and to redesign the COBE spacecraft to fit on the Delta vehicle. Design and development also continues on EUVE, which will carry out the first detailed all-sky survey of extreme ultraviolet radiation between 100 and 900 angstroms.

ROSAT, a cooperative project between the Federal Republic of Germany (FRG) and the United States will perform a high resolution imaging survey of the X-ray sky and provide indepth studies on selected objects. The U.S. will provide one of the ROSAT instruments and the launch services; Germany will provide the spacecraft, telescope, and other instruments. The X-ray imaging instrument being provided by the U.S. will be delivered in the second quarter of FY 1987. Although ROSAT *is* currently manifested for a 1994 Shuttle launch, a possible launch on an expendable launch vehicle in late 1989 or early 1990 *is* also under consideration.

Definition and design will continue in FY 1987 on the X-ray Timing Explorer. This mission, the last currently planned major effort in the Explorer line, can be ready for launch as early as 1993. During FY 1986, a "Dear Colleague" letter was issued to obtain proposals for future Explorers. Over 43 were received, and these will be evaluated in FY 1987, but selection for further study will depend on the availability of future launch opportunities for the Explorer program.

CHANGES IN FY 1987 AMENDED BUDGET

Although there is not change in total funding, internal reallocation of funds have been made. Additional funding required for spacecraft modifications to COBE necessary to accommodate the shift to the Delta launch vehicle is offset by a deferral of activities on EUVE. The delay in the ROSAT launch has resulted in additional costs, which have been partially offset by the cancellation of the Heavy Nuclei Collector (HNC) experiment. Solar-A was initiated as a target of opportunity.

BASIS OF FY 1988 ESTIMATE

During FY 1988, the reconstruction, integration and test of the COBE spacecraft structure and its instruments will be completed, and the spacecraft will begin pre-launch preparations. The major activity will be on the EWE development. Activities on ROSAT , and the development of the U.S. instrument for the Japanese Solar-A will also continue.

BASIS OF FY 1988 FUNDING REQUIREMENT

MISSION OPERATIONS AND DATA ANALYSIS

	1986 Actual	1987 Amended Budget	1987 Current Estimate	1988 Budget Estimate
		(Thousands of Dollars)		
High energy astronomy observatory extended mission....................	4,300	3,500	3,800	3,000
Solar maximum mission extended mission............................	3,200	8,500	8,500	9,000
Solar maximum mission retrieval/repair	3,100	---	---	---
Hubble space telescope operations.....	55,800	44,500	47,000	51,600
Hubble space telescope maintenance and refurbishment.......................	28,100	46,100	45,000	42,100
Explorers............................	17,200	23,100	21,400	22,400
Total..............................	111,700	125,700	125,700	128,100

OBJECTIVES AND STATUS

The purpose of the mission operations and data analysis effort is to conduct operations and analyze data received from physics and astronomy spacecraft after launch. The program also supports the operation of a number of spacecraft after their originally planned objectives have been achieved, for purposes of conducting specific investigations that have continuing, high scientific significance. The funding supports the data analysis activities of the many investigators at universities and other research organizations associated with astrophysics and solar terrestrial operational satellite projects. Actual satellite operations, including control centers and related data reduction and engineering support activities, are typically carried out under a variety of mission support or center support cohtracts.

In addition to the normal support required for mission operations, the Hubble Space Telescope program encompasses several unique aspects which must be provided for in advance of the launch. The Hubble Space Telescope is designed to operate for more than a decade, using the Space Shuttle/Orbital Maneuvering Vehicle combination and/or Space Station for on-orbit maintenance of the spacecraft and in-orbit changeout or repair of the scientific instruments.

The Hubble Space Telescope will be used primarily by observers selected on the basis of proposals submitted in response to periodic solicitations. Science operations will be carried out through an independent Hubble Space Telescope Science Institute. The Institute will operate under a long-term contract with NASA. While NASA will retain operational responsibility for the observatory, the Institute will implement NASA policies in the area of planning, management, and scheduling of the scientific operations of the Hubble Space Telescope.

CHANGES FROM FY 1987 AMENDED BUDGET

Although total funding remains unchanged, funding reallocations have been made within the program elements. Hubble Space Telescope Operations was increased by $2.5 million and Hubble Space Telescope Maintenance and Refurbishment was reduced by $1.1 million. These changes were made to take advantage of the opportunity for additional hands-on access for testing and for launch preparations to the spacecraft. Significant enhancements to on-orbit operating efficiency and development of operations capabilities originally scheduled for the post-launch period will be accelerated and achieved during the program stretchout. The $1.7 million reduction in the Explorer funding requirement is the result of delayed launches caused by the Shuttle accident.

BASIS OF FY 1988 ESTIMATE

The FY 1988 funding level is requried to maintain critical skills for the operation and maintenance of the Hubble Space Telescope, and to prepare for launch activities in the first quarter of FY 1989.

Mission operations, data analysis, and guest investigator programs will continue for the Solar Maximum Mission (SMM) and the International Ultraviolet Explorer (IUE). Funding will also continue for the High Energy Astronomical Observatories (HEAO 1-3), and the Infrared Astronomy Satellite (IRAS) data analysis. These programs have produced valuable data sets which are used by a wide segment of the astronomy community.

BASIS OF FY 1988 FUNDING REQUIREMENT

RESEARCH AND ANALYSIS

	1986 Actual	1987 Amended Budget	1987 Current Estimate	1988 Budget Estimate
		(Thousands of Dollars)		
Supporting research and technology.....	28,600	36,500	39,800	46,500
(Gravity Probe-B Definition)...........	(7,500)	(9,000)	(9,000)	(16,000)
Advanced technology development........	14,700	14,600	13,600	13,600
Data analysis..........................	5,700	---	---	---
Total................................	49,000	51,100	53,400	60,100

OBJECTIVES AND STATUS

This program provides for the preliminary studies required to define missions and/or payload requirements, as well as providing a research and technology base necessary to define, plan and support flight projects.

o Supporting Research and Technology (SR&T): The objectives of supporting research and technology are to: (1) optimize the return expected from future missions through scientific problem definition, development of advanced instrumentation and concepts, and sound definition of proposed new missions; (2) enhance the value of current space missions by carrying out complementary and supplementary ground-based observations and laboratory experiments; (3) develop theories to explain observed phenomena and predict new ones; (4) strengthen the technological base for sensor and instrumentation development and conduct the basic research necessary to understand astrophysics phenomena and solar-terrestrial relationships; and (5) the continued acquisition, analysis and evaluation of data from laboratories, balloons, rocket and spacecraft activities.

Research is supported in the disciplines of astronomy, astrophysics, gravitational physics, and solar and heliospheric physics. Research in astronomy and astrophysics involves the study of stars, galaxies, interstellar and intergalactic matter, and cosmic rays. The work in solar and heliospheric physics involves the study of the solar atmosphere, solar flares, and the influence of the Sun on interplanetary phenomena. The theory activities are related to all the Physics and Astronomy disciplines and are critical to the correlation of available information. The SR&T

funding will provide for continuation of definition work on Gravity Probe-B. The development of new instruments, laboratory and theoretical studies of basic physical processes, and observations by ground-based and balloon-borne instruments will also be continued. Results achieved in the SR&T program will have a direct bearing on future flight programs. For example, the development of advanced X-ray, ultraviolet, and infrared astronomy imaging devices under this program may enable spacecraft to carry instruments for astronomical observations which have increased orders of magnitude in sensitivity and improved resolution over currently available detectors.

The SR&T program carries out its objectives through universities, nonprofit and industrial research institutions, NASA centers and other government agencies. Current emphasis is being placed on studies of advanced instrumentation with increased sensitivity and resolution.

- Advanced Technological Development (ATD): The advanced technological development activities support detailed planning and definition of new potential physics and astronomy missions. ATD activities assure that future missions address the scientific questions most important to the evolution of knowledge in the field, and that those missions use the appropriate technology and techniques. Funding is applied to the definition and preliminary design for specific missions or subsystems/elements critical to eventual mission development in order that technical readiness and resources requirements may be adequately defined before the missions are proposed for implementation.

  Candidate missions for the 1980s and early 1990s that require ATD activities include the Advanced X-Ray Astrophysics Facility (AXAF) and the Space Infrared Telesope Facility (SIRTF). The AXAF mission, which is the first priority new mission recommendation in astronomy by the National Academy of Sciences, will study stellar structure and evolution, active galaxies, clusters of galaxies and cosmology. The AXAF's imaging X-ray telescope is planned to have a sensitivity approximately 100 times that of HEAO-2, a resolution increase of nearly a factor of twenty and an increase in wavelength range by a factor of two. The SIRTF will observe faint, cool infrared sources in the universe and will significantly build on the IRAS science foundation. Major Spacelab payloads being considered for future missions and requiring advanced technological development support include the Pinhole/Occulter Facility, a detector for imaging hard X-rays from solar and cosmic sources. During FY 1987, major emphasis will be on completing the AXAF definition and deepening the technological and system understanding of science instruments selected for definition. Technological preparation for SIRTF will also continue.

CHANGES FROM FY 1987 AMENDED BUDGET

The net increase of $2.3 million in research and analysis is a result of an additional $3.3 million to increase data analysis for university research activities, $1.0 million for ATD activities is offset by a $2.0 million reduction in studies for the Shuttle Infrared Telescope Facility as directed by Congress.

BASIS OF FY 1988 ESTIMATE

During FY 1988, the supporting research and technology program will support those tasks which contribute to maintaining a firm base for a viable physics and astronomy program. FY 1988 funding will also support continued studies on potential candidate missions such as the Advanced X-ray Astrophysics Facility and the Space Infrared Telescope Facility. In the data analysis activities to be carried out at university and government research centers in FY 1988, emphasis will be placed on correlative studies involving data acquired from several sources (spacecraft, balloons, sounding rockets, research aircraft and ground observatories). The Gravity Probe-B activities in FY 1988 are designed to verify the entire GP-B design, leading to confidence in the information necessary to decide the feasibility of progressing into the next phase of design and development activities.

BASIS OF FY 1988 FUNDING REQUIREMENT

SUBORBITAL PROGRAMS

	1986 Actual	1987 Amended Budget	1987 Current Estimate	1988 Budget Estimate
		(Thousands of Dollars)		
Sounding rockets......................	23,100	27,700	30,900	32,100
Airborne science and applications......	25,000	24,100	31,600	30,300
Balloon program......................	6,100	7,900	7,900	8,200
Spartan..............................	5,700	4,700	4,700	5,100
Total..............................	59,900	64,400	75,100	75,700

OBJECTIVES AND STATUS

The suborbital program uses balloons, aircraft, and sounding rockets to conduct versatile, relatively low cost research of the Earth's ionosphere and magnetosphere, space plasma physics, stellar astronomy, solar astronomy, and high energy astrophysics. Activities are conducted on both a national and on an international cooperative basis.

o Sounding Rockets:

A major objective of the sounding rocket program is to support a coordinated research effort. Sounding rockets are uniquely suited for performing low altitude measurements. (between balloon and spacecraft altitude) and for measuring vertical variations of many atmospheric parameters. Special areas of study supported by the sounding rocket program include the nature, characteristics, and composition of the magnetosphere and near space; the effects of incoming energetic particles and solar radiation on the magnetosphere, including the production of aurorae and the coupling of energy into the atmosphere; and the nature, characteristics, and spectra of radiation of the Sun, stars and other celestial objects.

Additionally, the sounding rocket program provides the physics and astronomy program with the means for flight testing instruments and experiments being developed for later flight on the Shuttle/Spacelab and space probes and for calibrating and obtaining vertical profiles in concert with current orbiting spacecraft.

Forty-four rockets are currently scheduled for launch in FY 1987. Included in this number are eight NASA launches in Greenland as a follow-up to the FY 1985 effort. Of significant interest in FY 1986 were two rocket launches to observe Halley's Comet which were recovered, field refurbished, and reflown for a total of four flights. These flights produced some of the data originally planned to be obtained from the Astro-1 Shuttle flight which was postponed as a result of the 51-L accident. An equivalent number of flights is scheduled for FY 1988.

o Airborne Science and Applications:

Research with instrumented jet aircraft has been an integral part of the NASA physics and astronomy program since 1965. For astronomy research, the airborne science and applications program operates the "Kuiper Airborne Observatory." This full-scale manned facility consists of a C-141 equipped with a 91-centimeter infrared telescope. The C-141 aircraft, able to fly for several hours at altitudes approaching 13 kilometers, provides a cloud-free site for astronomical observations. The ability to carry out observations at this altitude, above most of the infrared-absorbing water vapor in the Earth's atmosphere, has been essential in expanding astronomical observations into the infrared region of the electromagnetic spectrum from one micrometer to hundreds of micrometers.

In FY 1986, the C-141 flew 73 science flights to make far-infrared observations, including exploration of the star-forming regions and of other areas in our own galaxy and solar system. An expedition to New Zealand in the spring provided the only detailed study of infrared emissions from Comet Halley as it became visible shortly after perihelion. In FY 1987, about 70 missions are planned, including five flights from Hawaii, and a planned expedition to make celestial observations from the southern hemisphere. FY 1987 activities also include initiation of a study to develop and evaluate alternatives for developing a stratospheric observatory for infrared astronomy (SOFIA) as a potential follow-on for the C-141 in the 1990's. SOFIA would incorporate a 3-meter class infrared telescope mounted in a suitable aircraft, presumably a Boeing 747.

The Airborne Science and Applications program also operates an ER-2, two U-2Cs, and a C-130. In addition, an aircraft has been acquired to replace the CV-990 research facility, "Galileo II", which was destroyed in 1985. The replacement, a DC-8, is undergoing modifications and is expected to be ready for science operations in late 1987. Acquisition of a second ER-2, to replace the aging U-2Cs is under way. These aircraft support other major segments of the Space Science and Applications programs dealing with the earth, the oceans, and the atmosphere. They may serve as test beds for newly developed instrumentation and allow demonstration of new sensor techniques before their flight on satellites or on Shuttle/Spacelab missions. Data obtained from these aircraft are used to refine analytical algorithms, and to develop ground data handling techniques. For example, the ER-2/U-2Cs acquire stratospheric air samples and conduct in-situ measurements at altitude ranges above the capability of more conventional aircraft and below those of orbiting satellites. This capability is important in gaining an understanding of stratospheric transport mechanisms.

- Balloon Program:

  The Balloon Program provides a cost-effective means to test flight instrumentation in the space radiation environment and for making observations at altitudes which are above most of the water vapor in the atmosphere. Balloon experimentation is particularly useful when studying infrared, gamma-ray, and cosmic-ray astronomy. In many instances it is necessary, because of size, weight, cost, or lack of other opportunities, to fly primary scientific experiments on balloons.

  In addition to the level-of-effort science observations program, significant emphasis has been and will be placed on development of a balloon capable of lifting more than 3500 pounds, and to realize missions lasting several days.

  The balloon program funding is required for purchase of balloons, helium, launch services, tracking and recovery, as well as for maintenance and operations of the National Scientific Balloon Facility (NSBF) at Palestine, Texas. This facility supports the launch of about 80 percent of NASA's balloon payloads, and it is the Nation's primary means for carrying out large scientific balloon operations. Funding for the experiments flown on balloons is provided from other research and technology programs supporting the various scientific disciplines.

- Spartan Program:

  The Spartan missions involve low-cost Shuttle payloads flown as autonomous sub-satellites which are deployed and retrieved by the Space Shuttle. Six Spartan missions are currently under development, each with a different scientific instrument. Spartans allow the accomplishment of single, specific scientific objectives with efficiency and simplicity. The first Spartan flew successfully in 1985. It obtained valuable, new x-ray data on the nuclear region of our own galaxy and on the vast cluster of galaxies in the constellation Perseus. Detailed analysis of this data is continuing. The second Spartan, Spartan Halley, was lost with the Challenger. A third Spartan mission, manifested for FY 1991, will consist of a 17-inch diameter solar telescope with an ultraviolet coronagraph and a white light coronagraph to measure the intensity and scattering properties of solar light.

CHANGES FROM FY 1987 AMENDED BUDGET

$3.2 million was added to the sounding rocket program as part of the effort to augment ground based and suborbital investigations to sustain the vitality of the scientific research base during the Shuttle recovery period. The $7.5 million net increase in the Airborne Science and Applications program includes $5.0 million to be applied to acquisition/modification costs for the DC-8, $3.0 million to initiate replacement of the aging U-2C aircraft, $0.5 million for a feasibility study for a potential new airborne infrared telescope, and a reduction of $1.0 million in aircraft operations.

BASIS OF FY 1988 ESTIMATE

FY 1988 funds will provide for continuation of the sounding rocket, Spartan, and balloon programs including management and operation of the NSBF. This funding is also required to continue definition activities for balloon improvement and for potential long-duration balloon flights. In FY 1988, the Airborne Science and Applications funding will be used to continue flights of the Kuiper Airborne Observatory. Requested FY 1988 funding will allow operation of the DC-8, the ER-2's, and the C-130. Operation of these aircraft will allow continuation of airborne infrared astronomy exploration, collection and analysis of stratospheric air samples, testing of newly developed instrumentation, and the demonstration of new sensor concepts.

LIFE SCIENCES

RESEARCH AND DEVELOPMENT

FISCAL YEAR 1988 ESTIMATES

BUDGET SUMMARY

OFFICE OF SPACE SCIENCE AND APPLICATIONS — LIFE SCIENCES PROGRAM

SUMMARY OF RESOURCES REQUIREMENTS

	1986 Actual	1987 Amended Budget	1987 Current Estimte	1988 Budget Estimate	Page Number
		(Thousands of Dollars)			
Life sciences flight experiments......	32,100	31,700	30,400	32,900	RD 4-4
Research and analysis.................	34,000	38,000	41,800	41,700	RD 4-6
Total.............................	66,100	69,700	72,200	74,600	

Distribution of Program Amount By Installation

	1986 Actual	1987 Amended Budget	1987 Current Estimte	1988 Budget Estimate
Johnson Space Center..................	21,071	23,359	23,359	23,904
Kennedy Space Center..................	2,586	2,496	2,496	2,601
Goddard Space Flight Center,..........	380	215	215	215
Jet Propulsion Laboratory.............	1,202	1,016	1,016	1,016
Ames Research Center..................	27,317	28,157	30,657	32,379
National Space Technology Laboratories	40	50	50	50
Langley Research Center...............	525	390	390	400
Marshall Space Flight Center..........	60	110	110	---
Headquarters..........................	12,919	13,907	13,907	14,035
Total.............................	66,100	69,700	72,200	74,600

PROGRAM OBJECTIVE AND JUSTIFICATION

The goals of the Life Sciences program are to provide a sound scientific, medical, and technical basis for safe and effective manned space flight, and to advance the understanding of the basic mechanisms of biological processes by using the unique capabilities of the space program. Results from the research program are applied to: the immediate needs in the maintenance and health of the astronauts; understanding biological mechanisms and the response of biological systems to weightlessness; the design of the advanced life support systems for use on future missions; and understanding the biosphere of the planet Earth, as well as the origin, evolution, and distribution of life in the universe.

The Life Sciences program is the key to developing a capability to sustain a permanent manned presence in space and to utilize the space environment to study living systems. These activities include both ground-based and space research efforts which are mutually supportive and integrated, and use a composite of disciplines and techniques in both biology and medicine to address space-related medical problems and fundamental biological processes.

The Life Sciences research and analysis program includes five major elements: 1) space medicine, which is focused on the health and well-being of space crews by understanding and preventing any adverse physiological changes which occur in space flight and upon return to earth; 2) advanced life support systems, which is a program of research and technology development for life support systems necessary to maintain life in space autonomously for long periods of time; 3) gravitational biology, which consists of flight and ground-based experiments that focus on using microgravity as a biological research tool to understand basic mechanisms of the effects of microgravity on plants and animals; 4) exobiology research, which is directed toward understanding the origin and distribution of life and life-related molecules on Earth and throughout the universe; and 5) biospheric research, which is directed toward understanding the interaction between life on Earth and its physical and chemical environment.

The goals of the Space Medicine program are to assure space crew members' health and ability to function effectively in the space environment. In the future, experience gained from medical operations in space flight will allow a broader segment of the population to participate in all aspects of space missions. Particular emphasis is being placed on testing countermeasures designed to prevent physiological problems associated with exposure to the space environment. It is essential that long-term monitoring of space flight crews be performed in a standardized and organized fashion in order to develop risk factors and establish the long-term clinical significance associated with repeated exposure to the space environment. In addition, biomedical research is designed to understand the physiological basis for problems encountered in manned space flight. Areas of emphasis include: vestibular dysfunction, cardiovascular deconditioning, immunology, bone and muscle loss, and radiation damage. This research concentrates on trying to define potential flight protocols and countermeasures, first as space flight experiments and ultimately on an operational basis.

The Advanced Life Support System program seeks ways to develop technologies for more efficient life support systems for the space program. It also undertakes the scientific work in chemistry and biology necessary to understand how life can be maintained in closed systems which receive only energy from the external environment. All are aimed at potential future needs of long duration manned space flight and lunar colonization.

The goals of the Gravitational Biology program are to further our understanding of basic physiological mechanisms and the effects of microgravity on plants and animals through the use of the space environment. Research, which includes both ground-based and space flight experiments, is focused on clarifying gravity-sensing systems; the effects of microgravity on reproduction, development, physiology, and behavior; and gravity's influence on the evolution of life on Earth. These studies are aimed at providing information essential to the long-term survival of plants and animals in space as well as an understanding of gravity's past and present effect on life.

The Exobiology efforts are concentrated on studies of life's origin, with particular emphasis on developing sound hypotheses which could lead to discovering the relationships which may link the formation of the solar system and the origin of life. Ground-based research on model systems and analysis of extraterrestrial materials, coupled with the results of planetary flight experiments, are clarifying the mechanisms and environments responsbile for the chemical evolution leading to life's origin. Studies of life's origin and evolution will be extended to enhance our understanding of the interaction of the biota with the Earth's present environment, and thereby provide a more comprehensive picture of life--its past, present, and future.

The Biospherics Research Program seeks to utilize NASA technology in remote sensing, combined with ground-based research and mathematical modeling, to study the biosphere (the thin layer around the Planet that contains all of terrestrial life). The goal of the program is to understand the structure and function of the biosphere in order to understand how global biological processes and planetary properties modify and modulate one another. Knowledge of these interactions will ultimately allow predictions of how the habitability of the Earth can be affected by human activities or natural phenomena.

BASIS OF FY 1988 FUNDING REQUIREMENT

LIFE SCIENCES FLIGHT EXPERIMENTS

	1986 Actual	1987 Amended Budget	1987 Current Estimte	1988 Budget Estimate
		(Thousands of Dollars)		
Life sciences flight experiments......	32,100	31,700	30,400	32,900

OBJECTIVES AND STATUS

The objective of the Life : Flight Experiments progr is to imilate ormation and scientific questions fran the u life sci disci i and translate them into payloads designed to :p the understanding of the basic h mechanisms inv in t t to tlessness The ogr inc udes selection, inition, infl tion, analysi , and ting on me and biological investigations humans, animals and experience indicates that n ly undergo iolog changes in weightlessness. Thus far changes pp ar to be ible upon return t Earth, , many of the d are cally significant and ar not well r Wi weigh exposure beyond ral months, hes changes prove irrevers Shuttle/Spacelab miss suitable for gaining a greater of the r response to weightlessness wh will improve the of several exi problems (e.g., space adaptation syndrome) and will enhance the confidence of imating the physiological q of more sus l exposure (e.g. Space S ion)

Current i include l development life s i s g to b flown on the rs dedicated Life en mission (Space Li Sciences -1 SLS which s scheduled for late 1989 and will centrate on human igations Many of the iments an associated ligh hardware flown on ear Shuttle flights supported d enhanced tl ep s for 1 missions. I add tion, experiment developnt activities are currently underwa to support l ght f i Internationa Microgravity t (IML-1) mission in early 1990. Human l experiments, p investigat and anima s hardware test and checkout are planned.

The igations pl for SLS and IML-1 explore tl known prob of manned space ight through the use of t human and l j and also ude key inv in gravitational bi ipal investigator will examine cardiovascular adaptation, space tat syndr muscle bone demineralization, early anemia in and the effects of i ess on l t and animal developnt. The SLS-1 i ll be unique in several respects: it will be the first Shuttle/Spacelab mission dedicated entirely to life sciences, and will involve highly skilled scientists as payload specialists, thus permitting the use of numerous experimental techniques and procedures never before utilized in space.

In addition to the preparation and flight of previously selected experiments, increasing activity and emphasis will be directed towards the study and definition of experiments which can be conducted on the Space Station.

CHANGES FROM THE FY 1987 AMENDED BUDGET

The decrease of $1.3 million represents a reallocation from Flight Experiments to Research and Analysis, for a definition effort of an orbiting Health Maintenance Facility for potential use in the Space Station.

BASIS OF FY 1988 ESTIMATE

FY 1988 funding is required for the final preparation and flight of approved experiments and the continued definition and development of new experiments and hardware that will be flown on future Spacelab/Shuttle missions - i.e., Shuttle middecks, Japanese-J mission, the second dedicated life sciences mission (SLS-2), German D-2 mission, IML-2, and SLS-3. The selection of new experiments through the Announcement of Opportunity (AO) process is continuing. In addition, increasing activities are planned to support the development of Space Station Life Sciences experiments.

BASIS OF FY 1988 FUNDING REQUIREMENT

RESEARCH AND ANALYSIS

	1986 Actual	1987 Amended Budget	1987 Current Estimate	1988 Budget Estimate
		(Thousands of Dollars)		
Life sciences research and analysis...	34,000	38,000	41,800	41,700

OBJECTIVES AND STATUS

The research and analysis activity of the Life Sciences program is concerned with ground-based and pre-flight research in basic biology and in those medical problem areas that affect manned spaceflight. The program is comprised of five elements: (1) space medicine; (2) advanced life support systems research; (3) gravitational biology; (4) exobiology; and (5) biospheric research.

The Life Sciences Space Medicine program is responsible for bringing the technology and practice of medicine to bear on solving the problems of sustaining, supporting, and protecting individuals working in the space environment. The program provides the means for assuring the physical welfare, performance, and adequate treatment of in-flight illnesses or injuries to spaceflight crews. Such conditions as spatial disorientation, fluid shifts and endocrine changes which can decrease performance, cardiovascular tolerance, and possibly aggravate latent diseases, will be carefully evaluated to determine preventive measures. To this end, careful medical selection, periodic evaluation of health status, and in-flight monitoring of the time required for adaptation to the space environment will be continually undertaken. The supporting applied science element of the space medicine program is accomplished through a biomedical research program and seeks to develop the basic medical knowledge needed to enable men and women to operate more effectively in space. The program is organized into discrete elements, each designed to rectify a particular physiological problem known or expected to affect the human organism in space. Such problems as motion sickness, bone loss, and electrolyte imbalances are under intense scrutiny not only to provide a better understanding of their underlying causes, but also to develop more effective preventive measures. The program will make extensive use of ground-based simulation techniques which evoke, in both humans and animals, physiological changes similar to those seen in space.

The Advanced Life Support Systems research program concentrates on enhancing our ability to support a long-duration manned presence in space and optimizing the productivity of the Space Transportation System (STS) crews. Improvements are sought in spacecraft habitability and man-machine system engineering methods as well as a means to provide air, water, and food to support life directly. The program has developed technology for building apparatus to regenerate spacecraft air and water supplies in flight and is investigating the scientific basis for new systems such as food recycling for long-term missions. Research is in progress on space suits for quick reaction situations and on innovative approaches to designing space tools and work stations.

The Gravitational Biology program explores the role of gravity in life processes and uses gravity as an environmental tool to investigate fundamental biological questions. Specific objectives are to: (1) investigate and identify the role of gravity in plant and animal behavior, morphology and physiology; (2) identify the mechanisms of gravity sensing and the transmission of this information within both plants and animals; (3) identify the interactive effects of gravity and other stimuli (e.g., light) and stresses (e.g., vibration and disorientation) on the development and metabolism of organisms; (4) use gravity to study the normal nature and properties of living organisms; and (5) extend the limits of knowledge about plant and animal growth as well as long-term survival and reproduction in space.

The Exobiology program is directed toward understanding the origin and evolution of life, and life-related molecules, on Earth and throughout the universe. Research encompasses the cosmic history of the biogenic elements, prebiotic chemistry, early evolution of life, and evolution of advanced life. Understanding these processes in the context of the planetary and astrophysical environments in which they occurred will be emphasized. Flight experiments on planetary missions and in Earth orbit are important program elements. Theoretical and laboratory investigations are also included in this program to develop a better understanding of the conditions on Earth as related to early chemical and biological evolution.

The Biospheric Research program explores the interaction between the biota and the contemporary environment to develop an understanding of global bio-geochemical cycles. Laboratory and field investigations are correlated with remote sensing data to characterize the influence of biological processes in global dynamics. Biospheric modelling efforts are focused on integrating biology with atmospheric, climate, oceanic, terrestrial, and bio-geochemical cycling data to reflect the state of the biosphere as a function of both natural and anthropogenic perturbations.

CHANGES FROM FY 1987 AMENDED BUDGET

The increase of $3.8 million is the result of several actions; $1.3 million has been reallocated from Flight Experiments to Research and Analysis for a definition effort for an orbiting Health Maintenance Facility for potential use in the Space Station, $0.5 million has been added to restore funding for the Search for Extraterrestrial Intelligence program to the FY 1986 level, and $2.0 million was added to fund innovative methods of conducting experiments.

BASIS OF FY 1988 ESTIMATE

The Space Medicine program will collect infomtion on occupational exposures in zero-gravity on each Shuttle flight and conduct inflight clinical testing of countermeasures, especially in the areas of cardiovascular deconditioning, vestibular problem and rmscle atrophy. The program will also develop health care procedures, equipment, and facilities compatible with the space environment. Medical selection standards will continue to be reviewed with an aim of gradually mking space flight opportunities available to more of our population. The biomedical research element will begin to expand its research on physiological changes associated with longer exposure to weightlessness. Bone demineralization, rmscle atrophy and cardiovascular deconditioning will be studied so that appropriate countermeasures can be devised. At the same time, problem associated with the initial adaptation to weightlessness, such as vestibular dysfunction and fluid shifts, will continue to be vigorously investigated. Furthermore, increased emphasis will be placed on radiation biology so that it will be possible to precisely measure dosages and effects of cosmic and solar radiation. This infomtion will be required to determine the proper radiation shielding of humans in space. The performnce and efficiency of flight crews will be emphasized by research in psychology and human factors.

The Advanced Life Support System program will continue to investigate basic biological processes and physical methods to control the interior environments of mnned spacecraft, and will continue development of data acquistion systems and computer technologies to analyze and simulate human physical activities. Laboratory plant growth methods developed in recent years will be scaled up to obtain a capability to produce plant material at efficiency and productivity levels high enough for space life support applications.

The Gravitational Biology program will focus on expanding the investigation of plant and animl gravity sensing systems and gravitational affects on plant and animl reproduction and developnent. Research which leads to or includes space flight experiments will be emphasized with the objective of resolving discrete biological problem.

The Exobiology program will emphasize the developnent of new flight experiment concepts to clarify the non-biological mechanism for the synthesis of biologically significant molecules in space, and completing definition of system required before a search for extraterrestrial life can be initiated. These concepts will be crucial to our understanding of the origin of life on earth as well as assessing the possibility of these processes occurring elsewhere in the universe.

The Biospheric Research program will place emphasis on improving estimting techniques for determining the functional and structural state of the terrestrial biomass by combining ground-based measurements with remote sensing data. Additional emphasis will be placed on characterizing biogenic gas fluxes of key atmospheric constituents. This information is required for the development of a better understanding of global bio-geochemical cycles.

Emphasis will also be placed on the formulation of improved approaches to the operational management of space adaptation syndrome. In-flight evaluation of these approaches will be conducted to provide the basis for the development of more effective countermeasures. There will be an expanded interdisciplinary approach to determining how to enhance the capabilities, performance and efficiency of spaceflight crews. The object of this effort will be to allow humans, to the fullest extent possible, the opportunity to explore and work in space by improving the working environment and by facilitation of the human interaction with the automated devices that can be placed at their disposal.

PLANETARY
EXPLORATION

RESEARCH AND DEVELOPMENT

FISCAL YEAR 1988 ESTIMATES

BUDGET SUMMARY

OFFICE OF SPACE SCIENCE AND APPLICATIONS — **PLANETARY EXPLORATION PROGRAM**

SUMMARY OF RESOURCES REQUIREMENTS

	1986 Actual	1987 Amended Budget	1987 Current Estimte	1988 Budget Estimte	Page Number
	(Thousands of Dollars)				
Galileo developnent....................	64,200	77,000	71,200	55,300	RD 5-5
Magellan............................	120,300	69,700	92,600	59,600	RD 5-7
Ulysses..	8,800	24,000	10,300	10,800	RD 5-9
Mars Observer..........................	33,800	62,900	35,800	29,300	RD 5-11
Mission operations and data analysis..	67,000	77,200	80,000	77,000	RD 5-13
Research and analysis.................	59,500	63,500	68,500	75,300	RD 5-15
Total..............................	353,600	374,300	358,400	307,300	

Distribution of Program Amount by Installation

	1986 Actual	1987 Amended Budget	1987 Current Estimte	1988 Budget Estimte
Johnson Space Center..................	10,024	10,873	10,639	10,937
Marshall Space Flight Center..........	169	8	72	75
Goddard Space Flight Center...........	5,279	11,884	11,852	8,688
Jet Propulsion Laboratory.............	280,376	294,514	268,576	225,966
Ames Research Center..................	13,157	15,287	18,932	16,400
Langley Research Center...............	23	26	24	25
Headquarters..........................	44,572	41,708	48,305	45,209
Total..............................	353,600	374,300	358,400	307,300

PROGRAM IVES AND I(

The Planetary Exploration program encompasses the scientific exploration of the solar system including the planets and their satellites, comets and asteroids, and the interplanetary medium. The program objectives are: (1) to determine the nature of planets, comets, and asteroids as a means for understanding the origin and evolution of the solar system; (2) to understand the Earth better through comparative studies with the other planets; (3) to understand how the appearance of life in the solar system is related to the chemical history of the solar system; and, (4) to provide a scientific basis for the future use of resources available in near-Earth space. Projects undertaken in the past have been highly successful. The strategy that has been adopted calls for a balanced emphasis on the Earth-like inner planets, the giant gaseous outer planets, and the small bodies (comets and asteroids). Missions to these bodies start at the level of reconnaissance to achieve a fundamental characterization of the bodies, and then proceed to levels of more detailed study.

The reconnaissance phase of inner planet exploration, which began in the 1960's, is now virtually completed, although we still know little about the nature of the planet Venus' surface. Mars has provided program focus because of its potential as a site of biological activity. The Viking landings in 1976 carried the exploration of Mars forward to a high level of scientific and technological achievement, thereby setting the stage for the next step of detailed study. Analyses of meteorites and the lunar rock samples returned by Apollo continue to be highly productive, producing new insights into the early history of the inner solar system and thus leading to revision of our theoretical concepts. The Pioneer Venus mission is continuing to carry the study of the Earth's nearest planetary neighbor and closest planetary analog beyond the reconnaissance stage to the point where we have now obtained a basic characterization of Venus' thick, massive atmosphere, as well as fundamental data about the formation of the planet.

The exploration of the giant outer planets began relatively recently. The Pioneer-10 missions to Jupiter in 1973 and 1974 were followed by the Voyager-1 and 2 spacecraft encounters in 1979. Voyager-1 then encountered Saturn in November 1980, and Voyager-2 in August 1981. The Voyager data on these planets, their satellites, and their rings have revolutionized our concepts about the formation and evolution of the solar system. Voyager-2 encountered Uranus in January 1986 and has provided our first look at this giant outer planet. Its trajectory is carrying it to an encounter with the planet

Neptune in 1989. The Pioneer-10 and 11 and Voyager-1 spacecraft are on trajectories heading out of the solar system, as they continue to return scientific data about the outer reaches of the solar system.

Both the Galileo orbiter/probe mission to Jupiter and the Ulysses mission to the Sun had been ready for launch in May 1986 on the Space Shuttle/Centaur Upper Stage. The Challenger accident in January 1986 forced a postponement of these launches and subsequent cancellation of the Centaur launch stage resulted in further re-evaluations of these missions. The Magellan mission was also adjusted to accommodate a one-year launch delay caused by the Challenger accident and cancellation of the original Centaur upper stage.

Present plans now call for Galileo to be launched on a Shuttle/Inertial Upper Stage (IUS) combination in the 1989-1990 timeframe. The comprehensive science payload will extend our knowledge of Jupiter and its system of satellites well beyond the profound discoveries of the preceding Voyager and Pioneer missions. During twenty-two months of operation in the Jovian system, Galileo will inject an instrumented probe into Jupiter's atmosphere to make direct analyses, while the orbiter will have the capability to make as many as ten close encounters with the Galilean satellites.

Ulysses is a joint NASA and European Space Agency activity. The mission will carry a package of experiments to investigate the Sun at high solar latitudes that cannot be studied from the Earth's orbit. Ulysses will be launched in the 1989-1990 timeframe using the Shuttle and IUS/PAM-S launch stages.

Magellan, formerly the Venus Radar Mapper mission, will provide global maps of the cloud-shrouded surface of Venus, including its land forms and geological features. Using a synthetic aperture radar to penetrate the planet's opaque atmosphere, Magellan will achieve a resolution sufficient to identify small-scale features and to address fundamental questions about the origin and evolution of the planet. Magellan will also obtain altimetry and gravity data to determine accurately the planet's gravity field as well as internal stresses and density variations. With these data, the evolutionary history of Venus can be compared with that of the Earth. Magellan now is scheduled for launch in April 1989 from the Shuttle with an IUS.

Mars Observer will follow up on the earlier discoveries of Mariner 9 and Viking and will emphasize the geologic and climatic evolution of this complex planet. Mars Observer will utilize a modified Earth-orbiting spacecraft, thereby benefitting from aerospace industry's earlier investment in development.

Beginning in late 1985, we entered an exciting new phase of exploration by making our first close-up studies of the solar system's mysterious small bodies -- comets and asteroids. These objects may represent unaltered original solar system material, preserved from the geological and chemical changes that have taken place in even small planetary bodies. By sampling and studying comets and asteroids, we can begin to make vigorous inquiries into the origin of the solar system itself. These efforts began with the encounter of Comet Giacobini-Zinner by the International Comet Explorer (ICE) spacecraft in September 1985 and continued through our involvement with the 1986 encounters and observations of Comet Halley by U.S. and foreign spacecraft and by intensive studies of the comet from ground-based observatories coordinated through the International Halley Watch. In addition, we are conducting preliminary design and advanced technology for development of a new class of spacecraft, Mariner Mark II. At the same time we are studying a Comet Rendezvous/Asteroid Flyby (CRAF) mission in which this spacecraft would hard-land a probe on the nucleus of an active comet, with potential for close encounters of one or more asteroids en route to the target comet.

The Planetary Exploration program is also founded on a coordinated research and analysis effort. Research and analysis activities will continue to maximize the scientific return from both ongoing and future missions and from such Earth-based activities as lunar sample and meteorite analysis, telescope observations, theoretical and laboratory studies, and instrument definition. This program strives for interdisciplinary coordination among various research groups and for the wide dissemination of scientific results. A close coupling is also maintained between the research programs and planning activities that are undertaken to define the scientific rationale and technology needed for future missions.

BASIS OF FY 1988 FUNDING REQUIREMENT

GALILEO DEVELOPMENT

	1986 Actual	1987 Amended Budget	1987 Current Estimate	1988 Budget Estimate
		(Thousands of Dollars)		
Spacecraft..........................	34,175	39,100	35,100	20,200
Experiments..........................	14,215	17,100	16,100	12,700
Ground Operations....................	15,810	20,800	20,000	22,400
Total............................	64,200	77,000	71,200	55,300
Space transportation system operations	(10,900)	(22,000)	(22,000)	(57,800)

OBJECTIVES AND STATUS

The objective of the Galileo program is to conduct a comprehensive exploration of Jupiter, its atmosphere, magnetosphere, and satellites through the use of both remote sensing by an orbiter and in situ measurements by an atmospheric probe. The scientific objectives of the mission are based on recommendations by the National Academy of Sciences to provide continuity, balance, and orderly progression of the exploration of the solar system.

Current plans call for the orbiter and probe to be launched together in the 1989-1990 timeframe as a single combined payload using a Shuttle/Inertial Upper Stage (IUS) combination on an initial trajectory toward Venus, followed by two Earth swingbys. The three gravitational assists will provide the energy required for a trajectory to Jupiter. When the orbiter arrives at Jupiter it will provide remote sensing of the probe entry site and provide the link for relaying the probe data back to Earth. Twenty-two months of orbital operations will follow during which both Jupiter's surface and the dynamic magnetosphere will be comprehensively mapped. During this time ten close flybys of Jupiter's major satellites are targeted.

The Galileo flight system will be powered by two general purpose heat-source Radioisotope Thermoelectric Generators (RTG's) developed by the Department of Energy. The orbiter will carry approximately 100 kg of scientific instruments and the probe will carry approximately 25 kg of scientific instruments.

During FY **1987,** major activities of the Galileo program will include the implementation of thermal control design modifications to the spacecraft since, in passing Venus, it will be going closer to the Sun than originally planned. In addition, several critical parts changeouts will be made in order to improve the reliability of the spacecraft computers. All the scientific instruments will be updated and recalibrated preparatory to reinstallation on the spacecraft.

CHANGES FROM FY 1987 AMENDED BUDGET

The Amended Budget represented a preliminary estimate based on the recognized overall need for continued development and testing activity across all subsystems €or compatibility with the revised mission plan. The funding also reflected a possible need to provide additional shielding for the Radioisotope Thermoelectric Generators (RTG) to provide blast protection in the event of a Shuttle/Centaur accident. The **$5.8** million decrease in funding reflects the expected decision to discontinue RTG shielding based on analyses that shows little, if any, risk benefit from such shields in the case of the Shuttle/IUS launch, and a rephasing of funding requirements to support a launch in the **1989-1990** timeframe on a "solar cruiser" trajectory.

BASIS OF FY 1988 ESTIMATE

FY 1988 funds will provide for completion of the reassembly, integration and initial testing of the reintegrated spacecraft system. Modification of the flight software and mission operations system will be continued.

BASIS OF FY 1988 FUNDING REQUIREMENTS

MAGELLAN

	1986 Actual	1987 Amended Budget	1987 Current Estimate	1988 Budget Estimate
		(Thousands of Dollars)		
Spacecraft............................	74,965	27,800	58,100	38,300
Experiments...........................	40,823	23,100	25,600	7,900
Ground Operations.....................	4,512	18,800	8,900	13,400
Total..	120,300	69,700	92,600	59,600
Space transportation system operations	(20,200)	(22,000)	(22,000)	(74,700)

OBJECTIVES AND STATUS

The objective of the Magellan mission is to address undamental questions regarding the origin and evolution of Venus through global radar imagery of the planet. Magellan will also obtain altimetry and gravity data to accurately determine the planet's gravity field as well as internal stresses and density variations. The detailed surface morphology of Venus will be analyzed to compare the evolutionary history of Venus with that of the Earth.

The Magellan spacecraft will carry a single major scientific instrument, a synthetic aperture radar, which will be used to obtain high resolution (120 to 200 meter) images of the planetary surface as well as altimetric data. Gravity data will be obtained by processing radio signals from the spacecraft. Spacecraft development is making extensive use of existing designs, technology, and residual hardware; for example, the spacecraft will use an existing spacecraft structure, large antenna, and propulsion components from the Voyager program.

In April 1989, the Magellan spacecraft will be launched by the Shuttle/Inertial Upper Stage (IUS) on a direct trajectory to Venus. Arriving at Venus in July 1990, the spacecraft will perform a retro-propulsive maneuver and enter a near-polar elliptical orbit. After an initial check-out period, the spacecraft will map a major portion of the planet over a 243 day period (one Venus year) with a ground resolution of about 150 meters.

During 1986, the mission was readjusted to accommodate a one-year launch delay caused by the Challenger accident and cancellation of the Centaur upper stage. Good progress was made in initiating the necessary hardware changes. During FY 1987, major activities will include the assembly, testing and delivery of a test version of the radar instrument flight model. Spacecraft assembly and integration of the flight spacecraft will be completed. Also the final design reviews will be held for the mission operations system.

CHANGES FROM FY 1987 AMENDED BUDGET

The Budget Amendment funding level represented a preliminary estimate based on an assessment of the overall requirements compatible with the revised mission plan which assumed an August 1989 launch date. The $22.9 million increase results from redesign efforts required for the radar digital units, acceleration of the launch readiness from August 1989 to April 1989, and the need to procure hardware in place of Galileo spare hardware originally planned to be used by Magellan.

BASIS OF FY 1988 ESTIMATE

In FY 1988, the flight model of the radar instrument will be delivered for integration with the spacecraft and environmental testing will be initiated for the entire system. Integration of the mission operations system will be completed to be followed by initiation of operations testing and training preparatory for launch.

BASIS OF FY 1988 FUNDING REQUIREMENT

ULYSSES

	1986 Actual	1987 Amended Budget	1987 Current Estimate	1988 Budget Estimate
	(Thousands of Dollars)			
Spacecraft	775	10,800	4,800	3,300
Experiments	5,510	8,700	4,000	5,900
Ground Operations	2,515	4,500	1,500	1,600
Total	8,800	24,000	10,300	10,800
Space transportation system operations	(15,600)	(13,200)	(13,200)	(38,000)

OBJECTIVES AND STATUS

Ulysses is a joint mission of NASA and the European Space Agency (ESA). ESA is providing the spacecraft and some scientific instrumentation. The U.S. is providing the remaining scientific instrumentation, the launch, tracking support, and the Radioisotope Thermoelectric Generator (RTG). The mission is designed to obtain the first view of the Sun above and below the plane in which the planets orbit the Sun. The mission will study the relationship between the Sun and its magnetic field and particle emissions (solar wind and cosmic rays) as a function of solar latitude, to provide a better understanding of solar activity on the Earth's weather and climate.

Ulysses was restructured in FY 1981 from a two-spacecraft mission--one provided by the United States and one provided by ESA--to a single ESA spacecraft mission. However, the United States' participation in the program remains substantial. NASA is responsible for five of the nine principal investigator instruments, and three of the four European investigations have U.S. co-investigators.

Because of the Challenger accident and subsequent cancellation of the Centaur upper stage, the Ulysses launch is currently planned for the 1989-1990 timeframe, using the Shuttle and IUS/PAM-S launch stages. During 1986, spacecraft prelaunch testing at the Kennedy Space Center (KSC) was completed, the spacecraft was returned to ESA for storage and the instruments were returned to the investigators for storage and recalibration. Mission design activities were initiated to support the new mission profile and launch date. During 1987, effort will continue on studying the details of the new mission and mission operations planning. Support to ESA will continue in order to make the spacecraft compatible with the new upper stage configuration.

CHANGES FROM FY 1987 AMENDED BUDGET

The Amended Budget represented a preliminary estimate based 'on the recognized overall need for continued support for all subsystems compatible with the revised mission plan. The reduction of $13.7 million reflects the expected decision to discontinue RTG shielding based on analyses that shows little, if any, risk benefit from such shields in the case of the Shuttle/IUS launch and the results from rephasing funding requirements consistent with the revised launch readiness date.

BASIS OF FY 1988 ESTIMATE

FY 1988 funding will provide for completion of the documentation of the new spacecraft/launch vehicle interface, launch approval activities involving the RTG, and support for retesting the spacecraft and the science instruments.

BASIS OF FY 1988 FUNDING REQUIREMENT

MARS OBSERVER MISSION

	1986 Actual	1987 Amended Budget	1987 Current Estimate	1988 Budget Estimate
		(Thousands of Dollars)		
Spacecraft development................	16,185	33,100	11,600	7,800
Experiments..........................	16,390	26,600	22,800	18,100
Ground Operations....................	1,225	3,200	1,400	3,400
Total..............................	33,800	62,900	35,800	29,300
Space transporation system operations	(18,900)	(9,100)	(6,500)	(15,800)

OBJECTIVES AND STATUS

The Mars Observer mission is the first in a series of planetary missions utilizing a new low-cost approach to inner solar system mission exploration. This approach, which was recommended by NASA's Solar System Exploration Committee, starts with a well defined and focused science objective and makes use of high-inheritance, modified production-line Earth-orbital spacecraft. The objective of the Mars Observer mission is to extend and complement the data acquired by the Mariner and Viking missions by mapping the global surface composition, atmospheric structure and circulation, topography, figure, gravity and magnetic fields of Mars to determine the location of volatile reservoirs and characterize their interaction with the Martian environment.

The limitation on the number of launch opportunities through 1990 and the further restrictions placed on scheduling by the timing requirements for planetary launches have necessitated delaying the planned launch of Mars Observer from 1990 until the following planetary opportunity 25 months later. The current plan is to launch the mission in 1992 using the Space Shuttle with a Transfer Orbit Stage (TOS). The spacecraft will be inserted into a near-polar Martian orbit in 1993, from which it will carry out geochemical, geophysical, and climatological mapping of the planet over a period of a full Martian year, which is about two Earth-years.

In FY 1987, it is planned to complete the detailed design of the instrument hardware and to initiate fabrication of the Payload Data Subsystem. Detail design of the spacecraft will be continued.

CHANGES FROM FY 1987 AMENDED BUDGET

The decrease in the current estimate reflects the necessity of delaying the launch date. The reductions have been accommodated by the rephasing of activity to future years.

BASIS OF FY 1988 ESTIMATE

The FY 1988 funding is required to initiate instrument hardware fabrication and assembly and to maintain a minimum level of support in spacecraft and ground operations subsystem developments.

BASIS OF FY 1988 FUNDING REQUIREMENT

MISSION OPERATIONS AND DATA ANALYSIS

	1986 Actual	1987 Amended Budget	1987 Current Estimate	1988 Budget Estimate
		(Thousands of Dollars)		
Ulysses operations....................	---	300	---	---
Voyager extended mission.............	22,100	4,800	2,800	2,800
Pioneer programs.....................	6,a00	a,300	a,300	a,500
Voyager/Neptune mission..............	a,700	30,300	31,a00	26,100
Planetary flight support...	29,400	33,500	37,100	39,600
Total............................	67,000	77,200	a0,000	77,000

OBJECTIVES

The objectives of the mission oi and data ysis i are in flight operation of planetary spacecraft and the analysis f data from tl i Currently two classes of planetary spacecraft are ing--the ioneer and th Voyager spacecraft. The y flight support activities are those associated with the design and development of tary igh i s and other activities that p the mission control, tracking, tel and command functions for all planetary aft.

The two Vo ag spacecraft are now traveling thr the t ar y on trajec that will take into erstel space. Voyager 1 continues to provide data on h interp medium in that dist t of the solar system. In r 1986, Voyager 2 made a s flyby of the planet Uranus, the first time planet has ever been by a spacecraft. he t p of thi encounter, which began in November 1985, included led tions of the u i i and moons. Upon tion of the Uranus encounter, the spacecraft eg its path the planet Neptune, where, in 1989, it will ide us wi ur first close look at this distant planet.

oneers 10 and 11 will i to explor th st solar syst Pioneer 10 11 soon enter the region Pluto where the Sun's influence is secondary t those of true stellar spacecraft will continue the sear for tatic evidence of a ent planet Pioneers 6-9 are i collecting i on the interplanetary i fie and solar wi as they orbit the .

The Pioneer Venus orbiter continues to obtain data on Venus' atmosphere and magnetosphere and its interaction with the Solar Wind. In late 1985, the spacecraft's spin axis was adjusted to allow ultraviolet observations of Comet Halley. The Pioneer Venus was the only spacecraft able to observe the Comet at its closest approach to the Sun and it provided critical enhancements to the data gathered by foreign spacecraft.

The planetary flight support activities include the procurement, operation and maintenance of mission operations and general purpose scientific and engineering computing capabilities at the Jet Propulsion Laboratory (JPL). In addition, the activity supports the development of the Space Flight Operations Center (SFOC) at JPL. This facility will be a versatile, cost-effective means for carrying out multimission data acquisition, telemetry, image processing, and for commanding of planetary and orbital spacecraft.

FY 1987 funding is providing operational support for the Voyager and Pioneer operations, as well as for the extension of the Voyager 2 mission to a 1989 encounter with the planet Neptune. Activities are also continuing in multimission support development activities.

CHANGES FROM FY 1987 AMENDED BUDGET

The net increase of $2.8 million is the result of an increase of $3.6 million in Planetary Flight Support for the development of the Space Flight Operation Center (SFOC), which is needed to support the Magellan mission planned for launch in 1989, partially offset by a reduction in Voyager Extended Mission Operations due to lower than planned requirements for the Voyager-Uranus encounter and a delay in funding for Ulysses Operations. $1.5 million of this savings was reallocated to support initiation of the Voyager/Neptune Mission from the Voyager extended mission activity.

BASIS OF FY 1988 ESTIMATE

FY 1988 funding is required for the continued operation and data analysis activities in support of the Voyager and Pioneer missions. Development activities will also be continued in FY 1988 on the Space Flight Operations Center (SFOC) at the Jet Propulsion Laboratory.

BASIS OF FY 1988 FUNDING REQUIREMENT

RESEARCH AND ANALYSIS

	1986 Actual	1987 Amended Budget	1987 Current Estimate	1988 Budget Estimate
		(Thousands of Dollars)		
Supporting research and technology....	43,100	47,400	46,400	47,900
Advanced programs....................	9,600	10,100	15,200	20,700
Mars data analysis...................	3,100	2,900	2,900	3,700
Halley's comet co-investigations and watch..........................	3,700	3,100	4,000	3,000
Total.............................	59,500	63,500	68,500	75,300

OBJECTIVES AND STATUS

The research and analysis program consists of four elements required to: (1) assure that data and samples returned from flight missions are fully exploited; (2) undertake complementary laboratory and theoretical efforts; (3) define science rationale and develop required technology to undertake future planetary missions; and (4) coordinate an International Halley's Comet Watch and provide co-investigator support to the European Space Agency's Giotto mission to Halley's Comet.

The supporting research and technology activity includes planetary astronomy, planetary atmospheres, planetary geology/geophysics, planetary materials/geochemistry, and instrument definition.

The planetary astronomy activity includes all observations made by ground-based telescopes of solar system bodies, excluding the Sun. Emphasis is on the outermost planets, comets and asteroids. Observations are made at a wide range of wavelengths from ultraviolet to radio. The rate of new discoveries continues to be high, and the data acquired is used both for basic research in support of planetary program objectives and for direct support of specific flight missions. The planetary astronomy funding also provides for the continued operation of the Infrared Telescope Facility in Hawaii.

The planetary atmospheres activity includes data analysis, laboratory, and theoretical efforts. The properties of other planetary atmospheres are amenable to measurement with planetary spacecraft and can aid us in better understanding our own weather and climate. Observations of the atmospheres of

Venus, Jupiter and Saturn, acquired by Pioneer Venus and Voyager, have laid the basic observational groundwork for major advances in this field.

The planetary geology/geophysics activity is a broadly scoped program that includes the study of surface processes, structure, and history of solid canponents (including rings) of the solar system and investigation of the interior properties and processes of all solar system bodies, both solid and gaseous. This program emphasizes canparative studies to gain a fundamental understanding of the physical processes and laws which control the developnt and evolution of all planetary bodies, including the Earth. In this respect, data fran the Magellan mission **will** be of crucial importance.

The planetary materials/geochemistry activity supports an active scientific effort to determine the chemistry, mineral canposition, age, physical properties and other characteristics of solid rmterial in the solar system through the study of returned lunar sanples and meteorites and through laboratory and theoretical studies of appropriate geochemical problem. Extraterrestrial dust grains, collected for analysis, continue to yield new and otherwise unobtainable information about the solar system, and its early history. This program is coordinated with the lunar sample and meteorite research, which is supported by other agencies, such as the National Science Foundation. The operation of the Lunar Curatorial Facility is also supported by the planetary materials/geochemical funding.

The instrument definition activity is directed toward ensuring maximum scientific return from future missions by the definition and developnent of state-of-the-art scientific instrumentation, which are optimized for such missions.

The objective of the advanced program activity is to provide planning and preparation for the systematic exploration of the solar system on a scientifically and technically sound basis. Prospective planetary missions are identified and defined through long-range studies; the technological and fiscal feasibility is evaluated, and the scientific merit is determined through interaction with the scientific community. The strategy for future solar system exploration has been developed by the Solar System Exploration Committee (SSEC), an advisory group, which has recommended a comprehensive program of missions to the inner and outer solar system.

The Mars Data Analysis activity continues to ensure that we capitalize on the wealth of data provided by Viking and earlier missions and that we are scientifically prepared for the next phase of Mars exploration. While continuing to support a variety of scientific investigations, the major emphasis of this program will address the origin and evolution of Martian volatiles.

The International Halley's Comet Co-Investigations and Watch program is part of an international program of cooperative astronomical observations of Halley's Comet. During 1986, support was provided to nearly three dozen U.S. co-investigators on the European Space Agency's (ESA) Giotto mission, and to conducting complementary **remote** sensing investigations carried out with ground based telescopes, aircraft, rockets, and distant spacecraft. Concurrently, an observation program called the International Halley Watch, coordinated by the United States, conducted world-wide scientific observations of the Comet Halley. The objectives of the Watch are: (1) to coordinate scientific observations of Comet Halley through its 1985-1986 apparition; (2) to promote the use of standardized instrunentation and observing techniques; (3) to help insure that data are properly documented and archived; and (4) to receive and distribute data to participating scientists.

CHANGES TO FY 1987 AMENDED BUDGET

Funding in Advanced Programs was increased by $5.1 million to allow for a limited amount of preliminary design and advanced technology associated with the future developnent of the Mariner Mark II class of spacecraft. In addition, $1.0 million was reallocated from supporting research and technology to primarily provide additional support for Halley's Comet co-investigations.

BASIS OF FY 1988 ESTIMATE

During FY 1988, research efforts will continue in the areas of planetary astronomy, planetary atmospheres, planetary geology/geophysics, planetary materials/geochemistry, instrument definition, Mars data analysis, and in the developnt of required technology to undertake future missions. Ground telescope observations will provide data complementary to that obtained fran the flight missions, with emphasis on the outermost planets, comets and asteroids. A variety of efforts will be pursued to improve our understanding of planetary atmospheres, including laboratory studies of reactions in deep planetary and tenuous cometary atmospheres. Geology/geophysics research will be directed, in FY 1988, at specific problem in understanding the various processes that have shaped planetary surfaces, as well as geological analyses and a cartography effort based on the Galilean, Saturnian and Uranian satellite imaging data acquired by Voyager. Analysis of lunar samples, meteorites, and extraterrestrial dust particles will be continued in FY 1988 to determine their chemical and physical properties and thereby derive their origin and evolutionary history. Within Advanced Programs, instrument definition and advanced technology developnt for potential future missions will be also be continued with emphasis on the Mariner Mark II spacecraft.

The FY 1988 Halley's Comet Co-Investigations and Watch funding is required to continue support of U.S. co-investigators involved in the European Space Agency's Giotto mission who will be analyzing and archiving the data acquired during the encounter with Halley's Comet. International Halley Watch funding will support the archiving and distribution of ground-based observations.

The FY 1988 funding is also required to continue operations of both the Infrared Telescope Facility and the Lunar Curatorial Facility.

SOLID EARTH
OBSERVATIONS

RESEARCH AND DEVELOPMENT

FISCAL YEAR 1988 ESTIMATES

BUDGET SUMMARY

OFFICE OF SPACE SCIENCE AND APPLICATIONS — **SOLID EARTH OBSERVATIONS PROGRAM**

SUMMARY OF RESOURCE REQUIREMENTS

	1986 Actual	1987 Amended Budget	1987 Current Estimate	1988 Budget Estimate	Page Number
		(Thousands of Dollars)			
Shuttle/Spacelab payloads.............	21,800	21,600	21,600	21,100	RD 6-3
Geodynamics...........................	30,000	32,100	32,100	33,100	RD 6-4
Research and analysis.................	19,100	20,400	21,900	22,600	RD 6-6
Total...............................	70,900	74,100	75,600	76,800	

Distribution of Program Amount by Installation

	1986 Actual	1987 Amended Budget	1987 Current Estimate	1988 Budget Estimate
Johnson Space Center..................	400	100	100	---
Marshall Space Flight Center..........	285	300	300	400
Goddard Space Flight Center...........	34,778	36,800	37,800	38,200 / 29,200 (overprinted)
Jet Propulsion Laboratory.............	27,175	28,400	28,600	
Ames Research Center..................	743	700	700	700
National Space Technology Laboratories	760	800	900	900
Headquarters..........................	6,559	7,000	7,200	7,400
Kennedy Space Center..................	200	---	---	---
Total...............................	70,900	74,100	75,600	76,800

PROGRAM OBJECTIVES AND JUSTIFICATION

The objectives of the Solid Earth Observations Program are to understand the processes controlling the state of the land surface and the interior of the Earth as well as the interaction of the solid Earth with the atmosphere and the oceans. The Solid Earth Observations Program is an integral part of the overall NASA Earth Science and Applications effort to increase understanding of the planet Earth through the study of its dynamics, the physical processes which affect habitability, and solar-terrestrial environment.

Specific land surface objectives include determination of the terrestrial landscape including the biosphere and the hydrosphere, and understanding the changes and change mechanisms that are occurring within that landscape. Studies of the cycling of key biogeochemical elements, interactions between the biosphere and the climatic system, and the composition and evolution of crustal rock sytems are essential to these objectives.

The geodynamics research objectives include determination of the movements and deformation of the Earth's crust, the processes which drive tectonic plates, the rotational dynamics of the Earth and its interactions with the atmosphere and oceans, the Earth's gravity and magnetic fields, and the interior structure and composition of the Earth. These objectives require precise measurements of crustal movements and Earth orientation over an extended period along with accurate knowledge of the variability of the Earth's geopotential fields.

The objective of the Shuttle/Spacelab payload development project is to develop, test and evaluate Earth-viewing remote sensing instruments and systems to obtain data for solid earth observations research. The Shuttle Imaging Radar, which was flown on the Shuttle in October, 1984, has demonstrated the utility of spaceborne imaging radar for geologic exploration. The Large Format Camera (LFC), required for high resolution mapping applications, was flown successfully on the Shuttle in 1984 and is presently under consideration for commercialization. The next generation Shuttle Imaging Radar, involving use of SIR-B components and a multi-polarized, dual frequency instrument is under development for flight in the early 1990's. The imaging spectraneter and solid-state sensor research efforts will continue to focus on the development of such features as electronic scan, inherent geometric and spectral registration and programmable high spatial and spectral resolution.

; OF FY 1988 FUNDING REQUIREMENT

SHUTTLE/ PAYLOAD (IE Γ

	1986 Actual	1987 Amended Budget	1987 Current Estimate	1988 Budget Estimate
		(Thousands of Dollars)		
Imaging radar program	13,900	13,400	13,400	13,000
Large Format Camera	400	---	---	---
Advanced spectrometer	7,500	8,200	8,200	8,100
Total	21,800	21,600	21,600	21,100

OBJECTIVES AND STATUS

The bjectiv of this program is to develop, te and evaluate Earth viewi remote sensing instruments and r to obtain data for land remote sensing research.

ep are continuing F cialization of l Large F Camera (LFC components of the Shuttle Imaging Radar-B (SIR b s in b the next generation Imaging Radar instrument C The SIR will use polarized, dual frequency sensor technology SIR-C is in the development phase; System R Review and Antenna eliminary Design R are comple

Advanced spectrometer technology development activities include fundamental research in remote sensing involving airborne and spaceborne imaging spectrometer instruments. The imaging spectrometer and linear array solid-state sensor research focuses on the development of such features as inherent geometric and spectral registration and programmable high spatial and spectral resolution. The critical technology development and supporting research on the Shuttle Imaging Spectrometer Experiment (SISEX) and the linear array focal plane will continue.

BASIS OF FY 1988 ESTIMATE

FY 1988 funding is required for continued development of SIR-C technology, and for advanced spectrometer activities including the development of the Shuttle Imaging Spectrometer Experiment.

BASIS OF FY 1988 FUNDING REQUIREMENTS

GEODYNAMICS

	1986 Actual	1987 Amended Budget	1987 Current Estimate	1988 Budget Estimate
		(Thousands of Dollars)		
Crustal dynamics project..............	17,400	18,100	18,100	18,600
Laser network operations.............	8,100	8,600	8,600	8,900
Research and technique development....	4,500	5,400	5,400	5,600
Total...............................	30,000	32,100	32,100	33,100

OBJECTIVES AND STATUS

The objective of the Geodynamics program is to understand the origin, evolution, and current state of the solid Earth by measuring the movement and deformation of the tectonic plates and by measuring its rotational dynamics and potential fields. Laser ranging, microwave interferometry and the global positioning satellites are used to determine precise position locations. The global gravity and magnetic fields are determined from satellite observations.

Measurements over the past years have provided experimental determination of the velocities of several of the major tectonic plates. Measurements of regional deformation across the San Andreas Fault continue to indicate a relative movement of the Pacific and North American Plate of about 6 cm per year. In addition, measurements indicate that about 4 cm of this movement is occurring in Southern California. Measurements of polar motion and changes in the length of day have been correlated, to a high degree, with variations in the angular momentum and the inertial balance of the Earth's atmosphere due to high altitude winds. In 1982, the Earth's rotation was found to have slowed by five milliseconds due to the El Nino effect. The Earth's rotational dynamics are also influenced by motions of the Earth's core and the oceans. Models of the Earth's gravity field, derived from Laser Geodynamics Satellite (LAGEOS-1) data have provided the first evidence of gravity field variations. These variations are believed to be caused by continued relaxation of the crust following the last ice age and have confirmed estimates of the viscosity of the Earth's mantle layer. Analysis of the magnetic field, using data from Magsat has confirmed the diameter of the Earth's outer core and has provided new data on secular variations of the magnetic field.

BASIS OF FY 1988 ESTIMATE

In FY 1988, measurements of plate motion between North America and Europe will be continued in cooperation with NOAA and several European countries. Measurements of the motions of the Pacific Plate will also be continued in cooperation with DoD and Japan and will be extended to include China. In addition, regional crustal deformation measurements in western North America will continue in cooperation with NOAA, Canada and Mexico. Similar measurements will be initiated in Europe in cooperation with a consortium of 10 European, North African, and Mid-East countries. The Caribbean studies will be continued in FY 1987 and are expected to involve some eight countries in 1988.

LAGEOS-1 and other satellites will continue to be used for studies of plate motion. NASA systems in the U.S., Pacific, South America, and Australia will be operated in cooperation with laser systems in 12 other countries. The joint LAGEOS-2 mission with Italy will be launched by the U. S. in 1993.

Theoretical studies of crustal motion, internal Earth structure and composition, and the modeling and interpretation of geopotential fields will be continued in FY 1988. In addition, system studies of a second magnetic field satelllte for long-term measurements of the Earth's field, studies of geopotential research and laboratory development of room-temperature and cryogenic gravity gradiometer instrumentation will continue.

BASIS OF FY 1988 FUNDING REQUIREMENT

RESEARCH AND ANALYSIS

	1986 Actual	1987 Amended Budget	1987 Current Estimate	1988 Budget Estimate
		(Thousands of Dollars)		
Biochemical processes.................	4,400	4,800	4,800	5,000
Geological processes..................	6,000	6,300	6,300	6,500
Hydrologic processes..................	4,900	5,200	5,200	5,400
Remote sensing science...,............	3,800	4,100	5,600	5,700
Total................................	19,100	20,400	21,900	22,600

OBJECTIVES AND STATUS

The major objectives of the Solid Earth Research and Analysis Program are to characterize the physical, geological and biological state of the Earth's surface, to explore its variation with time and to understand the processes which control its state and its interactions with the atmospheric and hydrologic systems.

Existing operational and research sensor systems are used to gather data on land surface properties and their variations. Observations are also conducted using experimental systems on airborne and space-based platforms. Theoretical models are formulated and validated using these observational systems with the resulting algorithms being used in the analysis of land surface properties and processes. Observational systems are used which operate in the visible, infrared and microwave regions of the spectrum, and both active and passive systems are used. Much of the emphasis is on quantification of changes to the land surface, whether it be from natural or anthropogenic causes.

The geologic processes program addresses the study of the evolution of the Earth's crust on a global basis with multispectral remote sensing techniques. The relative distribution of rock types, spectral properties of rocks, regional tectonics, rock weathering processes and geobotanical relationships are important research topics that are being addressed for many types of geologic environments. Multispectral remote sensing data analysis studies are supported by laboratory and field spectrometry and field mapping efforts to verify spectral properties and interactions.

The Biochemical processes program conducts studies through global and continental scale observation programs using operational satellite data products and analytical techniques developed for this purpose. Additionally, high spectral resolution studies are conducted using aircraft platforms and regional scale studies are conducted using the Landsat Thematic Mapper. The areal extent and temporal variability of ecosystems are investigated, and the causal mechanism sought.

CHANGES FROM FY 1987 BUDGET ESTIMATE

The **$1.5** million increase will provide for additional research, and data analysis and be applied toward the replacement of the Synthetic Aperture Radar that was destroyed in the Galileo aircraft fire in **1985.**

BASIS FOR FY 1988 ESTIMATE

In FY **1988** emphasis will continue on investigations of the Earth's systems which are undergoing stress, in order to better understand the processes which control such systems. Specific regions will be identified for study, long-term observations will be initiated and data will be assembled from existing satellite data, and intensive field measurement programs will be defined. Pilot studies to validate methodologies will be conducted and global to regional scale process models will be developed and utilized for processing the data. A mixture of biomes and stress factors will be identified; initial emphasis will be on semi-arid to arid regions undergoing seasonal or multi-year drought and on forest biomes under stress from acid rain and conversion. The activities are closely associated with the International Satellite Land Surface Climatology Project (ISLSCP) and the International Global Change Program.

The FY **1988** activities will also emphasize studies to determine continental rock type and erosion processes in semi-arid regions in sedimentary basins. Sensor systems such as the Advanced Visible-Infrared Imaging Spectrometer, quad-polarization L- & C-Band imaging radar and the Thermal Visible-Infrared Imaging Spectrometer will be used in these investigations, and will serve'as prototypes for shuttle instruments now under development and for future Space Station polar platform instruments. The thematic mapper on the operational Landsat will continue to serve as the focal instrument for multidisciplinary investigations, with particular emphasis on the tectonic structure of continental highlands.

ENVIRONMENTAL OBSERVATIONS

RESEARCH AND DEVELOPMENT

FISCAL YEAR 1988 ESTIMATES

BUDGET SUMMARY

OFFICE OF SPACE SCIENCE AND APPLICATIONS

ENVIRONMENTAL OBSERVATIONS PROGRAM

SUMMARY OF RESOURCES REQUIREMENTS

	1986 Actual	1987 Amended Budget	1987 Current Estimate	1988 Budget Estimate	Page Number
		(Thousands of Dollars)			
Upper atmosphere research and analysis	31,100	33,400	33,400	34,400	RD 7-6
Atmospheric dynamics and radiation research and analysis..............	28,700	30,900	31,900	32,900	RD 7-8
Oceanic processes research and analysis...........................	17,400	20,800	20,800	21,500	RD 7-11
Space physics/research and analysis...	16,800	18,000	21,000	21,500	RD 7-13
Payload and instrument development....	5,300	12,000	12,000	19,400	RD 7-16
Earth radiation budget experiment.....	1,900	---	---	---	RD 7-19
Extended mission operations...........	35,000	33,600	33,600	26,800	RD 7-20
Interdisciplinary research and analysis..................	1,000	1,100	1,100	1,100	RD 7-22
Tethered satellite payloads...........	6,400	1,000	1,000	3,100	RD 7-23
Scatterometer.........................	14,000	35,900	32,900	22,700	RD 7-24
Upper atmosphere research satellite mission...........................	114,000	121,200	114,200	95,400	RD 7-26
Ocean topography experiment...........	---	29,000	19,000	90,000	RD 7-28
Global Geospace Science..............	---	---	---	25,000	RD 7-30
Total..............................	271,600	336,900	320,900	393,800	

RESEARCH AND DEVELOPMENT

FISCAL YEAR 1988 ESTIMATES

BUDGET SUMMARY

OFFICE OF SPACE SCIENCE AND APPLICATIONS

ENVIRONMENTAL OBSERVATIONS PROGRAM

SUMMARY OF RESOURCES REQUIREMENTS

	1986 Actual	1987 Amended Budget	1987 Current Estimate	1988 Budget Estimate
Distribution of Program Amount by Installation				
Johnson Space Center..................	30	100	150	200
Marshall Space Flight Center..........	12,566	7,800	8,000	10,300
Goddard Space Flight Center...........	171,638	193,400	187,900	198,600
Jet Propulsion Laboratory.............	28,350	80,200	67,900	127,200
Ames Research Center..................	5,879	6,400	6,700	6,900
Langley Research Center...............	20,700	14,300	14,700	11,800
National Space Technology Laboratories	115	100	150	100
Headquarters..........................	32,322	34,600	35,400	38,700
Total.............................	271,600	336,900	320,900	393,800

PROGRAM OBJECTIVES AND JUSTIFICATION

The objectives of the Environmental Observations program are to improve our understanding of the processes in the magnetosphere, atmosphere, and the oceans; to provide space observations of parameters involved in these processes; and to extend the national capabilities to predict environmental phenomena, both short and long term, and their interaction with human activities. Because many of these phenomena are global or regional, they can be most effectively, and sometimes only observed from space. NASA's programs include scientific research efforts plus the development of new technology for global and synoptic measurements. NASA's research satellites provide a unique view of the radiative, chemical, plasma acceleration, and dynamic processes occurring in the magnetosphere, atmosphere, and oceans.

To achieve these goals, a number of significant objectives have been established for the next decade. These include advancing the understanding of the upper atmosphere through the determination of the spatial and temporal distribution of ozone and select nitrogen, hydrogen, and chlorine species in the upper atmosphere and their sources in the lower atmosphere; optimizing the use of space-derived measurements in understanding large scale weather patterns; advancing our knowledge of severe storms and forecasting capabilities, ocean productivity, circulation, and air-sea interactions; improving the knowledge of seasonal'climate variability leading to a long-term strategy for climate observation and prediction; and enabling a comprehensive understanding of solar terrestrial processes and a detailed determination of the physics and coupling between the solar wind, magnetosphere, ionosphere, and atmosphere.

Effective utilization of remote sensing requires a balanced set of activities including: analytical modeling and simulation; laboratory research of fundamental processes; development of instrumentation, flight of 'the instruments on the Space Shuttle, dedicated spacecraft and flights of opportunity; collection of in situ ancillary or validation data; and scientific analysis of data. The approach is to develop a technological capability with a strong scientific base and then to collect appropriate data, through remote and in situ means, which will address specific program objectives.

The Upper Atmospheric Research Satellite (UARS) will place a set of instruments in Earth orbit which will make comprehensive measurements of the state of the stratosphere, providing data about the Earth's upper atmosphere in spatial and temporal dimensions which are presently unattainable.

Detailed definition studies of the instruments have been completed, and the design and development activities are well underway. Development of the UARS observatory will continue in FY 1988 consistent with a planned launch in 1991.

The Earth Radiation Budget Satellite (ERBS) was successfully launched in 1984, and data continues to be collected from the satellite. NOAA-F was launched December 12, 1984 and NOAA-G was launched September 17, 1986, both equipped with ERBE instrumentation. NASA is also continuing to support the National Oceanic and Atmospheric Administration (NOAA) by managing the implementation of the polar orbiting NOAA and Geostationary Operational Environmental Satellites (GOES) series on a reimbursable basis.

Design and development activities are being continued in FY 1988 on the NASA Scatterometer (NSCAT), the objective of which is to acquire global ocean data for operational and research use by both military and civil sectors. With the apparent decision by the U.S. Navy to cancel their Navy Remote Ocean Sensing System (N-ROSS) satellite, the planned spacecraft for NSCAT, studies and plans are underway for alternatives.

Development of the Ocean Topography Experiment (TOPEX) began in FY 1987 and will continue in FY 1988; its objective is to acquire precise observations of the surface topography of the oceans. These data, in conjunction with those from NSCAT, will enable the first determination of the wind forcing and ocean-current response of the global oceans.

The Nimbus spacecraft continues to collect unique data which is being used in the study of long term trends of the Earth's atmosphere, oceans and polar ice, and provides near real time data. Collection and analysis of Solar Mesosphere Explorer (SME) data, the only mesosphere data currently available, continues. The Dynamics Explorer spacecraft continues to collect valuable data on magnetosphere-ionosphere coupling processes. In addition, the International Sun Earth Explorer (ISEE-3) spacecraft, renamed International Cometary Explorer (ICE), has completed an exploration of the Earth's geomagnetic tail. On September 11, 1985, ICE accomplished the first encounter with a comet as it passed through the tail of Giacobini-Zinner. ICE also provided supporting solar wind measurements for the March 1986 Halley missions. In March-May 1986, the Polar Region and Outer Magnetosphere International Study (PROMIS) coordinated six satellites (ISEE 1 and 2, ICE, Active Magnetospheric Particle Explorer (AMPTE), Interplanetary Monitoring Platform (IMP-8), Dynamics Explorer (DE-1) and the Swedish Viking satellite to provide unique data on magnetospheric processes.

Shuttle payload and instrument development activities provide the airborne and spaceborne data necessary to conduct basic research projects as well as provide correlative and developmental feasibility information for major free-flying spacecraft. Instrument activities include Shuttle payloads such as Atmosphere Trace Molecules Observed by Spectroscopy (ATMOS), Active Cavity Radiometer (ACR), Light Detection and Ranging (LIDAR), and Space Plasma Physics flight of opportunity instruments such as those for the Japanese Geotail Spacecraft and the European Solar Heliospheric Observer (SOHO) and CLUSTER spacecraft.

The Global Geospace Science (GGS) program is proposed as an FY 1988 new start. It is a complementary science mission to the FY 1987 approved Collaborative Solar-Terrestrial Research (COSTR) initiative, in which the U.S. moves from a supporting to a leadership role in solar-terrestrial physics. GGS will make the first coordinated geospace measurements in the key plasma source and storage regions, with emphasis on the cause-effect relations of energy flow. Together with COSTR, GGS represents research of the highest scientific merit.

Along with the Solid Earth Observations program, the Environmental Observations activities compose an integral part of NASA's total Earth sciences and applications efforts, with emphasis on understanding the Earth as a planet, studying its dynamics, processes, habitability, and solar-terrestrial environment.

BASIS OF FY 1988 FUNDING REQUIREMENT

UPPER ATMOSPHERE RESEARCH AND ANALYSIS

	1986 Actual	1987 Amended Budget	1987 Current Estimate	1988 Budget Estimate
		(Thousands of Dollars)		
Upper atmospheric research............	18,700	20,100	20,100	20,700
Stratospheric processes..............	6,400	6,900	6,900	7,100
Tropospheric chemistry...............	6,000	6,400	6,400	6,600
Total............................	31,100	33,400	33,400	34,400

OBJECTIVES AND STATUS

The upper atmosphere research program is a comprehensive research and technology effort designed to investigate and monitor the phenomena of the upper atmosphere and related phenomena in the lower atmosphere. It is aimed at improving our basic scientific understanding of the global atmosphere and the methods needed to assess its susceptibility to significant chemical and physical change. The program's three major thrusts are in the areas of upper atmospheric research, stratospheric processes research, and tropospheric chemistry research.

In particular, the goal of the upper atmosphere research program is to understand the physics, chemistry and transport processes in the stratosphere on a global scale, and to assess as accurately as possible the perturbations to the atmosphere caused by man's activities. In order to accomplish this, efforts are underway to: (1) improve upper atmosphere and global troposphere models, validate them, and assess their uncertainties; (2) measure important trace chemical constituents, temperature, and radiation fields throughout the atmosphere; (3) develop sensors capable of making chemical and physical measurements of the upper atmosphere and the global troposphere both directly and remotely from space; (4) assemble and maintain the existing long-term data base of stratospheric and tropospheric ozone measurements to aid in the detection of long-timescale natural variations and man-made ozone changes; (5) determine the effects of global tropospheric chemistry on the atmosphere; (6) conduct theoretical and field studies of tropospheric/stratospheric exchange; and (7) carry out laboratory kinetics and spectroscopy investigations to support these activities.

A variety of in situ and remote sensing techniques are needed to meet the objectives of determining and understanding the distribution of ozone and other trace species in the atmosphere. Data sets from a limited number of satellites are now generally available to the scientific community, including a record of the global distribution of ozone extending back over a decade, and simultaneous observations of a number of trace constituents. This data is being exploited to determine if trends in the ozone amount has been detected and to understand those processes which are directly involved with these trends.

BASIS OF FY 1988 ESTIMATE

Recent developments in our understanding of the ozone layer have revealed a possible non-linear dependence of ozone depletion on the amount of fluorocarbon released to the atmosphere. These findings place increased urgency on the need to verify the completeness and accuracy of the theoretical stratospheric models. In **FY** 1988, tests of the models will be continued by means of field measurements, model calculations, and interpretation of satellite data. The development of more realistic two- and three-dimensional models will be continued. The global data sets from past and present satellites will be further analyzed in **FY** 1988 to aid in the understanding of large-scale atmospheric processes.

The comparison of balloon, aircraft, and ground-based measurements will be continued in **FY** 1988 to ensure the validity of the different techniques that have been developed and to observe chemical species in the stratosphere and troposphere to determine the exchange of gases between the lower and upper atmosphere. These balloon and aircraft measurement programs are the only way to measure many of the localized phenomena' of the atmosphere; they also help to validate 'satellite observations. Studies of potential new instruments for use on future satellites and suborbital measurement platforms will also be conducted in **FY** 1988 to ensure that new technologies are put to use in improving the capability and cost efficiency of tropospheric composition and upper atmosphere measurements.

The recent observations of a depletion in the amount of ozone over Antarctica in the austral spring have attracted a great deal of attention. In order to understand the chemical and dynamical processes that are causing this phenomenon, the UARP is planning a major aircraft mission in late **FY** 1987 - early **FY** 1988 using the NASA ER-2 and DC-8. Analysis and interpreation of the results of this mission will be a critical effort in **FY** 1988.

BASIS OF FY 1988 FUNDING REQUIREMENT

ATMOSPHERIC DYNAMICS AND RADIATION RESEARCH AND ANALYSIS

	1986 Actual	1987 Amended Budget	1987 Current Estimate	1988 Budget Estimate
	(Thousands of Dollars)			
Global-scale atmospheric processes research and analysis...............	13,400	13,400	14,400	14,800
Mesoscale atmospheric processes research and analysis.......................	7,600	8,600	8,600	8,900
Climate research and analysis.........	7,700	8,900	8,900	9,200
Total...............................	28,700	30,900	31,900	32,900

OBJECTIVES AND STATUS

The research and analysis activities within the Atmospheric Dynamics and Radiation program comprise a core effort which is fundamental to using space technology to solve problems in atmospheric science. The program's three main thrusts are in the areas of global-scale tropospheric processes research, mesoscale processes research and climate research.

The objectives of the global scale research program are to improve our understanding of large-scale atmospheric behavior and to develop improved capabilities to observe the atmosphere from space. The program involves the development of advanced remote sensing instrumentation to observe the atmosphere, the development of advanced analysis techniques to better utilize existing meteorological satellite data, and development of advanced numerical models which use satellite observations to describe the state of the atmosphere both diagnostically and predictively. Recent accomplishments include the development of techniques which more fully utilize passive multispectral data (IR and microwave) from the NOAA operational satellites to provide global maps of a number of key atmospheric and surface parameters. In addition, special attention has been devoted to developing active lidar techniques to provide detailed profiles of atmospheric temperature, pressure, and moisture data from future spaceborne platforms. Simulations of these advanced techniques indicate their increased potential in greatly improving meteorological prediction capability.

The objectives of the mesoscale processes research program are to improve our understanding of the behavior of the atmosphere on short (minutes to hours) time scales and over local to regional size scales (severe weather, such as tornadoes and hurricanes). Since all of the characteristic parameters of these mesoscale processes cannot be measured directly, new techniques are under study to derive the information from other observations which can be directly measured. Such an activity requires advanced data handling and analysis techniques which rely upon man-computer interactive display and manipulation. A joint NASA-NOAA project of this type was completed and is known as the Centralized Storm Information System. In the area of remote sensor development, successful flights of instrumentation on the ER-2 aircraft to observe cloud top dynamics and lightning have been completed, and a feasibility study of a potential lightning mapper has been completed. NASA is currently working with NOAA to determine the practical value of lightning mapping from geostationary orbit and the possibility of incorporating experimental lightning mapping observations on a GOES spacecraft.

The Climate Research Program seeks to develop a space capability for global observations of climate parameters which will contribute to our understanding of the processes that influence climate and its predictability. Research is focused in accordance with the National Climate Program priorities wherein NASA has the role of lead agency for solar and Earth radiation research. Future study thrusts will be aligned with programs of solar irradiance monitoring, Earth radiation budget monitoring and analysis, the global distribution and effect of cloud systems and stratospheric aerosols on the radiation budget, and on selected process studies which relate to monitoring of climate change. The past year's activities have stressed data analysis and model studies of the effects of the El Chichon volcano on climate. The first results of the data phase of the International Satellite Cloud Climatology Project (ISCCP) have been successfully archived and elements of the First ISCCP Regional Experiment (FIRE) have been completed. Data from ISCCP and FIRE will be analyzed in conjunction with the Earth Radiation Budget Experiment (ERBE) data to improve our knowledge of cloud-radiation interactions which affect our climate. In addition, measurements of the solar irradiance will continue through the repaired Solar Maximum Mission (SMM) spacecraft, Nimbus 7 and reflights of the Active Cavity Radiometer flown on Spacelab-1.

A significant research effort on developing the capability to observe rainfall from space has been initiated. This includes studies of instrumentation, sampling requirements, algorithm development and modeling to determine the feasibility of remotely sensing rainfall from space.

CHANGES FROM FY 1987 AMENDED BUDGET

The $1.0 million increase in FY **1987** will provide for augmented data analysis and research activities in the science and university communities to maintain a productive science return during the hiatus in the STS flight program.

BASIS OF FY 1988 ESTIMATE

FY 1988 funding is required to provide instruments and support for aircraft flights to study the detail of flows around thunderstorms and fronts, continue development and comparison of numerical models, study atmospheric scale interactions, and develop techniques to display model outputs in 3-dimensions. Analysis of the data collected in interagency field experiments during FY **1986** and **1987** will be performed. These data include the results of the Genesis of Atlantic Lows Experiment (GALE), the Microburst in Severe Thunderstorms Experiment (MIST), the First ISCCP Regional Experiment (FIRE) and the Satellite Precipitation and Cloud Experiment (SPACE). In addition, experimental, theoretical, and computational work will be done to better define the capabilities and requirements for the remote measurement of rainfall. Other activities will involve continued retrieval and archiving of global International Satellite Cloud Climatology Project data sets, analysis of data from the Earth Radiation Budget Experiment and the Stratospheric Aerosol and Gas Experiment, and continued ground-based and rocket flight support for solar irradiance monitoring. Technology development of active temperature, pressure, and moisture sounders as well as basic lidar technology development will also be continued in FY **1988.**

BASIS OF FY 1988 FUNDING REQUIREMENT

OCEANIC PROCESSES RESEARCH AND ANALYSIS

	1986 Actual	1987 Amended Budget	1987 Current Estimate	1988 Budget Estimate
		(Thousands of Dollars)		
Research and analysis................	17,400	20,800	20,800	21,500

OBJECTIVES AND STATUS

The Oceanic Processes Research and Analysis (R&A) program emphasizes the development and application of spaceborne observing techniques to advance our understanding of the fundamental behavior of the oceans, as well as to assist users with the implementation of operational systems. As such, the program operates in concert with a variety of federal agencies (e.g., Navy, NOAA, NSF) and foreign countries (e.g., Canada, Europe, Japan).

The Oceanic Processes R&A program is organized into three discipline areas: (1) physical, (2) biological, and (3) polar oceanography. In physical oceanography, satellite scatterometers and altimeters are used to observe surface roughness and topography, from which surface winds and ocean current response can be estimated. In biological oceanography, color scanners are used to observe chlorophyll concentratidn, from which primary productivity can be estimated. In polar oceanography, microwave radiometers and synthetic aperture radars are used to estimate the characteristics of sea-ice cover and the details of its motion.

The Oceanic Process R&A program is actively pursuing scientific research with other federal agencies and foreign countries for the World Climate Research Program (WCRP). Component WCRP efforts include the Tropical Ocean/Global Atmosphere (TOGA) and World Ocean Circulation Experiments (WOCE), a Global Flux Experiment (GFE), and a Program for International Polar Oceans Research (PIPOR).

BASIS OF FY 1988 ESTIMATE

In FY 1988, the physical oceanography research activities will include implementation planning for WOCE and TOGA, as well as the development of numerical models and associated data assimilation techniques for use in determining the general circulation of the oceans. In biological oceanography, the analysis of data from Nimbus-7 will be continued in order to estimate global ocean productivity, as well as to help with the conceptual design of the Global Flux Experiment. In addition, accommodation studies will be performed with EOSAT for potential flight of an ocean-oriented color scanner aboard the Landsat-6 spacecraft. In polar oceanography, emphasis will be placed on the experimental design for the Program for International Polar Oceans Research, which is planned to involve direct reception in Alaska of SAR data from the European Space Agency's ERS-1 and from the Japanese JERS-1 spacecraft due for launch in the 1989 - 1991 time frame. The NASA Ocean Data System is now functioning as a scientific support facility for the ocean research community. Coordination activities with the Office of Naval Research, NSF, and NOAA are being pursued in order to assure that appropriate computing facilities, data archives, and communication networks will be available for the utilization of spaceborne observations from missions planned within the next decade.

Advanced technology development activities will also be continued on prospective future sensors for flight aboard both the Shuttle and free-flying spacecraft.

BASIS OF FY 1988 FUNDING REQUIREMENT

SPACE PHYSICS RESEARCH AND ANALYSIS

	1986 Actual	1987 Amended Budget	1987 Current Estimate	1988 Budget Estimate
		(Thousands of Dollars)		
Plasma physics SR&T and data analysis	10,600	11,400	14,400	14,700
Advanced technology development..	2,900	3,000	3,000	3,100
Solar terrestrial theory.............	3,300	3,600	3,600	3,700
Total............................	16,800	18,000	21,000	21,500

OBJECTIVES AND STATUS

Space physics research and analysis is a broadly structured effort to enhance our understanding of the characteristics and behavior of plasmas in the solar corona, the interplanetary medium and in the vicinity of the Earth and other planets. These studies include: the complex coupling of the atmosphere with the ionosphere and the magnetosphere; the solar wind and how it interacts with planetary magnetospheres and ionospheres; and how variations in the solar wind are coupled into planetary environments and neutral atmospheres. This discipline also includes the conduct of active experiments to extract information under controlled conditions, and the use of space as a laboratory for the study of plasmas in parameter regimes that are unattainable on Earth. The understanding of the plasmas in the solar system, the only naturally occurring plasmas to which we have direct access, will also enable us to refine theories regarding astrophysical plasma processes.

One major thrust of the space physics program is directed at studies of the near Earth Geospace environment, from the flow of the solar wind past the magnetosphere, to manifestations of variations of the plasma environment detectable near the surface of the Earth. Not only are these studies of great interest for basic plasma physics and for the Earth sciences community, but also there are many practical ramifications, such as ionospheric influences on communication, global circulation of the atmosphere driven by magnetospheric input, the charging of spacecraft immersed in plasma, and the behavior of antennas and their signals in the magnetosphere.

This field of research is one of relative maturity, with emphasis on multipoint, in situ measurements and on active perturbation experiments rather than isolated exploratory observations. For example, there are presently four spacecraft systems--the Interplanetary Monitoring Platform, the

International Sun-Earth Explorer (ISEE), Dynamics Explorer (DE), and the Active Particle Tracer Explorer (AMPTE) taking such measurements. AMPTE has carried out a program of coordinated chemical releases and plasma diagnostics to investigate solar wind plasma entry into the magnetosphere and energization of plasmas directed both towards and away from the atmosphere. The campaign called PROMIS (Polar Region and Outer Magnetosphere International Study) took full advantage of these satellite systems during March-May 1986 when the Swedish Viking satellite contributed toward a unique opportunity for correlative measurements of the Earth's magnetosphere on a large scale. In addition to the in situ measurements of natural plasma environments as discussed above, a second major thrust of the space physics program is to use these natural environments as unique laboratories for basic plasma physics, especially through the use of active experiments to simulate plasma pheonomena under controlled conditions. There is an active program of sounding rocket and balloon investigations aimed principally at spatially or temporally isolated atmospheric, ionospheric or magnetospheric phenomena. Theoretical modeling and supporting laboratory activities are also being conducted.

Advanced technology development (ATD) provides for the definition of advanced missions and supporting instrument technologies. FY 1987 ATD efforts were directed at extending the definition of the WIND and POLAR missions including instruments, spacecraft, and ground systems of the Global Geospace Science (GGS) program and performing accommodation studies for incorporating continuous real-time solar wind data capability on WIND to meet USAF Air Weather Service's statement-of-need as a joint mission.

The solar terrestrial theory activity continues to provide a strong basis for all of the programs in both solar physics and space plasma physics. Theoretical groups are engaged in research on virtually every aspect of solar-terrestrial physics by using both fundamental process calculations and numerical models of large-scale phenomena. The active phase of AMPTE also provided controlled perturbations of the geospace environment, including a full-scale simulation of solar wind-comet interactions.

CHANGES FROM FY 1987 AMENDED BUDGET

The $3.0 million increase in FY 1987 will provide for additional research, data analysis and sounding rocket investigations to maintain a productive science return during the hiatus in the flight program.

BASIS OF FY 1988 ESTIMATE

During FY 1988, the space physics research and analysis activities will be continued with particular emphasis on the analysis of data obtained from the 1986 PROMIS campaign and from the International Cometary Explorer (ICE) which collected unique data in the Earth's distant magnetotail before going on to an encounter with the comet Giacobini-Zinner in September 1985. Definition studies will be conducted during FY 1988 for advanced missions such as the follow-on for the U.S.-Italian Tethered

Satellite System, which will investigate atmospheric and electrodynamics effects, a solar probe mission to study the unexplored region between four and sixty radii from the Sun, and Space Station Payloads including the Solar Terrestrial Observatory.

The solar terrestrial theory program will be continued during FY 1988. In addition, a comprehensive and quantitative aggregate model of solar-terrestrial interactions will continue to be developed.

BASIS OF FY 1988 FUNDING REQUIREMENT

PAYLOAD AND INSTRUMENT DEVELOPMENT

	1986 Actual	1987 Amended Budget	1987 Current Estimate	1988 Budget Estimate
		(Thousands of Dollars)		
Measurement of Air Pollution from Satellites **(MAPS)**....................	600	800	800	700
Atmosphere Trace Molecules Observed by Spectroscopy (ATMOS)............	1,000	2,100	2,100	2,500
Active Cavity Radiometer (ACR, ACRIM).	1,200	1,100	1,100	1,100
Light Detection and Ranging (LIDAR). ..	2,500	3,000	3,000	100
Collaborative solar terrestrial research (COSTR)...................	(3,800)*	5,000	5,000	15,000
Total.............................	**5,300**	12,000	12,000	19,400

*Non-add previously funded under Space Physics Research and Analysis.

OBJECTIVES AND STATUS

The Space Transportation System offers the unique opportunity for short-duration flights of instruments. The Environmental Observations program has incorporated this capability into the Shuttle/Spacelab payload development activities in these important aspects: early test, checkout and design of remote sensing instruments for long duration free-flying missions; and short-term atmospheric and environmental data gathering for basic research and analysis where long-term observations are impractical.

The objective of the Atmosphere Trace Molecules Observed by Spectroscopy (ATMOS) experiment is to make detailed measurements of gaseous constituents (e.g., hydrogen chloride, water, ammonia, methane) in the Earth's atmosphere by using the technique of infrared absorption spectroscopy. The data will help determine the compositional structure of the upper atmosphere, including the ozone layer and its spatial variability on a global scale. The instrument was launched in 1985 on Spacelab-3 and data analysis continues. It will be reflown on the ATLAS (formerly EOM) series. The science results from the first flight of ATMOS were of exceptional value, and the basic capability of ATMOS, to measure very low concentrations of trace species in the earth's atmosphere, was clearly demonstrated. In FY

1987, ATMOS commenced a ground observation program at Table Mountain Observatory which will continue until the instrument is readied for shipment to KSC for the ATLAS-1 mission.

The Measurement of Air Pollution from Satellites (MAPS) experiment is a gas-filter correlation radiometer designed to measure the levels of troposphere carbon monoxide and the extent of interhemispheric mass transport in the lower atmosphere. The instrument was flown successfully on two Shuttle flights, and data analysis continues. It is planned for four STS flights, one for each season of the year, to provide the first observations of the global seasonal variation of carbon monoxide in the Earth's atmosphere. Reflight of MAPS is also planned on the ATLAS series.

The Active Cavity Radiometer-1 (ACR-1) is designed to aid in the study of the Earth's climate and the physical behavior of the Sun. Reflights of ACR-1 on the ATLAS series are planned. Other experiments have also been selected for reflight, including some instruments which were flown on the Shuttle orbital flight tests, and Spacelabs-1 and -2.

The Collaborative Solar-Terrestrial Research Program (COSTR) will provide state-of-the-art instrumentation for flight opportunities on international spacecraft and various U.S. spacecraft of opportunity. The emphasis is on developing scientific instruments that have been conceived through the Space Plasma and Solar Physics Research and Analysis programs and through the Sounding Rocket program. The development and selection of opportunities will be coordinated and focused to answer questions identified in the National Academy of Sciences Committee on Solar and Space Physics report on priorities in solar system space physics. Most of the instruments developed through this program will provide a U.S. contribution to an international thrust in solar-terrestrial research in the 1989-1995 timeframe.

BASIS OF FY 1988 ESTIMATE

FY 1988 funds will be used to support the Measurement of Air Pollution from Satellites (MAPS) science team activities including data reduction, refurbishment for reflight and upgrading of the ground service equipment.

The initial flight of the Atmosphere Trace Molecules Observed by Spectroscopy (ATMOS) instrument was completed in 1985, with greater than expected science results. The FY 1988 funding is required to support the ground observation program of ATMOS as well as continued science team activities, data processing and analysis, and limited refurbishments.

FY 1988 funding is also required to continue the Active Cavity Radiometer (ACR) data processing, science team activities, and refurbishment for reflight on future Shuttle ATLAS flights, and development of a free-flyer version of ACR.

Development activities will continue on the international (U.S. and French) Light Detection and Ranging (LIDAR) airborne instrumentation following completion of conceptual definition, breadboard laboratory activities, and preliminary design reviews for this multi-phase user program. In this advanced state-of-the-technology program, both NASA and the French are supplying science knowledge and hardware to demonstrate first-time detail measurements of the atmosphere to aid in forecasting.

In FY 1988, the COSTR program will continue development of U.S. provided instruments for the ISAS/NASA GEOTAIL mission which will explore the Earth's magnetosphere and deep geotail region. While ISAS will provide the Geotail Spacecraft and the majority of the instruments, NASA will provide instruments requiring unique capabilities to measure the hot, low density plasmas, energetic plasmas, low intensity waves and weak magnetic fields in the deep magnetic tail. In addition, NASA will begin development of U.S. provided instruments and mission support equipment for the ESA/NASA joint CLUSTER and SOHO missions. These missions will provide detailed measurements of solar variability and solar oscillations, the origin and flow of the solar wind, the interaction of the solar wind with the terrestrial magnetosphere, and the resultant space plasma microprocesses. ESA will provide the SOHO and CLUSTER satellites, and the majority of the instruments. NASA will provide instruments for solar oscillations and solar corona measurements and several space plasma instruments that are unique in their capabilities and performance.

BASIS OF FY 1988 FUNDING REQUIREMENT

EARTH RADIATION BUDGET EXPERIMENT

	1986 Actual	1987 Amended Budget	1987 Current Estimate	1988 Budget Estimate
		(Thousands of Dollars)		
Earth radiation budget experiment.....	1,900	---	---	---

OBJECTIVES AND *STATUS*

The objective of the Earth Radiation Budget Experiment (ERBE) is to measure the temporal and spatial variations in the Earth's radiation budget to gain basic insight into the causes for climatic fluctuations.

Initial experimental Earth radiation budget instruments were flown on the Nimbus satellites. Sampling studies based on those experiments have shown that adequate global coverage requires a multiple satellite system. These studies also indicate the need for improved calibration of the sensors and measurements covering full seasonal cycles. In order to provide adequate and meaningful coverage, identical Earth radiation budget instruments have been installed on the NOAA-F and NOAA-G satellites and on one dedicated NASA observatory (ERBS). The scientific objectives and measurement requirements were developed by a combined NOAA/NASA/university/industry team of scientists and recommendations of the National Academy of Sciences.

In addition to the ERBE instruments, the NASA observatory carries the Stratospheric Aerosol and Gas Experiment (SAGE II) which provides stratosphere aerosol data.

The ERBS spacecraft was launched by the Space Shuttle to an altitude of 300 km and then propelled to the operational altitude of 610 km by an auxiliary on-board propulsion system in October, 1984. The other ERBE instruments are being flown on NOAA-F and NOAA-G; NOAA-F was launched in December 1984, and NOAA-G was launched in September 1986.

Funding for ERBE mission operations and data analysis will be provided through the Environmental Observations Extended Mission Operations budget.

BASIS OF FY 1988 FUNDING REQUIREMENT

EXTENDED MISSION OPERATIONS

	1986 Actual	1987 Amended Budget	1987 Current Estimate	1988 Budget Estimate
		(Thousands of Dollars)		
Operations for the extended mission of:				
Nimbus 7............................	6,200	5,100	5,100	4,100
Solar mesosphere explorer (SME).....	1,800	700	700	800
Correlative measurement/solar backscatter ultraviolet instrument..	1,900	2,500	2,500	1,700
Earth radiation budget experiment extended operations...............	7,600	9,000	9,000	8,000
Active magnetospheric particle tracer explorer extended operations........	3,000	3,300	3,300	2,600
International sun-earth explorers....	5,800	4,100	4,100	3,100
Interplanetary monitoring platform...	700	700	700	'700
Dynamics explorer extended operations	8,000	6,000	6,000	3,600
Shuttle Imaging Radar-B.............	---	2,200	2,200	2,000
San Marco extended operations........	---	---	---	200
Total...............................	35,000	33,600	33,600	26,800

OBJECTIVES AND STATUS

The objectives of the extended mission operations program is to provide for the operations, data processing, validation and data analysis of missions which have completed basic operations funded by approved project support.

Launched in 1978, the Nimbus-7 spacecraft continues to provide significant quantities of both atmosphere and solid earth global data for multi-discipline investigations and applications. These include atmospheric dynamics and chemistry resulting in global ozone measurements that are helping to understand the complicated heat exchanges of the atmosphere-ocean system, and, for the first time, global ocean data and sea ice concentration as well as properties of both polar caps. NASA supplies this unique sea ice concentration data in near real-time to the joint U.S. Navy-NOM Ice Center. The ocean color measurements provide the only data on open ocean and coastal areas chlorophyll concentration, which relates to abundance of phytoplankton, the basic element of the ocean food chain. Current studies of complete ocean basins are expanding the understanding of global productivity. Nimbus-7 operations and data reduction/validation activities will continue in **FY** 1988 to support the strong demand for data.

The Solar Mesosphere Explorer (SME), launched in October 1981, is providing major input to our overall atmospheric parameter data base. SME is producing simultaneous measurements needed to understand the complex chemical processes taking place in the mesosphere, including data measurements of ozone, atomic oxygen, nitric oxide and solar irradiance. Data results indicate greater short-term variations and magnitude than was expected of many of the mesospheric properties. A ground truth program to aid in the validation of the SME data is also being undertaken. SME is providing excellent data on the effect of volcanoes on the Earth's atmosphere.

Solar terrestrial research activities rely on data received from the International Sun-Earth Explorers, (ISEE-1 & 2), the Interplanetary Monitoring Platform (IMP), the Active Magnetospehric Particle Trace Explorer (AMPTE), and the Dynamics Explorers which are still operational. IMP continues to provide the only available source of solar wind input measurements to the Earth. IMP, along with ISEE-1 & 2, DE, AMPTE, and the Swedish Viking satellite successfully conducted a multisatellite campaign called Polar Regions and Outer Magnetospheric International Study (PROMIS) in 1986. The ISEE-3 spacecraft, renamed the International Cometary Explorer (ICE), provided complementary solar wind measurements upstream of Comet Halley in 1986, and was retargeted for a return to Earth orbit in 2014 for retrieval and presentation to the National Air and Space Museum (NASM).

BASIS OF FY 1988 ESTIMATE

FY 1988 funding is required to support continuing mission operations and data analysis activities for ISEE-1 and 2, IMP, DE, ICE and AMPTE. Operation of the Nimbus and SME satellites and processing of the collected data will be continued as will activities to provide ground truth for a NASA-developed ozone instrument to be flown on a NOAA meterological satellite. The SME and Nimbus satellites continue to produce extremely valuable data on ozone concentrations which will be used to estimate the occurrence of natural and man-made variations, sea surface temperatures, aerosol measurements, and ocean productivity. Correlative ground truth activities will also be continued in **FY** 1988; these in situ observations are needed to verify the quality of remote observations and improve our ability to interpret them.

In addition, **FY** 1988 funding is required for operating the ERBS spacecraft, data processing and analysis from the total three-instrument system, and from the SAGE-I1 instrument on ERBS.

BASIS OF FY 1988 FUNDING REQUIREMENT

INTERDISCIPLINARY RESEAR

	1986 Actual	1987 Amended Budget	1987 Current Estimate	1988 Budget Estimate
		(Thousands of Dollars)		
Interdisciplinary research and analysis	**1,000**	**1,100**	**1,100**	**1,100**

OBJECTIVES AND STATUS

Interdisciplinary research activities need to be conducted to quantitatively characterize the Earth's chemical, physical, and bioloical processes on the land, along with the interactions between the land, the oceans, and atmosphere, which are of particular importance in assessing the impact of these pheonmena on global, physical, and biogeochemical processes. Such research is essential to investigating and assessing long-term physical, chemical, and biological trends and changes in the Earth's environment. Included in the program activities are joint efforts from a variety of disciplines, including atmospheric science, climatology, biological sciences, geochemistry, and oceanography.

BASIS OF FY 1988 ESTIMATE

In FY **1988,** interdisciplinary studies will be continued with emphasis on integrating discipline-specific research activities of Oceanic Processes, Atmospheric Dynamics and Radiation, Upper Atmosphere/Troposphere Chemistry, and Land Processes into a unified program which will help increase our understanding of critical global processes. Emphasis will be placed on specific pilot studies such as those understanding the biogeochemical processes controlling the concentration of atmospheric methane, characterizing changes in properties of the land surface and their effect on climate, and understanding the role of the oceans in the global carbon cycle.

BASIS OF FY 1988 FUNDING REQUIREMENT

TETHERED SATELLITE PAYLOADS

	1986 Actual	1987 Amended Budget	1987 Current Estimate	1988 Budget Estimate
		(Thousands of Dollars)		
Tethered satellite payloads...........	6,400	1,000	1,000	3,100

OBJECTIVES AND STATUS

The Tethered Satellite System (TSS) will provide a facility for conducting experiments weighing 500 kg or less from distances of 100 km above or below the Space Shuttle. The TSS will allow unique science to be undertaken such as observations of atmospheric processes occurring within the lower thermosphere (below 180 km altitude), observations of crustal geomagnetic phenomena, and direct observation of magnetospheric-ionospheric-atmospheric coupling processes in the 125–180 kilometer region. In addition, the satellite, coupled to the conducting tether, can generate large amplitude hydromagnetic waves and electrodynamic waves in the local space plasma, thus enabling active space plasma and magnetospheric physics experiments to be performed. The objective of the initial TSS mission is to verify the controlled deployment, retrieval and on-station stabilization of the satellite tethered from the orbiter, and to carry out an electrodynamics experiment using a conducting tether extended 20 km above the orbiter.

The TSS is an international cooperative project with the Italian government. The United States is developing the tether deployment and retrieval system, is responsible for overall project management and system integration, development and integration of the U.S. provided instruments, and flight on the Shuttle. Italy is developing the satellite and is responsible for development and integration of Italian provided instruments. An Announcement of Opportunity for investigations was issued in April 1984. Selection of investigators was completed in late 1985 and instrument design initiated in 1986.

BASIS OF FY 1988 ESTIMATE

The FY 1988 funding is required to continue development of U.S.-provided instruments on TSS-1 and core equipment development and integration.

BASIS OF FY 1988 FUNDING REQUIREMENT

SCATTEROMETER

	1986 Actual	1987 Amended Budget	1987 Current Estimate	1988 Budget Estimate
		(Thousands of Dollars)		
Scatterometer..........................	14,000	35,900	32,900	22,700

OBJECTIVES AND STATUS

The Scatterometer will provide accurate, global measurements of ocean surface winds which will be useful for both oceanography and meteorology. In addition to providing wind field data, Scatterometer data will permit the first global study of the influence of winds on ocean circulation, provide data on the effects of the oceans on the atmosphere, and provide improved marine forecasting (winds and waves). Flight of the instrument in 1990-1991 will provide an overlap of data gathering with the World Ocean Circulation Experiment, Tropical Ocean-Global Atmospheres Experiment planned by the international oceanographic community; and additionally, concurrent flight with the Ocean Topography Experiment (TOPEX) would result in unique measurements of the ocean's driving force (winds) and the resulting ocean response (topography).

The feasibility of using the Scatterometer technique from space to accurately measure winds was demonstrated by Seasat in 1978. Definition studies conducted by NASA during FY 1983 and early FY 1984 resulted in the determination that the performance requirements as stated jointly by the research community and the Navy could be satisfied by utilizing system design concepts similar to those used on the Seasat Scatterometer. The major improvements include the addition of two antennas for improved wind direction determination and the addition of digital filtering to compensate for earth rotational effects.

The Scatterometer was to have been flown on the Navy Remote Ocean Sensing System (N-ROSS) satellite in late 1990. With the apparent decision by the Navy to cancel N-ROSS development, the program is seeking an alternate, compatible flight option. As the Navy is still interested in Scatterometer data, it is assisting the agency in obtaining an alternate flight.

CHANGES FROM FY 1987 AMENDED BUDGET

The reduction of $3.0 million is due to an anticipated delay in flight of from 6 to 12 months.

BASIS OF FY 1988 ESTIMATE

During FY 1987, various hardware components will be delivered, construction of the radio frequency subsystem will continue, the procurement of the second of two computer systems will begin, and a Critical Design Review will be conducted . Planned FY 1988 activities will include the continuation of hardware development leading to testing and integration of the Scatterometer Flight Model, delivery of the second computer system and beginning of its testing, and continued refinement of post launch research and verification plans.

BASIS OF FY 1988 FUNDING REQUIREMENT

UPPER ATMOSPHERE RESEARCH SATELLITE PROGRAM

	1986 Actual	1987 Amended Budget	1987 Current Estimate	1988 Budget Estimate
		(Thousands of Dollars)		
Spacecraft..........................	66,000	73,200	69,200	59,400
Experiments..........................	48,000	48,000	45,000	36,000
Total..........................	114,000	121,200	114,200	95,400
Space Transportation System Operations	(---)	(18,400)	(---)	(---)

OBJECTIVES AND STATUS

The Upper Atmosphere Research Satellite (UARS) program is the next logical step in conducting a comprehensive program of research, technology development and monitoring of the upper atmosphere aimed at improving basic scientific understanding. This mission, scheduled for a STS launch in 1991, is essential for understanding the key radiative, chemical and dynamical processes which couple together to control the composition and structure of the stratosphere. The UARS mission will provide the first integrated global measurements of: ozone concentration; chemical species that affect ozone; energy inputs; temperature; and winds in the stratosphere and mesosphere. These measurements will complement the measurements of ozone and of atmospheric parameters affecting ozone that were made on Nimbus and SAGE. The UARS program is a critical element in overall stratospheric research and monitoring efforts; it will provide the first full data set on stratospheric composition and dynamics which will be required when very difficult decisions must be made in the future regarding production of chlorofluorocarbons. The UARS mission will also contribute to the assessment of the impact of stratospheric changes on our climate and will provide the data needed for a full understanding of the stratosphere. These understandings are essential for subsequent design and implementation of a long-term stratospheric monitoring activity.

A final selection of ten experiments has been made, including infrared and microwave limb sounders which require advances in cryogenics, solid-state devices and microwave antennas beyond earlier capabilities. The instrument design and development activities are underway. A Solar Backscatter Ultraviolet (SBUV) instrument will be modified to fly on the Shuttle during the UARS mission and to provide correlative data. In addition, development of the central ground data handling facility, which will permit near-realtime interactive utilization of data by the twenty-one design and theoretical investigator teams, is underway.

CHANGES FROM FY 1987 AMENDED BUDGET

The UARS launch schedule has been delayed and is currently planned for launch in October **1991.** This delay has caused a rephasing of development activities, resulting in the **$7** million reduction.

BASIS OF FY 1988 ESTIMATE

The FY **1988** funds are required for continuation of the development activities on the ten UARS instruments including flight hardware fabrication, instrument assembly and environmental testing leading to instrument delivery to the spacecraft in **1989.** In addition, the spacecraft development and hardware fabrication activities will continue.

The ground data handling facility will enable a higher level of interaction among experimenters and theoreticians than has existed with past programs. Implementation of this concept requires that the system be developed on a timely parallel path with the flight hardware **so** that individual experiment data processing subsystems, including algorithms and the interactive data base, provide maximum interaction and effectiveness in the design and development phase of the program and are fully verified at launch time. In order to achieve this, FY **1988** funding **is** required to continue design and development of the ground data handling facility including hardware delivery and checkout, software preliminary and critical design reviews, science team support and science algorithm development.

BASIS OF FY 1988 FUNDING REQUIREMENT

OCEAN TOPOGRAPHY EXPERIMENT

	1986 Actual	1987 Amended Budget	1987 Current Estimate	1988 Budget Estimate
		(Thousands of Dollars)		
Ocean topography experiment (TOPEX)...	---	29,000	19,000	90,000

OBJECTIVES AND STATUS

The goal of the Ocean Topography Experiment (TOPEX) is to utilize satellite radar altimetry to measure the surface topography of the global oceans over a period of three years with sufficient accuracy and precision to significantly enhance our understanding of the oceans' general circulation and its mesoscale variability. The capability of satellite altimetry to address this goal was demonstrated in 1978 by NASA's highly successful Seasat program. Such information is needed to better understand how the atmosphere drives the circulation of the oceans, how the oceans in turn influence the atmosphere and ultimately, the role of the oceans in climate.

Current plans call for NASA and the French Space Agency (CNES) to collaborate on TOPEX in order to more fully exploit the scientific value of the data. In exchange for this scientific collaboration and the flight of a French altimeter and tracking system, CNES will launch TOPEX in late 1991 using Ariane. TOPEX is also being planned in concert with the World Ocean Circulation Experiment (WOCE), a major international oceanographic field program being planned under the auspices of the World Climate Research Program (WCRP). WOCE will combine satellite observations from TOPEX with traditional in situ observations to enable the first comprehensive determination of the three-dimensional current structure of the global oceans. When further combined with ocean surface winds from the NASA Scatterometer (NSCAT), unique measurements of the oceans' driving force (winds) and the resulting ocean response (topography) will have been obtained.

CHANGES FROM THE FY 1987 AMENDED BUGET

Consistent with Congressional action on the FY 1987 budget, TOPEX was reduced by $10 million.

BASIS OF FY 1988 ESTIMATE

During FY 1987 a satellite contractor and a science team was selected, and sensor and ground data system development began. In FY 1988, preliminary design of the satellite and ground data systems will be well underway. Sensor development will continue through the Critical Design Review phase leading to the initiation of fabrication by late FY 1988. At the same time the science team will be refining their research plans and will assist in assessing design options as they relate to achieving scientific success with TOPEX.

BASIS OF FY 1988 FUNDING REQUIREMENT

GLOBAL)SPACE SCIENCE

	1986 Actual	1987 Amended Budget	1987 Current Estimate	1988 Budget Estimate
		(Thousands of Dollars)		
Global Geospace Science...............	---	---	---	25,000
Space Transportation System Operations	(---)	(---)	(---)	(3,100)

OBJECT AND STATUS

The Global Geospace Science (GGS) is : as a FY 1988 r initiati and will be part of the ! St contributi to the International Solar es a Physics ISTP program. This program i an international, lt aborati science mission designed i ide the measurements necessary for a new and comprehensive understanding of the interaction between the Sun and the th.

The GGS is a complementary science mission to the Collaborative Solar Terrestrial Research (COSTR) program initiated in FY 1987 to provide instruments and launch support and to gain science return in a cooperative effort with the European Space Agency (ESA) and the Japanese Institute of Space and Aeronautical Science (ISAS). The scientific value of this effort would be greatly enhanced by the addition of the two spacecraft proposed in the GGS program. The combined program would include five spacecraft missions: two U.S. spacecraft, WIND and POLAR; two ESA spacecraft, SOHO and Cluster; and one ISAS spacecraft, GEOTAIL. NASA will launch and provide upper stages for all spacecraft except SOHO. ESA will provide for launch and associated costs for SOHO. Initiation of GGS in FY 1988 will move the U.S. from a supporting to a leadership role in this international cooperative program.

The Global Geospace Science (GGS) mission will measure and model the effects of the Sun on the Earth's space system to enhance our understanding of the processes and flow of energy and matter in the solar energy chain from outer geospace to atmospheric deposition. GGS will also enhance our ability to assess the importance of variations in atmospheric energy deposition from the geospace system to the terrestrial enviroment. GGS consists of two fully instrumented U.S. spacecraft, WIND and POLAR, making simultaneous measurements in key geospace regions. Instruments and theory investigations were selected through an Announcement of Opportunity to U.S. and foreign investigators. GGS provides the first coordinated geospace measurements in key plasma source and storage regions, multi-spectral global auroral imaging, and multi-point study of magnetospheric response to solar wind.

Essentially all commitments by the foreign governments are in place and their development activities have commenced. Approval of the GGS will allow the United States to become a full partner in the ISTP program reinforcing our commitment to international cooperation and is essential to maintaining continued leadership in solar terrestrial physics.

BASIS OF FY 1988 ESTIMATE

Definition studies are complete and FY 1988 funds are required to initiate development of GGS spacecraft instruments and ground system. FY 1988 funding will allow initiation of these efforts in time to take advantage of simultaneous measurements provided by the Collaborative Solar Terrestrial Research (COSTR) program and other solar-terrestrial research efforts.

MATERIALS
PROCESSING IN SPACE

RESEARCH AND DEVELOPMENT

FISCAL YEAR 1988 ESTIMATES

BUDGET SUMMARY

OFFICE OF SPACE SCIENCE AND APPLICATIONS

MATERIALS PROCESSING IN SPACE PROGRAM

SUMMARY OF RESOURCES REQUIREMENTS

	1986 Actual	1987 Amended Budget	1987 Current Estimate	1988 Budget Estimate	Page Number
		(Thousands of Dollars)			
Research and analysis................	12,100	12,900	13,900	14,400	RD 8-3
Microgravity Shuttle/Station payloads.	18,900	26,500	34,000	31,500	RD 8-4
Total..........................	31,000	39,400	47,900	45,900	

Distribution of Program Amount by Installation

	1986 Actual	1987 Amended Budget	1987 Current Estimate	1988 Budget Estimate
Johnson Space Center..................	2,274	2,505	3,255	3,013
Marshall Space Flight Center..........	6,447	10,829	13,429	12,804
Lewis Research Center.................	7,843	8,843	11,593	10,633
Langley Research Center...............	1,278	1,165	1,965	1,906
Jet Propulsion Laboratory.............	7,199	8,807	11,407	11,052
Headquarters..........................	5,959	7,251	6,251	6,492
Total..........................	31,000	39,400	47,900	45,900

PROGRAM OBJECTIVES AND JUSTIFIC

The Ma Processing in Space pr emphasizes the science and t of processing mterials to understand constraints in by gravitational forces and the unique li made possible by oll these processes i the sp m Ground-based research, technology development, and payload ion vi in FY 1 are being d on ix mjor processing areas: metals and alloy elec mterials, glass and ceramics, biotechnology, tion, and luid dynamics I transpor These i will provide the tif t f f p pp tions f r echno as well as provide a better under of how these processes occur on the ground. Definition tudies il be performed Shutt and Space tion experiment candidates in ar such as conta less experiments, carbustion science, ifi and crystal gr ow and blood storage. Also included are maintenance of capabilities for i in dr tubes, towers and aircraft. and science for Joint o and Exchange Agr are included in this

Microgravity Shuttle/Space Station payloads is a consolidation of ongoing activities which provide a range of experimental capabilities for all scientific and commercial participants in the Microgravity Science and Applications program. These include Shuttle mid-deck experiments, the Materials Experiment Assembly and the Nlaterials Science Laboratory, which is carried in the orbiter bay. These capabilities will enable users to develop different experiments in a cost-effective manner and allow a better understanding of the technical risks associated with experiment concepts before attempting to develop more complex hardware; define and implement Microgravity Science experiment equipnent development and conduct key in-space experiments in support of current Space Station activities and future microgravity Space Station Laboratory work in Materials Science. In addition, reflight of investigations on Shuttle/Spacelab missions and the mid-deck is provided for in Materials Experiment Operations.

BASIS OF FY 1988 FUNDING REQUIREMENT

RESEARCH AND ANALYSIS (MATERIALS PROCESSING)

	1986 Actual	1987 Amended Budget	1987 Current Estimate	1988 Budget Estimate
		(Thousands of Dollars)		
Ground-based investigations, analysis and studies................	12,100	12,900	13,900	14,400

OBJECTIVES AND STATUS

The research and analysis activity provides the scientific foundation for all current and future projects in the Microgravity Science and Applications program. Emphasis is placed on ground-based research which is expected to evolve into space investigations with potential for future applications. This activity also supports technology development for future ground and space capabilities, and applications activities leading toward privately-funded space enterprises. Most research projects are initiated as a result of proposals from the scientific community which have been extensively reviewed by peer groups prior to selection. The FY 1987 funding is being used to support ongoing research.

CHANGES FROM FY 1987 AMENDED BUDGET

The funding increase of $1.0 million will be used to augment the use of low-gravity ground-based facilities (drop tubes/towers and aircraft) and for the Microgravity Materials Science Laboratory at the Lewis Research Center.

BASIS OF FY 1988 ESTIMATE

Ground-based research and analysis will be continued in FY 1988 in the areas of metals and alloys, electronic materials, glass and ceramics, biotechnology, combustion, and fluid dynamics and transport phenomena. Research will be conducted to define the role of gravity-driven influences in generic processing methods. Effort will continue at the centers for bioprocessing research located at the University of Arizona and the University City Science Center in Philadelphia, PA as well as the Microgravity Materials Science Lab at the Lewis Research Center.

! OF FY 1988 FUNDING [redacted]

IT SHUTTLE/SPACE STAT PAYLOADS

	1986 Actual	1987 Amended Budget	1987 Current Estimate	1988 Budget Estimate
		(Thousands of Dollars)		
Materials experiment operations.......	18,900	26,500	34,000	31,500

OBJECTIVES AND STATUS

The Micr /Sp Station payloads provi a wide range of p uni for ifi and r experiments i micrograv science and Development of tile mid-deck and cargo expe d Space ion ts are sup r un this activity. eliminary data analysis on Shuttle experiments alr flown has h promising results.

CHANGES FROM FY 1987 AMENDED BUDGET

As a result of Congressional direction, this area has been increased by **$7.5** million. This increase will be used to initiate conceptual design and procurement activities for Space Station Laboratory Module rmlti-user facilities, such as levitation devices, crystal growth hardware, and fluid physics experiment equipment. Advanced technology development efforts for high rate video and automation and robotics activity will also be initiated.

BASIS OF FY 1988 ESTIMATE

FY 1988 funding is required to continue basic and applied research activities using mid-deck and cargo bay experiments leading to several flights over the next few years. Investigations will be planned in' fluid dynamics, glasses, electronic mterials, biotechnology, metals and alloys, and combustion. Development will begin on a number of Physics and Chemistry Experiments **(PACE)** as well as continued developnent of several pieces of advanced equipnent in the areas of electronic crystal growth, biotechnology, metallic casting, and levitation.

Funding will also support definition activity for Space Station hardware development.

COMMUNICATIONS

RESEARCH AND DEVELOPMENT

FISCAL YEAR 1988 ESTIMATES

BUDGET SUMMARY

OFFICE OF SPACE SCIENCE AND APPLICATIONS — **COMMUNICATIONS PROGRAM**

SUMMARY OF RESOURCES REQUIREMENTS

	1986 Actual	1987 Amended Budget	1987 Current Estimate	1988 Budget Estimate	Page Number
	(Thousands of Dollars)				
Advanced Communications Technology Satellite (ACTS)	81,900	---	*85,000	----	
Research and analysis	9,770	14,000	13,000	14,400	RD 9-4
Search and rescue	1,100	1,000	1,000	1,300	RD 9-6
Technical consultation and support studies	2,518	3,200	3,200	3,400	RD 9-7
Experiment coordination and operations support	1,112	1,300	1,300	1,400	RD 9-8
Total	96,400	19,500	103,500	20,500	

Distribution of Program Amount by Installation

	1986 Actual	1987 Amended Budget	1987 Current Estimate	1988 Budget Estimate
Goddard Space Flight Center	2,924	5,087	5,349	5,644
Jet Propulsion Laboratory	6,393	8,272	6,733	6,660
Langley Research Center	36	---	---	---
Lewis Research Center	83,753	5,100	86,870	6,417
Headquarters	3,294	1,041	4,548	1,779
Total	96,400	19,500	103,500	20,500

*A proposed rescission of $26,000 for this project is included in the President's Budget.

I AND STATUS

The Communications Research and Analysis program continues to provide the development of subsystem component technology required by NASA, other government agencies, and U.S. industry for advanced communications satellite systems. Special emphasis is being given to pursuing technologies with high potential for improving spectrum utilization, satellite switching, and intersatellite link technologies, since these technologies are the key to future growth of the communication satellite and terminal markets. In addition, the mobile communications technology program will continue to address the development of critical enabling technologies needed to insure growth of a commercial mobile satellite service in the U.S. This effort, in cooperation with U.S. industry, Canada, and other government agencies, will help implement a first generation commercial system at the end of the decade.

The Search and Rescue program is an international cooperative program that demonstrates the use of satellite technology to detect and locate aircraft or vessels in distress. The United States, Canada, France, and the Soviet Union developed the system, in which Norway, the United Kingdom, Bulgaria, Finland and Denmark also participate. A five satellite system is now in service (two U.S. and three U.S.S.R. satellites) and has been credited with saving over 675 lives in numerous worldwide incidents. The operational responsibility for this program was transferred to NOAA in 1985.

The technical consultation and support program will continue to provide for studies of radio interference, propagation and special systems required for the growth of existing satellite services and the extension of new satellite applications. Support to the Department of State, the Federal Communications Commission, the National Telecommunications snd Information Administration, and other Agencies in the development of frequency and orbit sharing techniques and strategies for upcoming World Administrative Radio Conferences (WARC's) is continuing.

The experiment coordination and operations support program assists other federal agencies and public sector organizations in the development of experimental satellite communications for emergency, disaster and public service applications. Operation of the Applications Technology Satellite (ATS- 3) is continuing through contracts with the University of Miami.

Development work will be terminated on the Advanced Communications Technology Satellite (ACTS) demonstration flight. A proposed rescission has been included in the President's Budget for this project.

BASIS OF FY 1988 FUNDING [redacted]

RESEARCH AND ANALYS

	1986 Actual	1987 Amended Budget	1987 Current Estimate	1988 Budget Estimte
		(Thousands of Dollars)		
Research and analysis..................	9,770	14,000	13,000	14,400

VES

The i Research and Analysis progr r r developnent of high-ri technolog required to mintain U.S. p eminence in the ir satelli communicat market, to n bl new and innovative l ice an to meet the i needs of NASA and of other govermnt en i i program on the "interconnecti gie of on-board switching, ll k and n as well as advanced radio]) technologi Advanced studies are performed to ermine the future telli i r of the country and to define the r equir to meet tl needs. The technology is developed and tested g an advanced proof-of-concept (pr The POC devices and carponents are then integrated i a i terminal, i cmnications network in a labora hey undergo comprehensi tion.

In l work s continuing on advanced communications technologies. The laser cmications l: will permit improved ications between ites and ground termina l low t orb ting ehicles such as the Space t or Space or and between t and other geosynchronous orbiting li such as the Tracking and Data Relay ite (TDRS). Technology de lopmen is also in the area of thic microwave integrated ( ) have signif i or icat in tipor spacecraft matrix low noise receivers and mlti beam antenna arrays and formi networks. A number of industry studies are being sponsored to assess new areas of communicati echnolog required for tl 1 0

The mbile communications technologies activity is aimed at accelerating the introduction of a commercial mbile satellite service in the U.S., and developing and testing power, bandwidth and orbital-slot efficient ground segment technology and networking techniques needed to insure its growth. *An* innovative NASA offer to encourage industry participation was signed in FY 1985 as the basis for the program, and in early FY 1986, the NASA technology program received the support of industry at a mjor government/industry briefing. Recently the Federal Communications Commission allocated a frequency for danestic mobile satellite service. In FY **1986** system design studies were carpleted and hardware development was initiated. In FY **1987** field tests of selected hardware elements will be conducted.

CHANGES FROM THE FY 1987 BUDGET ESTIMATE

The reduction of **$1.0** million reflects the reallocation of funding to provide for other high priority requirements.

M I S OF FY 1988 ESTIMATE

During FY **1988**, advanced studies and selected technology developnent will continue in the high risk areas of microwave and optical technology, satellite switching, RF system, and intersatellite links. Work in these technology areas will support U.S. industry, NASA, and other govermnt agencies and address national economic and security interests.

In FY **1988** all prototype components for the mobile communications technology experiment will be carpleted and field testing of the full mobile terminal will begin.

BASIS OF FY 1988 FUNDING REQUIREMENT

SEARCH AND RESCUE

	1986 Actual	1987 Amended Budget	1987 Current Estimate	1988 Budget Estimate
		(Thousands of Dollars)		
Search and rescue	1,100	1,000	1,000	1,300

OBJECTIVES AND STATUS

The Search and Rescue program, developed by NASA and international partners, has demonstrated the feasibility of using satellites to improve significantly the ability to detect and locate general aviation aircraft and marine vessels during emergencies. The Search and Rescue satellite system has met all specifications and was declared operational in July 1985. The system has received world-wide acclaim and has been credited with saving over 675 lives to date. In addition, the system is demonstrating the potential to save millions of dollars annually in search logistics costs.

In FY 1987, work is continuing to improve system software efficiency, develop low-cost 406 MHz hardware, and initiate development techniques that will enhance the ability of the system to locate quickly those in distress.

BASIS OF FY 1988 ESTIMATE

In FY 1988, an experiment using geostationary satellites for instant alert will be completed and the results analyzed. Work to improve cost and performance of emergency beacons will continue.

BASIS OF FY 1988 FUNDING REQUIREMENT

TECHNICAL CONSULTATION AND SUPPORT STUDIES

	1986 Actual	1987 Amended Budget	1987 Current Estimate	1988 Budget Estimate
		(Thousands of Dollars)		
Technical consultation and support studies.....................	2,518	3,200	3,200	3,400

OBJECTIVES AND STATUS

Technical consultation and support studies provide the technical basis for regulatory and policy development to assure the orderly growth of existing and new satellite services. Unique analytical tools are developed and used to solve problems of inter- and intra-satellite/terrestrial system interference. Emphasis is placed on orbit and spectrum utilization studies, which include the development of frequency and orbit sharing techniques and strategies, design standards, and the determination of the effect of propagation phenomena and man-made noise on performance, design, and efficient use of the geostationary satellite orbit and the radio spectrum.

During FY 1986, a geostationary orbit arc allotment planning concept was developed as part of the U.S. preparations for the 1988 Space World Administrative Radio Conference (SWARC). Proper preparation is critical to U.S. objectives for maintaining flexibility in the use of orbiting and operating communications satellites. During FY 1987, work will proceed to obtain an international frequency allocation for mobile satellite operation.

BASIS OF FY 1988 ESTIMATE

In FY 1988, work will be completed on the geostationary orbit arc allotment planning method and support will continue for the second session of SWARC. Studies will continue €or the purposes of identifying techniques to increase the efficient use of the limited orbit/spectrum resources and to understand and alleviate the adverse effects of propagation phenomena on space communications.

BASIS OF FY 1988 FUNDING [redacted]

EXPERIMENT 'I(AND OPERATIONS SUPPORT

	1986 Actual	1987 Amended	1987 Current Estimte	1988 Budget Estikte
		B e n d s of Dollars)		
Experiment coordination and operations support...........	1,112	1,300	1,300	1,400

OBJECTIVES AND STATUS

The objectives of this program are to support and to docunent a wide range of user experiments and demonstrations of the application of satellite cmnications. Past experiments on experimental satellites, such as the Applications Technology Satellite (AIS) series and the Communications Technology Satellite (CTS), have successfully provided users with the experience necessary to mke informed decisions regarding the satellite cmnications functions. NASA's role to stimulate use of unique space facilities has led to wider application of commercial satellites that better meet the needs of potential users.

The remaining Applications Technology Satellite (ATS) ATS-3, continues to support the National Science Foundation, the National Oceanic and Atmospheric Administration, the Department of Commerce, the Department of Interior, the Drug Enforcement ministration, several universities, state and local governments, and a number of domestic and international disaster relief organizations. Support is provided through satellite voice and data links for scientific and cmnications experiments to North and South America, most of the Atlantic Ocean, and a large part of the eastern Pacific including Hawaii and Antarctica.

BASIS OF FY 1988 ESTIMATE

In FY 1988, operational support for ATS-3 will continue. NASA will maintain approval and policy control of the AIS program. NASA will continue planning support for educational, scientific, and public service communications experiments for organizations within the Western hemisphere, and will support similar experimental activities of Pacific basin organizations within the footprint of the AIS-3 coverage.

INFORMATION
SYSTEMS

RESEARCH AND DEVELOPMENT

FISCAL YEAR 1988 ESTIMATES

BUDGET SUMMARY

OFFICE OF SPACE SCIENCE AND APPLICATIONS | **INFORMATION SYSTEMS PROGRAM**

SUMMARY OF RESOURCES REQUIREMENTS

	1986 Actual	1987 hnded	1987 Current Est imte	1988 Budget Estimate	Page Number
		B e n d s of Dollars)			
Data systems..........................	â,500	9,300	9,400	9,700	RD 10-2
Information system..................	9,100	11,900	11,900	12,600'	RD 10-2
Total......,........................	17,600	21,200	21,300	22,300	

Distribution of Program Amount by Installation

	1986 Actual	1987 hnded	1987 Current Est imte	1988 Budget Estimate
Goddard Space Flight Center...........	12,293	15,047	15,047	15,749
Jet Propulsion Laboratory..............	3,889	4,195	4,295	4,496
Ames Research Center..................	100	300	300	314
National Space Technology Laboratories	175	255	255	267
Headquarters..........................	1,143	1,403	1,403	1,474
Total..............................	17,600	21,200	21,300	22,300

RESEARCH AND DEVELOPMENT

FISCAL YEAR 1988 ESTIMATES

OFFICE OF SPACE SCIENCE AND APPLICATIONS — **INFORMATION SYSTEMS PROGRAM**

PROGRAM OBJECTIVES AND JUSTIFICATION

The objectives of the Information Systems program are to: develop and demonstrate advanced capabilities of managing, distributing, and processing data and information; inplement information system standards and provide common software in order to lower data system costs; and develop the basis for data services to provide improved access to, and rapid delivery of, space data and advanced data systems in support of the nation's satellite programs and space science and applications projects.

This program provides for timely developnent of data system capabilities to meet the needs of flight missions and mjor space science and applications programs. The early demonstration of capabilities has a high potential for reducing ground data system developnent risks and for providing timely delivery of data to researchers.

CHANGES FROM FY 1987 AMENDED BUDGET ESTIMATES

The increase of $.1 million in FY 1987 enables studies of advanced processing systems, such as the Hypercube at the Jet Propulsion Laboratory, for potential application in planned science programs.

BASIS OF FY 1988 ESTIMATE

The FY 1988 Information Systems funding is required to provide support for space science and applications programs. Funds are required: to continue developnent of planetary, earth resources, and astrophysics data systems projects which are being implemented at the Jet Propulsion Laboratory, the Goddard Space Flight Center, and participating academic institutions; to continue implementation of on-line data directories and catalogs; to operate the large-scale computers in the Space and Earth Sciences Computing Center (SESCC) and the archives at the National Space Science Data Center (NSSDC) (both facilities located at the Goddard Space Flight Center); to develop common software to support ongoing research in the space and earth sciences; and to continue developnent of data management and data archiving to support flight projects, discipline program offices, and other NASA program offices. The FY 1988 funding levels will also provide the university/research community with inproved access to NASA computational facilities and data archives by expanding network cmnications links, by increasing online data storage capacities, and by developing standards for data and protocols.

COMMERCIAL
PROGRAMS

NATIONAL AERONAUTICS AND SPACE ADMINISTRATION

FISCAL YEAR 1988 ESTIMATES

RESEARCH AND DEVELOPMENT BUDGET PLAN FOR COMMERCIAL PROGRAMS

Commercial Programs	1986 Actual	1987 Budget Estimate	1987 Current Estimate	1988 Budget Estimate
	(Thousands of Dollars)			
Technology utilization........................	10,580	15,670	15,700	18,300
Commercial use of space.......................	16,220	25,600	25,600	35,700
Total..................................	26,800	41,270	41,300	54,000

TECHNOLOGY
UTILIZATION

RESEARCH AND DEVELOPMENT

FISCAL YEAR 1988 BUDGET ESTIMATES

BUDGET SUMMARY

OFFICE OF COMMERCIAL PROGRAMS | **TECHNOLOGY UTILIZATION PROGRAM**

SUMMARY OF RESOURCES REQUIREMENTS

	1986 Actual	1987 Amended	1987 Current Estimte	1988 Budget Estimate	Page Number
		Bends of Dollars)			
Product Development....................	1,140	1,470	1,500	1,920	RD 11-4
Acquisition, Dissemination and Network Operations....................	3,270	4,100	4,100	4,730	RD 11-4
Program Development, Evaluation and Coordination.........................	1,590	1,780	1,780	2,380	RD 11-4
Technology Applications.................	4,580	5,950	5,950	6,620	RD 11-5
Industrial Outreach...................	---	2,370	2,370	2,650	RD 11-5
Total...............................	10,580	15,670	15,700	18,300	

Distribution of Program Amount by Installation

	1986 Actual	1987 Amended	1987 Current Estimte	1988 Budget Estimate
Johnson Space Center..................	247	325	325	382
Kennedy Space Center...................	473	708	708	859
Marshall Space Flight Center...........	421	284	284	452
National Space Tech. Labs.............	278	a20	820	737
Goddard Space Flight Center............	1,090	1,307	1,337	1,232
Jet Propulsion Laboratory................	663	925	925	1,042
Ames Research Center...................	203	286	286	602
Langley Research Center................	588	817	817	672
Lewis Research Center.................	488	805	805	357
Headquarters...........................	6,129	9,393	9,393	11,965
Total...............................	10,580	15,670	15,700	18,300

OFFICE OF COMMERCIAL PROGRAMS

TECHNOLOGY UTILIZATION PROGRAM

PROGRAM OBJECTIVES AND JUSTIFICATION

The NASA Technology Utilization Program is designed to strengthen the national economy and industrial productivity through the transfer and application of aerospace technology resulting from NASA's R&D programs. To accomplish this objective, NASA has established and operates a number of technology transer mechanisms to provide timely access of useful technologies to the private and public sectors of the economy. Almost every part of U.S. industry is affected by the technology transfer process, especially in such areas as automation, electronics, materials, and productivity. In the public sector, medicine, rehabilitation, transportation and safety are areas in which aerospace technologies have been especially beneficial. The specific objectives of the program are:

o To accelerate and facilitate the application of new technology into the commercial sector, thus shortening the time between the generation of advanced aeronautics and space technologies and their effective use in the economy;

o To encourage multiple secondary uses of NASA technology in industry, education, and government, where a wide spectrum of techno ogical problems and needs exist;

o To develop applications of NASA s aerospace technology, including its unique facilities, to priority nonaerospace needs of the Nation.

OBJECTIVES AND STATUS

NASA has continued its broad and comprehensive efforts to promote and encourage the effective application and use of new and innovative aerospace technologies throughout the public and private sectors of the U.S. economy. Of particular note is the upward growth of industrial and business subscribers to NASA Tech Briefs which now exceeds 130,000 readers. This 60% increase since January 1985 represents a growth rate averaging oyer 5,000 new subscribers per month...an effective measure of the importance and value which U.S. industry places on new and emerging technologies.

Moreover, the NASA-sponsored Industrial Applications Center (IAC) network has made significant strides in developing effective linkages with state-sponsored institutions engaged in industrial and economic growth. This broadening and strengthening of the nationwide technology transfer network is continuing to gather momentum with nearly 20 of the 50 states now being linked to transfer products and services available through the **IAC** efforts. NASA expects to continue this effort during the balance of FY **1987** and on into FY **1988**. **An** additional milestone was reached in late **1986** when the Federal Laboratory Consortium **(FLC)** for Technology Transfer (formerly established under P.L. **99-502)** and NASA elected to enter into an agreement which establishes formal linkages between the NASA **IAC** network and the various Federal laboratories. Based on the successful conpletion of an experimental program between the NASA IAC at the University of Southern California and the FLC Farwest Region, **IAC** industrial clients **will** now be able to gain controlled access **to** Federal laboratories nationwide that are engaged in research and developnent activities of parallel comnercial interest. This effort should spur and accelerate the process for the transfer and application of Federally-sponsored technologies into the mainstream of the U.S. economy. **NASA** is also seeking to familiarize and involve the private sector to a greater extent. The hiatus in Shuttle flights caused by the Challenger accident has shifted the focus of NASA's commercial programs from in-space experimentation to ground-based opportunities and exploitation of available technology. The **IAC** are a natural focal point for increasing awareness of available technology and opportunities.

Several important events occured during the past year in which several NASA-sponsored Technology Applications projects came to fruition. Among these **was** the first human implant of the Programmable Inplantable Medication System (PIMS) at the Johns Hopkins University (JHU) Hospital in November **1986**. This successful human application of PIMS which culminates several years of intensive collaborative effort between NASA, JHU Applied Physics Laboratory, and various private sector firms, initiates a two-year clinical test period in which **20** or more implantations **will** occur. All of the scheduled applications during the test period **will** be for patients with chronic diabetes.

Finally, NASA authorized an experimental technology transfer program at the Jet Propulsion Laboratory as a means to enhance access to that laboratory's technology by the private sector. In **May** **1986**, NASA entered into a cooperative agreement with the non-profit California-based Research Institute for the Management of Technology **(RIMTECH)** to introduce JPL technology to industrial users in the Southern California area. For an entry fee, **RIMTECH** clients are offered NASA's technical assistance, information retrieval services, licensing rights and the possibility of cofounding of projects in the developnent stage. NASA, in turn, fulfills its charter and accrues the benefits of a broadened high-tech base industry, incentives for JPL employee creativity, potential royalities fran patent licensing, and reverse technology transfers to NASA/JPL from industry.

BASIS FOR FY 1988 ESTIMATE

	1986 Actual	1987 Amended Budget	1987 Current Estimate	1988 Budget Estimate
		(Thousands of Dollars)		
Product Development	1,140	1,470	1,500	1,920

Based on the increasing response to Tech Briefs and expanding IAC network, increases in new technology identification and reporting are anticipated in FY 1988. These resources will provide for evaluation and packaging of these technologies for publication to become available to industry to stimulate active interest in participating in NASA's Technology Utilization and Commercial Use of Space programs.

	1986 Actual	1987 Amended Budget	1987 Current Estimate	1988 Budget Estimate
		(Thousands of Dollars)		
Acquisition, Dissemination and Network Operations	3,270	4,100	4,100	4,730

In FY 1988, NASA plans to strengthen the Technology Counselor network at its field installations to provide for expanded identification of NASA technical capabilities and expertise. This capability and expertise is necessary for matching and cross-correlating NASA technology with industry needs specified by NASA Industrial Applications Centers. To facilitate timely and efficient interaction between Technology Counselors, Industrial Applications Centers and other organizations in the NASA technology transfer network, a coherent, microcomputer-based communications system is planned for FY 1988. Increased effective communication and data storage and retrieval systems will greatly enhance the overall capability of the network to coordinate technology transfer activities, and respond to user needs efficiently with minimum overlap and duplication of effort. Moreover, the system will enable technology transfer managers to maintain appropriate controls over the process to insure overall program effectiveness and management accountability.

	1986 Actual	1987 Amended Budget	1987 Current Estimate	1988 Budget Estimate
		(Thousands of Dollars)		
Program Development, Evaluation and Coordination	1,590	1,780	1,780	2,380

With an expanded role in industrial outreach, additional emphasis will be required in the development of program goals and objectives in terms of long range plans for NASA Technology Utilization (TU) and Commercialization Use of Space (CUS) programs. Focused efforts on assessing potential participants in U.S. industry, preparing information guidelines to support cooperative relationships throughout the NASA technology transfer network, as well as satisfying anticipated increased demand for TU/CUS program publications and responses to increased number of program inquiries are among the many management planning and support requirements. Specific actions are also planned for FY 1988 to strengthen program development, evaluation and coordination on an internal as well as external basis to support the national technology transfer network and commercial use of space outreach efforts.

	1986 Actual	1987 Amended Budget	1987 Current Estimate	1988 Budget Estimate
	(Thousands of Dollars)			
Technology Applications................	4,580	5,950	5,950	6,620

In FY 1988, a broadening of application team responsibilities is anticipated to assist NASA Industrial Applications Centers in brokering industrial client problems with existing aerospace technologies leading to project definition and industry-driven cooperative projects. This effort will result in increased tangible and meaningful applications of aerospace technology in the private sector, thus enhancing the productivity and competitive posture of U.S. industry.

	1986 Actual	1987 Amended Budget	1987 Current Estimate	1988 Budget Estimate
	(Thousands of Dollars)			
Industria) Outreach....................	---	2,370	2,370	2,650

In FY 1988, NASA will utilize its existing dissemination center network to contact and acquaint U.S. industrial firms with opportunities to actively interact and participate with NASA in technology transfer and space commercialization. Such contacts are envisioned on a face-to-face basis, with appropriate follow-up including seminars, conferences and workshops to explore more detailed characteristics of the "opportunities" for interaction. The NASA Industrial Applications Centers are in a unique position to serve as NASA's surrogate in aligning U.S. industrial interests in space commercialization as well as opportunities for commercialization of advanced technologies resulting from NASA's R&D programs. The technological needs of industry -- and of NASA -- would benefit from this synergistic approach designed to bring engineering resources of both in closer proximity.

Successful technology transfer occurs most frequently in an environment where knowledge is shared easily and advantages through cooperative endeavors are explained and understood. It is this role that the NASA dissemination center network can readily fulfill.

COMMERCIAL
USE OF SPACE

RESEARCH AND DEVELOPMENT

FISCAL YEAR 1988 ESTIMATES

BUDGET SUMMARY

OFFICE OF COMMERCIAL PROGRAMS — **COMMERCIAL USE OF SPACE**

SUMMARY OF RESOURCES REQUIREMENTS

	1986 Actual	1987 Amended	1987 Current Estimte	1988 Budget Estimate	Page Number
	(Thousands of Dollars)				
Commercial Applications R&D............	12,940	22,600	22,600	31,000	RD 12-4
Commercial Development Support........	3,280	3,000	3,000	4,700	RD 12-5
Total..............................	16,220	25,600	25,600	35,700	

Distribution of Program Amount by Installation

	1986 Actual	1987 Amended	1987 Current Estimte	1988 Budget Estimate
Johnson Space Center..................	150	560	560	1,040
Kennedy Space Center..................	50	---	---	---
Marshall Space Flight Center..........	4,334	6,350	6,350	11,430
National Space Technology Laboratories	236	110	110	300
Goddard Space Flight Center...........	40	890	890	1,000
Jet Propulsion Laboratory..............	190	---	---	---
Ames Research Center..................	168	280	280	580
Langley Research Center................	450	820	820	1,340
Lewis Research Center.................	1,294	1,170	1,170	1,940
Headquarters..........................	9,308	15,420	15,420	18,070
Total..............................	16,220	25,600	25,600	35,700

OFFICE OF COMMERCIAL PROGRAMS — COMMERCIAL USE OF SPACE PROGRAM

PROGRAM OBJECTI AND JUSTIFICATION

The goal of the Commercial Use of Space Program i to provide a iona cus i support of the :p of U.S. p sector investment and inv in civi space act ties while izing new high technology commerci space ventures and g the d of marke for l space services. The fi objectives f the program are to:

- Establish close working relations with the private sector and academia to encourage investment in space technology and the use of the in situ attributes of space - vacuum, microgravity, and radiation for commercial purposes.
- Facilitate private sector space activities through inproved access to available NASA capabilities.
- Encourage an increase in private sector investment in the comnercial use of space independent of NASA funding.
- Develop and inplement comnercial space policy NASA-wide.

OBJECTIVES AND STATUS

Nine Centers for the Commercial Developnent of Space (CCDS) have been established since the start of the program. A solicitation is underway to obtain proposals for as many as five new CCDS in 1987. Average cost of a CCDS is just under $1 million per year.

The Office of Commercial Programs (OCP) is building rmlti-user, rmlti-use govermnt hardware that will reduce individual entrepenuer experiment costs to a level that can be afforded. This hardware consists of various types of furnaces, mterials processing equipnent, and experiment carrier supporting structures that private companies may use for space experiments. Use of the hardware provides access to microgravity through flights on the shuttle, on NASA aircraft, and on sounding rockets. The total estimated cost of the present program will be approximately $50 million with hardware delivery starting in 1987.

The OCP has assumed responsibility for integration and mission management of unique Joint Endeavor

Agreement flight experiments. Work will start in FY 1987 to prepare experiments for flight and thus have them in a flight-ready status when the shuttle resumes flight. The work consists of analyzing the experiment's characteristics and requirements and making provision for the physical placement onboard the shuttle.

BASIS FOR FY 1988 ESTIMATE

	1985 Actual	1987 Amended Budget	1987 Current Estimate	1988 Budget Estimate
		(Thousands of Dollars)		
Commercial Applications R&D...........	12,940	22,600	22,600	31,000

In order to mintain momentum in commercial use of space activities, NASA will continue to establish Centers for the Commercial Developnent of Space (CCDS). Institutions with strong research capabilities in sciences and engineering, in collaboration with industry and/or industrial associations, will be encouraged to participate. The Centers are joint undertakings involving, to the extent practicable, teams of industrial corporations and/or govermnt agencies (other than NASA) and/or non-profit institutions. Resources support and technical assistance will be partially furnished by NASA with the remainder furnished by the Center members. In FY 1985, NASA provided partial funding to establish five Centers for the Commercial Developnent of Space. In FY 1986, NASA funded four additional Centers for a total of nine CCDS in operation. Awards are planned for FY 1987 and FY 1988 for an eventual total of up to 18 Centers sirmltaneously operating. NASA's individual CCDS funding is planned for five years in order to stimulate and stablize the Centers' activities. Nevertheless, NASA's support, on a year-to-year basis, will depend on a favorable annual review of the Centers' progress in stimulating commercial use of space. There is a mandatory requirement for industry participation in each Center, including the expenditure of corporate resources. NASA support will be reduced and finally discontinued at the end of five years as the successful Centers achieve self-sufficiency.

NASA's goal of expanding opportunities for U.S. private sector investment and involvement in civil space and space-related activities will be partially achieved by increasing the amount of space-related research conducted by the private sector, the number and type of NASA and private sector facilities available for space use, and the private sector awareness of the opportunity to use NASA's terrestrial and space-based facilities for potential commercial research.

Through coordination with various industrial sectors, the commercial R&D enhancement efforts will provide generic, rmlti-use research experimentation equipnent. This equipment, as well as ground-based hardware, software and analytical tools will be developed in order to expand the technical research database on the commercial uses of space required by the private sector to help mke economic decisions to commit to research and, potentially, mnufacture. Emphasis is placed on building the required technical infrastructure. The main thrust of the effort will be directed by the private sector in coordination with NASA. Resources will also be made available to obtain flight support experimentation hardware required by industrial researchers. This my include across-the-bay carriers, such as Hitchhiker4 or Materials Science Laboratories, as well as mid-deck augmentation racks or derivatives thereof. Both analytical and physical integration support are required for experiments conducted under Joint Endeavor Agreements (JEA). The NASA support for JEA's is directly proportional to the number of commercial research and developnent flight experiments scheduled and it is intended to encourage private sector use of space facilities. The use of ground-based research facilities, aircraft and sounding rockets for commercial experimentation will be given emphasis in order to provide limited access to the microgravity enviromnt for certain commercial experiments. Sounding rocket use will allow proof-of-concept testing and hardware check-out in a limited duration microgravity enviromnt.

	1986 Actual	1987 Amended Budget	1987 Current Estimate	1988 Budget Estimte
Commercial Developnent Support........	3,280	3,000	3,000	4,700

The support of the Commercial Use of Space Program requires a broad foundation. Ad hoc and continuing studies by experts are required to provide the direction and feedback needed by the program, especially where the economic, commercial and technical circumstances are changing rapidly. Short and long range plans and agency policy are adjusted based on the results of the studies. Support services and equipnent hardware maintenance are the other elements of commercial developnent support.

AERONAUTICS AND
SPACE TECHNOLOGY

NATIONAL AERONAUTICS AND SPACE ADMINISTRATION

FFISCAL YEAR 1988 ESTIMATES

RESEARCH AND DEVELOPMENT BUDGET PLAN FOR AERONAUTICS AND SPACE TECHNOLOGY

	1986 Actual	1987 Budget Estikte	1987 Current Estimte	1988 Budget Estimate
		(Thousands of Dollars)		
Aeronautical research and technology...........	337,257	376,000	376,000	375,000
Transatmospheric research and technology.......	---	45,000	45,000	66,000
Space research and technology..................	151,400	171,000	171,000	250,000
Total....................................	488,657	592,000	592,000	691,000

AERONAUTICAL
RESEARCH AND
TECHNOLOGY

RESEARCH AND DEVELOPMENT

FISCAL YEAR 1988 ESTIMATES

BUDGET SUMMARY

OFFICE OF AERONAUTICS AND SPACE TECHNOLOGY — AERONAUTICAL RESEARCH AND TECHNOLOGY

SUMMARY OF RESOURCES REQUIREMENTS

	1986 Actual	1987 Amended Budget	1987 Current Estimate	1988 Budget Estimate	Page Number
		(Thousands of Dollars)			
Research and technology base...........	228,557	272,900	272,900	285,200	RD 13-6
Systems technology programs..	108,700	103,100	103,100	89,800	RD 13-35
Total..............................	337,257	376,000	376,000	375,000	
Distribution of Program hunt by Installation					
Johnson Space Center.......	1,000	1,100	---	---	
Marshall Space Flight Center...........	1,000	1,100	1,600	1,700	
Jet Propulsion Laboratory...............	213	200	200	200	
Goddard Space Flight Center............	383	300	300	300	
Ames Research Center...................	141,894	165,600	167,900	161,700	
Langley Research Center................	96,218	118,400	118,000	121,500	
Lewis Research Center..................	88,396	82,600	80,300	81,900	
Headquarters..........................	8,153	6,700	7,700	7,700	
Total..............................	337,257	376,000	376,000	375,000	

PROGRAM OBJECTIVES AND USTIF

The goal of the **NASA** aeronautical research and technology program is to conduct effective and productive aeronautical research and develop technology which contributes materially to the enduring preeminence of U.S. civil and military aviation. This goal is supported by five comprehensive program objectives: (1) identify and concentrate on those emerging technologies with potential for order-of-magnitude advances in aircraft capability and performance that will enhance U.S. industrial competitiveness; (2) sustain the excellence of **NASA's** research centers by modernizing and enhancing the efficiency of national facilities, advancing scientific and engineering computational capabilities, and enhancing staff technical excellence by selecting highly qualified personnel and providing them with challenging career opportunities; *(3)* ensure timely and efficient transition of research results to the U.S. aerospace community through reports, conferences, workshops, and active participation of industry in contractual and cooperative programs; *(4)* ensure the strong involvement of universities in **NASA's** program to broaden the nation's base of technical expertise and innovation; and (5) provide technical expertise and facility support to the Department of Defense (DOD), other government agencies, and U.S. industry for major aeronautical programs. These objectives require a broad program of fundamental research, that focuses on critical technologies and accelerates technology readiness for future vehicles.

The **NASA** aeronautical research and technology program is intended to provide results well in advance of specific applications through long-term independent research and technology which is not driven by the development and operational pressures often encountered by the DOD and industry. Fundamental research in the traditional aeronautical disciplines is pursued concurrently with systems research directed at interaction among disciplines, components, and subsystems. Ongoing and planned research in the program represents a major contribution to the technological foundation for securing and maintaining world leadership in aeronautics for the United States.

CHANGES FROM FY 1987 AMENDED BUDGET

The FY 1987 funding for the aeronautical research and technology program has not changed from the estimate submitted last year. Funding adjustments within disciplines have been made in response to changing program requirements and accomplishments, and are explained within each individual program statement.

BASIS OF FY 1988 ESTIMATE

The FY 1988 research and technology program has been redirected to emphasize and focus on those technological opportunities which have potential for order-of-magnitude increases in vehicle capabilities and substantive impact on U.S. competitiveness. Previous progress in hypersonic technologies has led to the creation of the joint DOD/NASA national aero-space plane program. This program is being supported over the entire spectrum of fundamental disciplinary research and technology in the aeronautics program. The ongoing turbine engine hot section technology (HOST) and the ceramics for turbine engines systems technology programs have been combined and augmented into a high-temperature propulsion materials program aimed at revolutionary advances in engine thrust-to-weight ratio applicable to a broad range of aerospace vehicles. The demand for NASA's unique aeronautics research and test facilities is growing with the emergence of the national aero-space plane program and a new generation of military aircraft requiring extensive wind tunnel testing. In order to meet growing demand for development and new research needs with aging facilities, NASA is accelerating its wind tunnel modernization program, while also launching a broad study to identify the highest priority needs to guide future facilities enhancements. A brief summary of the key elements of the research and technology base and systems technology programs follows.

In fluid and thermal physics, research will focus on aerodynamic benchmark experiments to provide the data base for validating recent breakthrough computational fluid dynamic analyses for three-dimensional viscous flows and for developing models of complex flow phenomena. Activities will emphasize linking gas dynamics and chemical kinetics in advanced simulation codes for application to viscous, real-gas, external flows about hypersonic flight vehicles. In the fundamental flow physics area, emphasis is focused on the experimental and computational analysis of turbulence, turbulent flows, and vortical flows capitalizing on pathfinding advances in numerical aerodynamic simulation technology. Devices and design techniques to reduce viscous drag for supersonic aircraft will be developed from this research.

Applied aerodynamics will concentrate on high angle-of-attack aerodynamics, developing techniques to control vortex instabilities to enhance the maneuverability of future high-performance aircraft. Emphasis also will be placed on rotorcraft acoustics, air load prediction, and augmented flight dynamics. The 40x80-foot wind tunnel will become fully operational, supporting many joint programs with the DOD and industry, as well as NASA specific research.

In the propulsion area, research is providing a fundamental technology base for advanced propulsion systems. Emphasis will be placed on detailed flow measurements in the large, low-speed centrifugal compressor facility to verify three-dimensional viscous flow codes for turbomachinery and on thin film sensors for use on propulsion components made of high-temperature composite materials, including ceramics. Development and verification of analytical codes for supersonic combustion ramjets, variable geometry inlets, and propulsion/airframe integration will also be pursued for very high-speed flight.

Materials and structures activities will include fundamental research in high-temperature materials; advanced design concepts and processing technology to exploit the unique properties of composites; computational methods development for analysis of loads and structural response of advanced vehicle configurations and engine systems; and structural concepts for hypersonic vehicle applications, including methods for active and passive thermal management. A focused effort will continue in rotorcraft air loads to develop and validate noise and vibration prediction technology.

In information sciences research, multiple process architectures, operating systems, programming languages, and algorithms for very high performance applications will be explored. Special emphasis will be placed on fundamental research related to software systems that perform with ultra-high reliability in spite of either hardware or software faults.

Controls and guidance research will investigate active controls technology for structural weight reduction and control of aeroelastic response, techniques for dynamic integration of structures and controls to optimize performance and identify problems early in the design process, and application of artificial intelligence and expert systems to achieve advanced cockpit automation. Emphasis on analytical modeling and airborne detection of wind shear will address technology for safer adverse weather operations.

Human factors research will pursue technology advances to enhance the overall capability, safety, and reliability of the crew-cockpit system. Emphasis will be placed on flight crew procedure monitoring with automated error detection and correction, flight validation of rotorcraft workload prediction methods, computer-based modeling of crew performance, vision system requirements for automated nap-of-the-earth rotorcraft flight, and field studies of pilot error in automated aircraft.

Flight systems research will be directed at improving safety of flight in severe weather conditions. This includes technology for safe operations of aircraft and helicopters in icing conditions and for design of aircraft better able to survive encounters with severe weather. Improvements of analytical and experimental techniques for high-speed aircraft, including powered-lift aircraft with vertical or short takeoff and landing capabilities, will continue.

In systems analysis, studies will continue toward identifying the most promising aircraft concepts for future high-speed civil transportation.

Rotorcraft system technology activities will include development of a comprehensive helicopter data base in loads, vibration, acoustics, and performance to validate predictive methodologies and completion of a cooperative research program with the U.S. rotorcraft industry. Active controls and advanced rotorcraft configuration research, such as tilt rotor and X-wing, will accelerate with the promise of dramatic improvements in speed, agility, maneuverability and productivity for civil and military operations.

The turbine engine hot section technology program and the ceramics for turbine engines program will be combined and augmented to develop a fundamental high-tenperature mterials technology base for advanced propulsion system. The principal focus will be on ceramics, carbon-carbon and metal mtrix composite mterials. These advanced mterials will enable much higher tenperatures than present turbines and engine hot section components can withstand, with prospects for totally eliminating the need for cooling air -- currently a costly penalty to engine performance. This technology will allow sustained supersonic cruise, high thrust-to-weight engines for advanced vertical takeoff and landing concepts, and much higher fuel efficiency.

High-performance aircraft research will concentrate on the application of integrated propulsion and flight controls to enhance military aircraft mission effectiveness, selection of the most promising supersonic vertical takeoff and landing configuration(s) for focused technology development, and extended verification of the advanced technologies incorporated into the X-29A forward-swept-wing aircraft. Detailed design, fabrication, aircraft modification, and flight qualification testing will continue on the joint NASA/Navy oblique wing technology program, leading to flight tests in FY 1989.

The advanced turboprop program will emphasize increased fundamental understanding of source noise, cabin acoustics, and installation aerodynamics encarpassing both single- and counter-rotation propellers. The general aviation and commuter engine research program will continue to provide the technology base for small gas turbine engines to improve fuel consumption through advanced high-pressure ratio, mixed-flow component technology and innovative cycle concepts.

The numerical aerodynamic simulation (NAS) initial operating configuration will be fully operational in the new facility in 1987. The second high-speed processor will be integrated into the system, and the support subsystem will be upgraded for the extended operating configuration, which will be operational in mid-1988. Operation support will be combined with NAS developnent in systems technology to increase the efficiency of mnaging the NAS and to enhance its development in an integrated fashion.

BASIS OF FY 1988 FUNDING REQUIREMENTS

RESEARCH AND TECHNOLOGY BASE

	1986 Actual	1987 Amended Budget	1987 Current Estimate	1988 Budget Estimate	Page Number
		(Thousands of Dollars)			
Fluid and thermal physics research and technology	29,210	39,500	39,500	29,000	RD 13-7
Applied aerodynamics research and technology	51,680	57,100	56,100	61,000	RD 13-10
Propulsion and power research and technology	32,355	35,700	38,700	41,000	RD 13-14
Materials and structures research and technology	27,830	39,000	39,000	42,000	RD 13-18
Information sciences research and technology	23,816	26,800	23,800	26,000	RD 13-22
Controls and guidance research and technology	20,653	24,500	24,100	27,600	RD 13-25
Human factors research and technology	21,360	24,000	24,000	26,000	RD 13-29
Flight systems research and technology	17,891	21,500	21,900	26,100	RD 13-30
Systems analysis	3,762	4,800	5,800	6,500	RD 13-33
Total	228,557	272,900	272,900	285,200	

	1986 Actual	1987 Amended Budget	1987 Current Estimate	1988 Budget Estimate
	(Thousands of Dollars)			
Fluid and thermal physics research and technology..........................	29,210	39,500	39,500	29,000

OBJECTIVES AND STATUS

The fluid and thermal physics research and technology program is a combined analytical and experimental research effort directed at external aerodynamics. One of its principal objectives is the development of computational methods, which will increase the speed and efficiency of three-dimensional (3-D) flow solvers by two orders of magnitude, for the prediction and simulation of complex fluid flows over aircraft. A second objective is the validation of prediction and simulation methods by means of a coordinated experimental test program with particular focus on accurate 3-D turbulent models for attached or separated flows. This activity provides improved insight into the fundamentals of flow physics, as well as the detailed flow measurements required for verification of the computations. Drag reduction research is conducted with emphasis on developing specific devices and design techniques to reduce overall aircraft drag by up to 60 percent. Rapid progress is being made in the development and validation of computational techniques that will lead to reduced development time and costs for future aircraft and will provide the basis for achieving new and higher levels of aircraft and missile performance.

The goal of computational fluid dynamics (CFD) research is to predict and simulate the aerodynamic flow field for complete aircraft or missile configurations in any flight condition. To this end, the program includes the development of computer codes for simulating turbulence and for solving complex fluid dynamics problems, including steady and unsteady, inviscid, and viscous flow over two- and three-dimensional geometries from low subsonic to hypersonic speeds. Improved algorithms for Euler and Navier-Stokes codes were developed for efficient use of new supercomputer technology to make possible early utilization of the advanced capabilities provided by the initial operations of the numerical aerodynamic simulation (NAS) program. Significant progress has been made in the application of CFD techniques to complete aerodynamic configurations. For the first time, viscous flow over an entire aircraft has been computed and validated for realistic flight conditions. In addition, gas dynamic and chemical kinetic effects have been incorporated into computational codes that simulate the viscous, real-gas external flows about hypersonic vehicles.

The advancement and confidence in CFD research relies heavily on a detailed understanding of flow physics which provides input for more accurate mathematical modeling of the flow. Increased effort has, therefore, been devoted to the modeling of turbulence and to the validation of CFD codes.

Detailed benchmark data bases are being acquired to provide the flow field and boundary conditions for the validation of computational codes. A vortical flow data base was generated from detailed low-speed experiments of a delta wing model at high angles of attack for CFD code validation. The understanding and control of viscous flow phenomena are vital in the development of advanced aerodynamic configurations. Significant progress has been made in viscous flow research, particularly in the drag reduction area. Wind tunnel and flight tests have proven the riblet as an effective device for turbulent drag reduction, providing a 6-percent reduction in skin friction drag. Also, the large eddy break-up concept has been computationally analyzed and redesigned for application to transonic flows. Active laminar flow control research on the Jetstar aircraft is nearing completion, and results have proven that wing flow suction in a small region at the leading edge is effective in establishing laminar flow over a large portion of the wing. It was demonstrated that severe environmental effects, tested under realistic operational conditions, do not adversely affect the drag reduction. Natural laminar flow research flight testing was begun on the F-14 aircraft where the effects of sweep and Mach number on boundary layer transition will be explored.

Experimental and analytical aerodynamics research efforts have resulted in a number of low- and medium- speed airfoil designs being transferred to industry. The national transonic facility (NTF) was heavily utilized in experimental research and problem-solving testing. Extensive, tests were conducted on a modified EA-6B model in the NTF where low-speed stability and lift were significantly improved. These modifications provided an 18-percent increase in lift at low speed. Advances in analytical aerodynamics included the development of an accurate thin-layer Navier-Stokes method for transonic, high-Reynolds number flows of isolated wings. Construction of the fluid mechanics laboratory at the Ames Research Center was completed. This laboratory contains a number of small research facilities that are used for fundamental fluid physics investigations. Theory and experiments are being closely coupled in this environment in turbulence modeling, vortical flow studies, high angle-of-attack flows, and for other complex fluid phenomena. Advances were made in the understanding of vortex-thrust and vortex-lift phenomena through testing of wing leading-edge extensions and cavity flaps.

CHANGES FROM THE FY 1987 AMENDED BUDGET

The total funding level for Fluid and Thermal Physics Research and Technology program did not change. However, Cyber 205 operations costs of approximately $3.0 million were transferred to this program from Information Sciences Research and Technology. This increase was offset by other support reductions.

BASIS OF FY 1988 ESTIMATE

In FY 1988, the CFD program will continue to improve 3-D configuration analysis and design. This will be accomplished principally through the development of numerical algorithms with an order-of-magnitude improvement in speed and efficiency over current solvers. Particular focus will be given to validating Navier-Stokes prediction codes for unsteady rotorcraft aerodynamics and codes incorporating real-gas effects and finite-rate chemistry to predict aerodynamic performance, heat transfer, and engine/exhaust flows for hypersonic vehicle concepts. Development of applications codes will be broadened to include greater integration of aerodynamics, structures, propulsion, and controls.

Aerodynamic benchmark experiments designed to validate CFD techniques and provide data for flow modeling will be conducted. Data will be acquired to improve the modeling of complex flows that experience separation, vortical motions, and streamwise or transverse curvature.

Viscous flow research in FY 1988 will focus on improving the understanding of the physics of turbulent flows and the development of techniques and devices to reduce or eliminate turbulence induced aircraft drag. Development of the holographic velocimeter concept will be pursued as a means of exploring fundamental turbulence phenomena and gathering turbulence modeling data. The modification and extension to supersonic speeds of existing subsonic turbulent skin friction reduction devices will be carried out. An analysis technique will be developed for predicting hypersonic boundary-layer transition. Methods will be developed for reducing induced drag. Research in turbulence control will be performed where sensors and logic circuitry will be used in controlling the adverse effects of turbulence. The F-14 variable-sweep transition flight experiment with natural laminar flow wings will be completed. The concept of hybrid laminar flow control, where laminar flow control and natural laminar flow techniques are combined, will be explored.

Research in experimental and analytical aerodynamics will focus on the analysis of vortical flows. Vortex formation, breakdown, and control will be studied in a series of wind tunnel tests. Additionally, wind tunnel tests of high-alpha leading-edge and trailing-edge separation phenomena will be conducted to understand the flow physics and investigate possible mechanisms for controlling vortex formation. A large panel aerodynamics computer code will be enhanced with advanced flow solvers to handle transonic flows. National transonic facility correlation model test results will be used in calibrating three transonic wind tunnels. Fundamental skin friction experiments on laminar flow concepts, leading-edge breakup devices (LEBUs) and riblets will be performed in flight at subsonic and supersonic speeds to build the technology base for drag reduction. Boundary-layer transition control on low- and medium-speed airfoils will be investigated in wind tunnel tests.

	1986 Actual	1987 Amended Budget	1987 Current Estimate	1988 Budget Estimate
		(Thousands of Dollars)		
Applied aerodynamics research and technology..........................	51,680	57,100	56,100	61,000

OBJECTIVES AND STATUS

The objective of applied aerodynamics research is to generate advanced technology to improve the performance and flight dynamics of future aircraft and missiles through analytical and experimental programs. The effort is directed at specific technology goals associated with each class of vehicle: (1) increased efficiency for subsonic aircraft through airframe and propulsion integration, greater stall–spin resistance, improved takeoff and landing performance using powered lift, and a 60–percent reduction in cruise drag; (2) accurate prediction of the aerodynamic sources of rotorcraft noise and vibration, and the improvement of rotorcraft performance and flight dynamics for doubled productivity and agility; (3) high angle–of–attack maneuverability, sustained supersonic performance, and short takeoff and vertical landing (STOVL) capability for high–performance aircraft; (4) a 50–percent increase in lift–drag ratio for supersonic cruise aircraft; and (5) a 40–percent increase in hypersonic lift–drag ratio for hypersonic and transatmospheric vehicles. These programs utilize a broad variety of test facilities and are supported by continuing development of test techniques and instrumentation. The objective of the test techniques research is to improve experimental capability and achieve an order–of–magnitude improvement in the accuracy of wind tunnel data. In addition, the program includes aeroacoustics research that develops the basic predictive capabilities and control techniques for specific noise problems, such as the effect of acoustic loads on aircraft structure and system performance.

Subsonic aerodynamics research emphasizes development of technology to reduce induced drag and minimize interference drag. High lift systems are being explored that are applicable to advanced, low–drag natural laminar flow wings. The benefits and limitations of unconventional configurations using forward sweep and canards are being demonstrated by wind tunnel testing. For general aviation aircraft, stall–spin prevention research continues with analysis of twin–engine designs and large-scale tests of a business jet with a spin–resistant airfoil. Recent stall–spin research results have led to a new Federal Aviation Administration (FAA) certification regulation. Drag reduction research using laminar flow control (LFC) is emphasizing the practical installation effects, such as panel edges, and intersections in a flight test of an LFC glove on the NASA Learjet. In subsonic powered-lift research, large–scale testing of new concepts is underway, including cooperative programs with industry, the Department of Defense, and allied governments. A NASA/Navy large–scale model of the subsonic Grumman 698 tilt fan aircraft is being tested in the recently upgraded 40x80-foot wind tunnel. An advanced technology transport is being analyzed and tested for the U.S. Air Force.

In rotorcraft aerodynamics research, basic acoustic analysis is showing promise for the reduction of certain types of noise and higher order aerodynamic computer codes are being developed, along with detailed airloads experiments, to provide the prediction accuracy required for design and certification of improved vehicles. Validation of computer codes for the prediction of blade aerodynamics was supported by several small-scale wind tunnel tests to address wake geometry and blade vortex interaction. Application of these codes to modification of the Blackhawk helicopter rotor blades provide a 3-percent increase in lift capability. Support for the V-22 tilt rotor program continues, using the upgraded 40x80-foot wind tunnel for prototype testing and the XV-15 tilt rotor aircraft with new advanced technology blades for performance tests. Work on combat maneuverability with the U.S. Army in simulation of air-to-air engagements to determine fundamental flying qualities and agility requirements was conducted. Active control of individual blade pitch is also being investigated and shows high promise of improving noise, vibration, control augmentation, and performance.

The high-performance research program is examining three high payoff areas for aerodynamic investigation: (1) sustained supersonic cruise, (2) high angle-of-attack maneuverability, and (3) vertical lift operation. For supersonic cruise, new nonlinear approaches to laminar flow and airfoil shapes are being developed to double cruise efficiency. In high angle-of-attack research, active and passive control of vortex flow has shown promise for improving the control problems associated with this maneuver condition. In addition, the use of multiaxis thrust vectoring is being explored after successful free-flight tests in the 30x60-foot wind tunnel. These fundamental efforts are developing the research base for flight experiments to be conducted under the systems technology element for high-performance flight research. In the supersonic fighter STOVL program, an ejector lift-vectored thrust fighter model is being constructed in large scale by Canada for testing by NASA in a cooperative program. In addition, in-house studies of other supersonic STOVL concepts are underway to support an early decision to choose the most attractive approach.

Activities in hypersonics were expanded in FY 1987 in both the experimental and theoretical areas. Experimental wind tunnel tests were conducted on advanced aerospace configurations that show promise for atmospheric cruise flight applications and airbreathing accelerator launch vehicles. The application of computational fluid dynamics to the simulation and analysis of complex flow fields was carried out using a newly developed computer code which simulates viscous hypersonic flows about realistic configurations.

Research leading to new testing capability and techniques continues to be pursued to support aerodynamics research. The national transonic facility is continuing to demonstrate capability for cryogenic wind tunnel testing in order to simulate full-scale conditions with independent control of compressibility, viscosity, and aeroelasticity parameters. Models tested to date include the space shuttle, the EA-6B for the Navy, and the Pathfinder I, a generic transport with interchangeable components. Nonintrusive measurement devices, such as laser anemometers which provide large payoffs in accuracy and productivity, will continue to be improved.

In aeroacoustics research, model tests which quantify the effects of the acoustic fatigue loads on the aft end of high-performance fighters have been completed. Flight tests of twin-plume resonance are under way to confirm these loads and investigate a method of detuning the jets to reduce acoustic fatigue.

CHANGES FROM FY 1987 AMENDED BUDGET

The decrease of $1.0M in applied aerodynamics research and technology primarily reflects decreases in test techniques (-$0.2M), rotorcraft (-$0.4M), and fighter attack aircraft (-$0.3M) technologies and other small adjustments.

BASIS OF FY 1988 ESTIMATE

In FY 1988, subsonic aerodynamics research will develop technology to reduce induced drag and minimize interference drag. High lift systems that are applicable to advanced, low-drag, natural laminar flow wings will be designed. The benefits and limitations of unconventional configurations using forward sweep and canards will be demonstrated by wind tunnel testing.

Activities in rotorcraft aerodynamics research will include an intensive schedule of large-scale tests in the 40x80-foot wind tunnel, focusing on the aerodynamic phenomena that cause noise, vibration, loads, and unstable rotor dynamics behavior. A bearingless main rotor will be tested to define high-speed dynamic stability and loads for this advanced configuration. A simplified method of higher harmonic control for vibration reduction will be tested on a full-scale rotor. The aerodynamic interference between a main rotor, fuselage, and a tail rotor will be investigated in another test. Each of these tests seeks to validate a portion of an analysis code that predicts the aerodynamic behavior involved. Small-scale tests will also be conducted to understand the strong influences of the rotor wake on airloads prediction. In flight dynamics research, a new activity will be started in cooperation with the U.S. Army's development of a variable-stability research helicopter. This new research tool will have higher harmonic pitch control, a flexible research control system, and a highly maneuverable rotor system. Such capabilities are key to understanding the potential for advanced control on highly maneuverable combat rotorcraft.

High-performance aerodynamic research in sustained supersonic cruise will translate the improvements predicted in airfoil and laminar flow into carefully constructed wind tunnel experiments. High angle-of-attack research will investigate stability and control at angles up to 80 degrees to support the planned flight research on the F-18 vehicle and will provide the aerodynamic data base necessary for piloted simulations of maneuvers using thrust vectoring for control. In powered-lift technology, the large-scale fighter model of an ejector lift/vectored thrust model will be tested in the 40x80-foot wind tunnel in a cooperative effort with Canada. Several studies and tests on critical technology areas, such as sustained supersonic cruise and ground-effect penalties in hover, will be undertaken in support of the U.S./United Kingdom program in supersonic STOVL. Simulation of the proposed STOVL concepts will determine required levels of control power and flying qualities criteria.

In the area of test techniques and instrumentation, development of advanced cryogenic instrumentation with emphasis on accurate boundary layer diagnostics, sensing of model attitude and structural deformation, and the development of an ultra-high force balance will continue in the national transonic facility. In other test techniques activity, the laser holography visualization effort will focus on measurement of turbulence quantities in order to provide detailed data bases to support turbulence modeling and CFD validation efforts. Adaptive walls will become operational in the Langley Research Center 0.3-meter and the Ames Research Center 2-foot wind tuhnels. Fluorescent techniques will be developed for simultaneously sensing temperature, velocity, density, and skin friction parameters. The recently developed liquid crystal coatings for boundary layer research will be extended to supersonic and hypersonic flows.

Additional emphasis will be placed on modernizing and improving the test efficiency of NASA's major wind tunnels to meet increasing research and development demand. Specific focus will be on test instrumentation and data acquisition systems to increase the productivity of national wind tunnels. Additional investments will be made in maintenance and operations to assure reliability and availability of these national resources for major development programs.

The FY 1988 aeroacoustics research will focus on the development of three-dimensional flow prediction of near-field acoustics in the tip region of supersonic propellers.

Hypersonic cruise/transatmospheric concepts will be designed, tested, and analyzed to establish a data base for this evolving aerospace vehicle class. Wind tunnel models will be constructed and tested over a wide speed range (through hypersonic Mach numbers) to simulated high altitudes over a range of Reynolds numbers at the Langley Research Center. The computational fluid dynamics program at the Ames Research Center will be expanded to include real-gas effects and the effects of flow-field separation on realistically complex aerodynamic shapes.

	1986 Actual	1987 Amended Budget	1987 Current Estimate	1988 Budget Estimate
		(Thousands of Dollars)		
Propulsion and power research and technology	32,355	35,700	38,700	41,000

OBJECTIVES AND STATUS

The objective of the propulsion and power research and technology program is to provide the understanding of the governing physical phenomena at the disciplinary, component, and subsystem levels that will support and stimulate future improvements in propulsion system performance capability, efficiency, reliability, and durability. Research is being performed on a wide variety of subsystems with applications ranging from the general aviation class through the hypersonic aerospace plane. Ongoing disciplinary research on instrumentation, controls, internal fluid mechanics, and aerothermodynamic concepts is providing the foundation necessary for continued advancements at the component and subsystem level. These research efforts will lead to major propulsion system improvements for all types of aircraft.

Hypersonic propulsion research has as its objective the maturing of supersonic combustion technology and the study and development of propulsion concepts for high-speed cruise in the Mach number range of 3 to 6. A Mach 5 inlet has been designed using two-dimensional codes and was tested at small scale using flow visualization to obtain qualitative information and attractive instrumentation placements subsequent to large-scale experiments. The flow was found to be highly three-dimensional, showing that two-dimensional codes will be inadequate for design of high-speed inlets. Analytical development includes a time-dependent, three-dimensional, fully elliptical Navier-Stokes code to analyze complex flow fields and subsequently serve as a design tool.

For high-performance applications, the goal is to develop technology to support propulsion systems capable of vertical takeoff and landing using powered lift and in-flight thrust vectoring capability. Fabrication of the powered-lift test rig has been completed at the Lewis Research Center. In 1987, the rig will be used for evaluation of the U.S./Canadian ejector concept to obtain system performance and loss data. Fabrication of the hot gas ingestion model will be completed in 1987, and testing will begin in the low-speed 9x15-fopt wind tunnel at the Lewis Research Center to determine the extent and effect of hot gas ingestion into the inlet during powered-lift operations. These results will be used to verify hot gas injection computer codes that are currently under development.

The objective of small engine research is to achieve a fuel consumption reduction of 50 percent and multifuel capability for intermittent combustion engines. Research emphasis for stratified-charge rotary engines, offering possible multifuel capability, includes improved understanding of the physics that will enable accurate prediction of advanced engine performance and operating boundaries. The computer modeling of rotary engine flow fields has been completed along with the fabrication of a rig to perform detailed flow measurements. At Deere and Company, a 40-cubic-inch single-rotor engine obtained 160 horsepower, the highest power density ever attained in a rotary engine. In 1987, new fuel injection schemes and advanced rotors are being investigated for improved fuel consumption. For small gas turbines, a large, low-speed centrifugal compressor facility is currently scheduled for completion and initiation of research in FY 1987. The facility will be used to investigate boundary layers and secondary flows and verify advanced three-dimensional viscous flow codes for turbomachinery.

In supersonic cruise, the objective is to develop technology for lightweight, effioient propulsion concepts for supersonic cruise conditions. Research is being focused on the analysis and experimental verification of the supersonic throughflow fan. This system offers the potential of 20-percent fuel savings compared to an advanced variable-cycle engine for a long-range supersonic transport-type aircraft. The design of a proof-of-concept fan stage and rig is nearing completion using advanced three-dimensional Euler and Navier-Stokes codes. In 1987, the rig will be fabricated and checked out in preparation €or test of the supersonic throughflow fan.

Instrumentation and control research is aimed at developing advanced high-temperature sensors and optical nonintrusive measurement systems for research applications and engine sensors and controls for future propulsion systems. The first optical instrumentation system, that allows nonintrusive flow measurement of all three velocity components through a single viewing port, has been used to map a turbine stator cascade to develop verification data for secondary flows. Bench tests have started on an advanced anemometer that has the capability of measuring detailed flow characteristics very near fixed surfaces. In support of high-temperature electronics development, a silicon carbide-based diode was demonstrated at 300°C, and the final major step in device fabrication capability was completed by demonstrating plasma etching. Studies are underway to eliminate the occurrence of antiphase boundaries, discovered during the past year, during production of silicon carbide crystals. Unchecked, this could degrade the performance of devices fabricated from the crystals. In FY 1987, the performance of a control sensor failure accommodation control on an F-100 engine will be demonstrated at the Lewis Research Center over the flight envelope.

Internal computational fluid mechanics (ICFM) is an increasingly important tool for understanding flow phenomena and as a basis for design capability in aeropropulsion systems. The objective is to develop advanced algorithms and methods for analysis of complex three-dimensional flows in high-speed inlets and nozzles, turbomachinery, and chemically reacting flows and to validate the analytical techniques with fundamental benchmark experiments. A quasi three-dimensional Navier-Stokes code has been developed for turbomachinery, and a full three-dimensional code will be operational in 1987. The potential to describe the flows in more than one stage of turbomachinery was recently demonstrated with a new multistage code which reduces computer time significantly. An experiment was performed using laser diagnostics to develop a unique data set describing the structure of a normal shock interacting with a boundary layer and the flow field downstream of the shock. This flow field is typical of those found in high-speed inlets and transonic turbomachinery. The data set is currently being used to verify two- and three-dimensional Navier-Stokes analysis codes.

CHANGES FROM FY 1987 AMENDED BUDGET

The increase of $3.0M in propulsion and power research and technology primarily reflects increases in small engine technology, internal computational fluid mechanics, and supersonic cruise technology.

BASIS OF FY 1988 ESTIMATE

Hypersonic propulsion activities will continue with development of the analytical and experimental data base for supersonic combustion and Mach 3 to 6 high-speed cruise systems. Code development will continue for the complex flow fields in scramjet combustors, variable geometry inlets, and high-speed propulsion and airframe integration. Algorithms for high-speed flows (up to Mach 20) that reduce required computer time will be extended to three-dimensional capability and to include chemical heat release. Experimental efforts will include the evaluation of a scramjet module that reduces stresses in the walls of the combustor by transitioning from a two-dimensional inlet to an axisymmetric combustor. In addition, the Mach 5 two-dimensional inlet test will be completed at the Lewis Research Center in the 10x10-foot supersonic wind tunnel which will be used to verify advanced three-dimensional Navier-Stokes codes that will be capable of analysis of practical high-speed inlets.

High-performance aircraft research will include an evaluation of a complete simulation of a supersonic advanced short takeoff and vertical landing aircraft and propulsion system. A General Dynamics E-7 ejector system test on the powered-lift rig will be completed to determine the detailed pressure drop and flow distribution on a representative configuration. Short diffuser inlets will be evaluated to determine potential performance at high angle-of-attack operation for supermaneuvering capability.

Supersonic cruise research will continue to focus on the supersonic throughflow fan concept. The tests will be completed on the inlet and diffuser portions of the test rig and compared to analytical predictions to help verify the codes being used for the design of supersonic inlets and ducts. The fan will be fabricated and tests initiated by the conclusion of 1988. The results of the fan experiments will be used to verify three-dimensional viscous analysis codes and help guide the development of off-design analysis codes. Systems studies will be conducted to determine critical technologies required for a propulsion system that incorporates a supersonic throughflow fan for various high-speed applications.

Small engine research includes rotary engines and increased emphasis on gas turbines. Laser anemometer flow measurements will be used to verify a generalized multidimensional rotary engine computer program that will be used to design the aerodynamic shape of a lightweight rotor for incorporation into the experimental program at Deere and Company. Gas turbine research efforts will concentrate on developing an experimental data base using the large low-speed centrifugal rig completed in 1987. The rig will allow detailed measurements using laser anemometers of boundary layers developed on the rotor, secondary flows, and separated flow regions in both the rotor and diffuser, and the effect of tip clearance on the flow structure in the compressor.

Advanced instrumentation and controls research will continue to focus on nonintrusive measurement and high-temperature structural phenomena for code verification and optical sensors and actuators for propulsion system application. The four-spot laser anemometer will measure near-wall boundary-layer flow in a warm turbine facility to verify advanced codes. A second nonintrusive optical flow measurement system, an electronic heterodyne holographic interferometer, will be used to define flow structure in highly accelerating regions, such as shocks in a transonic cascade. High-temperature applications will include the demonstration of a thin-film heat flux sensor and characterization of a silicon carbide-based metal-oxide semiconductor field effect transistor at 400°C. Preliminary designs of functional fiber optic sensor and actuator systems will be completed for an integrated propulsion/flight control system.

Research emphasis in internal computational fluid mechanics will continue on advanced prediction capabilities for high-speed propulsion. For both existing codes and new codes under development, predictions of the aerodynamic flow field will be combined with reacting flow, combustion, and heat transfer to yield the capability of describing the total process taking place within a propulsion system. An advanced algorithm for simulating shocks in high-speed flows will be tested in a three-dimensional Navier-Stokes code. An advanced three-dimensional Navier-Stokes testbed solver will be completed with the capability of replacing algorithms without restructuring the code. Analytical and experimental efforts will continue on unsteady flows with shear layers to investigate the effect of shear layer excitation on mixing control in high-speed combustion systems. A multistage turbomachinery code will be improved to include viscous effects and fundamental experiments will begin for data required to enable use of the average-passage approach necessary to model the real turbomachinery case where the flow is not averaged.

	1986 Actual	1987 Amended Budget	1987 Current Estimate	1988 Budget Estimate
		(Thousands of Dollars)		
Materials and structures research and technology..........................	27,830	39,000	39,000	42,000

OBJECTIVES AND STATUS

The objectives of the materials and stru tures research and techn logy program are to: (1) investigate and characterize advanced metallic, ceramic, polymer, and composite materials; (2) develop novel structural concepts and design methods to exploit the use of advanced materials in aircraft; (3) advance analytical and experimental methods for determining the behavior of aircraft structures in flight and ground environments; and (4) generate a research data base to promote improvements in performance, safety, durability, weight reduction, and economy in aircraft. Areas of emphasis include high-temperature engine and airframe materials and structural concepts; composite materials application; life prediction; thermal and dynamic response, including aeroelasticity; helicopter structural dynamics and airloads; and more accurate and efficient integrated design optimization methods for airframes and engines.

Research in turbine engine materials continues to create a strong technology base for ceramic materials applications at higher temperatures with increased reliability and reproducibility. A new ceramic design code that accounts for the brittle material behavior has been successfully developed and transferred to industry. Improvement of ceramic material strength at high temperature has been successfully accomplished with a new sintering process using silicon nitride. The development of ceramic composites is expected to provide a material system that is of sufficient strength and durability to have a wide range of design applications in advanced turbine engines.

In aircraft materials research, studies are being conducted in advanced material systems for very lightweight and very high temperature applications to understand mechanisms of damage, the environmental effects on the properties of composites, the prediction of microstructure, and the bulk properties of materials. Significant advances have been made in understanding alloy chemistry and secondary processing of advanced fiber-reinforced aluminum alloy; strong, high-temperature, silicon-carbide fiber-reinforced intermetallics for aircraft propulsion systems; and a new process for three-dimensional, woven, thermoplastic composites for airframe structures.

Computational structural mechanics (CSM), a major thrust in FY 1987, continues to focus on the development of advanced structural analysis and computational methods that exploit advances in computer hardware and software, such as multiple processors and parallel processing capability. A CSM software testbed concept has been developed to accelerate the development and evaluation of new computational methods and computer systems utilization. CSM analysis methods have already made important contributions to the understanding and improvement of the shuttle solid–rocket motor clevis/tang joint design.

Research in aircraft structures emphasizes the development of design and analysis technology for efficient damage–tolerant advanced composite structural components and innovative structural concepts. Thermomechanical structural analysis has been developed for high–temperature complex engine structures. Methodology for solving interdisciplinary design problems, including design optimization, is continuing. The prediction of structural loads due to intense acoustic radiation in advanced turboprop applications is being pursued. Significant accomplishments made in 1987 include the development of advanced geodesic composite panel design concepts with filament–wound isogrid panel construction, proven construction and fabrication technique of a half–scale fuel strut for a scramjet engine concept, and validated three–dimensional stress analysis of cracked structures which allowed improved redesign of the blades of large wind tunnel drive fans.

In the aeroelasticity program, new and more efficient unsteady aerodynamic computational methods, with emphasis on transonic flow, are being developed and verified with experiments. A comprehensive transonic unsteady aerodynamic and aeroelastic analysis code has been transferred to industry and the Air Force for application. A new concept for an actively controlled flexible wing has been successfully tested in the transonic dynamics tunnel, and this concept represents a breakthrough for future advanced high–speed aircraft design to alleviate maneuver loads with improved roll rates. Aeroelastic analysis performed on the X–wing aircraft revealed new design aspects which will improve the operational aeroelastic stability.

In rotorcraft research, an augmented effort starting in 1987 is focused on measuring and understanding the detailed rotor airloads through wind tunnel and shake tests. Initial airload data will be acquired with the UH–60 helicopter in flight. Whirl testing and flight tests of the Boeing Model *360* will extend the airload and structural dynamic data base to airspeeds beyond 180 knots. A new test apparatus is being constructed for the 40x80–foot wind tunnel to test both of these rotors to compare with the flight test results. A better definition of difficult–to–model fuselage components is being pursued to overcome the large prediction errors for airframe vibratory response.

Hypersonic research continues to explore innovative new materials and structures concepts for airframe and propulsion systems for advanced aerospace vehicles. In both areas, studies are directed toward the development of new lightweight material systems and structural concepts that will withstand the extreme high temperature and loads encountered in the hypersonic flight regime. An integrated flow/thermal/structural analysis methodology has been developed and verified with experimental results. Current research in hypersonic materials has established the feasibility for three–dimensional woven carbon–carbon fiber–stiffened structure and an arc spray processing technique for advanced metal matrix fabrication. A new vehicle sizing methodology has been developed for vehicle weight assessment and optimized for both structural loads and failure criteria.

BASIS OF FY 1988 ESTIMATE

Research on materials will concentrate on advancing the understanding of material behavior, properties, microstructures, and processing parameters for advanced metallic, ceramic, polymer, and composite materials. Strong emphasis will be placed on advanced high-temperature metallic and nonmetallic materials. New and tougher resin/fiber composites, high-temperature polyimides (700^{o}F), aluminides, and aluminide matrix-silicon carbide composites will be developed. Work on powder metallurgy and weldable superplastic forming techniques for aluminum will continue with greater emphasis. Fundamental material behavior and processing techniques for brittle materials will be pursued. Generalized, multiaxial constitutive models for composites will be developed for prediction of environmental effects, cyclic damage, and rate dependence.

In the structures area, emphasis will be placed on development of innovative structural concepts for composites using advanced filament winding and pultrusion, as well as design concepts using high-temperature brittle materials. Analytical and experimental studies will continue to develop advanced structural concepts and configurations that exploit the advantages of composites. Structural analysis will concentrate on nonlinear methods for predicting the structural response under complex thermomechanical load histories. Synthesis and optimization methodology will be used to obtain high-performance aircraft structures. Efforts in structural response under acoustic loads will continue. Facilities for high-temperature structural fatigue will be developed to increase the experimental capabilities in fatigue/failure assessment on advanced structural materials.

The dynamics and aeroelasticity program will emphasize the development of improved analytical tools for predicting unsteady aerodynamic loads for transonic flow with particular emphasis on three-dimensional flow for the total vehicle configuration. Innovative flutter suppression research will be pursued together with the development of novel flight deflection measurement techniques, such as electro-optical sensor systems. New aeroelasticity concepts, such as the flexible actively controlled wing developed in FY 1987, will be refined through systematic wind tunnel tests, and data will be correlated with analysis.

In the area of integrated analysis and design optimization, efforts will concentrate on the development of efficient methods in CSM for the analysis of complex aerospace vehicles and propulsion systems. Emphasis will be placed on nonlinear analysis of high-temperature engine structures and nonlinear transient dynamics of multibody problems and rotating shafts. Large displacement procedures will be developed for analyzing stiffened composite panels required for composite airframe design. CSM analysis methods development will continue in the areas of concurrent computing methods with multiple and parallel processor computers and efforts in software testbed development will be expanded. Research will also be initiated to exploit the Cray 2 supercomputer of the numerical aerodynamic simulator for CSM research applications.

Research in subsonic transports, commuter airplanes, and general aviation aircraft will be focused on safety issues for ground operation and crash load alleviation. Structural and dynamic analysis will be conducted to understand ground handling problems, including friction and rolling effects on tires. Work will continue on the development of airframe subfloors using the energy absorbing composite structural concepts. Advanced tire testing activities will utilize the aircraft landing dynamics facility recently modified to obtain 220-knot test speed capability.

The rotorcraft activity will continue to concentrate on the detailed airloads and airframe structural dynamics. The large rotor test rig for the 40x80-foot wind tunnel will be completed and ready for use to test the UH-60 and Boeing Model 360 rotors planned in FY 1989. A model 360 helicopter with extensively instrumented rotor blades will begin flight testing to augment the data base obtained with wind tunnel and shake tests. Effective approaches for active vibration suppression, as well as structural detuning, will be studied. The fuselage vibration analysis will be extended to include rotor/fuselage coupled vibration.

In FY 1988, more emphasis will be directed toward hypersonic materials and structures research. Innovative concepts to enable future high-speed, high-temperature aerospace vehicles will continue to be developed. Integrated flow/thermal/structural analysis methods will be used for accurate mission loads prediction to aid the development of lightweight, efficient, and durable design of airframe and propulsion systems. New concepts and methodology for controlling the aeroservoelastic behavior at hypersonic speeds will be pursued. Actively cooled primary structural concepts will be investigated. Hypersonic materials research will be focused on carbon-carbon control surfaces; constitutive behavior and characterization of high-temperature, lightweight composites; fabrication of intermetallic composites with low density matrices; and oxidation-resistant and thermal barrier coatings.

	1986 Actual	1987 Amended Budget	1987 Current Estimate	1988 Budget Estimate
		(Thousands of Dollars)		
Information sciences research and technology..........................	23,816	26,800	23,800	26,000

OBJECTIVES AND STATUS

The objectives of the information sciences research and technology program are to increase NASA's capabilities in advanced aerospace computing and to exploit key computer science disciplines to meet the agency's unique computing requirements. Support for computational fluid dynamics (CFD) and other aerospace research disciplines is provided by developing a fundamental understanding of the relationships between essential algorithms and advanced architectures and exploiting the potential of concurrent processing to significantly increase computing power. Software engineering to support aerospace research includes research and development of concepts for advanced operating systems, programming languages, and user interfaces for distributed and parallel architectures. Another key objective is to establish the technology base for cost-effective, reliable computing in complex, mission-critical hardware and software systems.

Significant progress toward enabling efficient computation of aerospace algorithms was made in the last year. The most fruitful approach has been to ensure that computer architectures and the computational algorithms are well matched. It was demonstrated that multiple instruction/multiple data stream architectures with common (shared) memory, such as the Cray XMP and Cray 2, can efficiently process CFD algorithms. By use of an approximate factorization, three-dimensional flow problems were split into separate one-dimensional problems which ran on independent processors, with the three-dimensional grid data accessible through common memory.

The usual mapping of data to the hypercube architecture for performing fast Fourier transforms is not efficient when performing nearest neighbor mesh computations on the same data. Since these computations are used together in many CFD algorithms, it is important to use a mapping which is good for both. This year, a code mapping which shows promise in greatly increasing the efficiency of CFD calculations on the hypercube is being investigated. Other algorithms currently being investigated on the hypercube architecture include multigrid Navier-Stokes solvers.

A special purpose architecture for solving Navier-Stokes equations, the systolic Navier-Stokes processor, has been designed and a prototype was built this year. The high performance of this system has been achieved in a very cost-effective design which will enable supercomputing capability for NASA flow codes without use of expensive general purpose supercomputers.

Research on the implementation and application of sparse distributed memory (SDM) was initiated this year. SDM is a fundamental breakthrough in computer memory architecture. It is theoretically capable of learning to recognize similar events and conditions by experience and training without the need for programming by software. Simulations are underway to verify essential capabilities of SDM. Intelligent systems based on SDM might include avionics that are able to effectively manage unanticipated events which, in turn, would increase the reliability of highly automated aerospace vehicles.

There have been significant research results this year which support NASA's goal of establishing a technology base for reliable, fault-tolerant computer systems in mission-critical applications. A reconfigurable concurrent architecture has been defined which provides significantly higher reliability with less redundancy than previous approaches. This kind of architectural research will ultimately enable flight-crucial computer systems to automatically reconfigure in order to maintain adequate performance and to degrade gracefully upon further failure.

A high-speed mainframe computer networking subsystem (CNS) has begun operation to help NASA achieve its goal of improving the effectiveness and productivity of large mainframe computers which are essential for aeronautics research and technology programs. Using the program support communications network (PSCN), the CNS has achieved a transmission rate of 1.544 million bits per second. The network enables efficient transmission of large data and program files between NASA's geographically distributed research centers.

CHANGES FROM FY 1987 AMENDED BUDGET

The decrease of $3.0M in this program is primarily the result of the Ames Research Center's Cyber 205 computer no longer being funded within this program area.

BASIS OF FY 1988 ESTIMATE

Research in matching computer architectures and algorithms will continue to serve NASA's needs for efficient processing of aerospace algorithms. Investigations of the most advanced supercomputers, such as the Cray 2, and their use for computational fluid dynamics research and similar problems will continue. In addition, more comprehensive approaches may be established in cooperation with the Defense Advanced Research Projects Agency (DARPA) and the National Science Foundation (NSF). One approach under consideration is the formation of a center for advanced architectures which would bring together application scientists, computer architects, and software specialists to study the utility of specific architectures for specific algorithms. This center would allow sharing of advanced computers and research results.

A hardware prototype of sparse distributed memory (SDM) will be built. This will be used to conduct application studies to test the theory with real pattern recognition problems. A study will be conducted to determine the feasibility of a modified SDM for performing simulations of dynamic gases at far greater resolution than currently possible.

In the area of redundant software, studies will quantify the reliability gained as a function of redundancy and will develop strategies for reducing errors. The cost and reliability of very large aerospace software projects will hinge on integrated, comprehensive, and automated software management tools. For this reason, increasing emphasis will be placed on software support environments. This work will concentrate on management of the software life cycle.

NASA is working with other federal agencies to identify the issues and devise a plan for interconnecting the NASA PSCN and other research-oriented networks, including those from the NSF, DARPA, National Academy of Sciences, and the Department of Energy. This will establish a consistent mechanism to allow sharing of both computing and network resources.

	1986 Actual	1987 Amended Budget	1987 Current Estimate	1988 Budget Estimate
		(Thousands of Dollars)		
Controls and guidance research and technology..........................	20,653	24,500	24,100	27,600

OBJECTIVES AND STATUS

The objectives of the controls and guidance research and technology program are to: (1) investigate emerging controls, guidance, artificial intelligence, and display 'technologies which offer automation/system integration for aviation effectiveness and efficiency; (2) develop architectures for flight-crucial systems for future aircraft and devise analytical methods and techniques for assessing their reliability and performance; (3) develop methods to alleviate the threat of wind shear and heavy rain through airborne detection and avoidance; (4) develop advanced controls and guidance theories and analysis methods for extending the performance envelope and reliability of highly augmented future aircraft; and (5) explore new concepts for achieving integration of multidisciplinary technologies.

Control theory research includes activities on analytical methods, controls modeling, and applications. Methods for analyzing and simulating reconfigurable/restructurable control systems continue to be a major focus with the objective of achieving automatic failure detection and identification in order to accommodate unanticipated failures in real time. A control law was developed for damping shock-induced flutter. A new research thrust is the development of the theory for closed-loop control by symbolic processing to allow the use of high-level mission goals for effective and safe flight management and control.

Guidance and display concepts research is directed toward enabling flight and ground systems tolerant of human error. In the guidance concepts area, progress has been made in formulating approaches to utilize and apply artificial intelligence and expert systems technology in various aircraft applications. For military airplanes, the main thrust involves flight evaluations of automated wingman and advanced lead-pilot advisor concepts; for civil aircraft, the main emphasis is on the air traffic controller associate. A controller descent advisor and expert system schedule advisor have been demonstrated in air traffic control simulations. A technique for high-resolution stereo displays in 3-D has been demonstrated. A new approach for increasing thin-film electroluminescent display brightness by an order of magnitude has been conceived and will be evaluated in prototype hardware.

Flight-crucial systems research has concentrated on the development of a technology base for the design, validation, and assessment of highly reliable guidance and control systems. The avionics integration research laboratory facility at the Langley Research Center is the focus for a significant part of this research, which has extensive industry and university involvement. Activities in fault injection, computer synchronization, and software reliability have been completed to validate reliability estimation computer programs. Three reliability prediction computer codes have been effectively transferred to industry.

Controls and guidance research directly applicable to subsonic transports includes activities on advanced transport operating systems, airborne Doppler radar wind-shear detection, advanced digital control system architectures, and flight safety. The joint NASA/Federal Aviation Administration airborne wind shear program was initiated in 1986. A takeoff and landing monitor was developed and successfully evaluated by over 30 pilots. The monitor provides pilots with an integrated display of aircraft state during takeoff/landing, including safety warnings and indications of optional stopping positions on the runway.

Rotorcraft guidance and controls research involves unique concepts to enable automated nap-of-the-earth (NOE) flight. Flight tests were completed on a highly portable low-cost beacon landing system. It shows great promise for use in a battle-damaged airfield mission scenario for both fixed-wing and rotorcraft applications. A real-time terrain-following and terrain-avoidance trajectory coupler was developed for low-altitude rotorcraft flight.

Controls and guidance research directly applicable to high-performance aircraft includes the integrated airframe and propulsion control system architecture program aimed at the development of validation methodology for complex integrated control systems and the integration of aerodynamic, structural, propulsive, and control system dynamics. A comprehensive set of control system design metrics has been selected based upon analytical studies of nonlinear aerodynamics and flexible aircraft models. These metrics are being evaluated in piloted real-time simulations.

Hypersonic vehicle controls and guidance research is directed toward guidance and outer-loop control concepts which can significantly affect the performance and efficiency of hypersonic cruise vehicles operating at very high altitudes. Conventional guidance and control techniques may not be optimum in the upper atmospheric environment at which these vehicles will operate, and new considerations, such as extremely high-temperatures, may dictate completely new primary guidance and control modes. Initial studies are underway for evaluating active controls concepts for future aerospace vehicle concepts.

CHANGES FROM FY 1987 AMENDED BUDGET

The decrease of $0.4M in controls and guidance research and technology is the net effect of a number of changes internal to the program, including decreases of $0.6M in guidance and display concepts and $0.2M in flight crucial systems, offset by an increase of $0.4M in fighter/attack aircraft technology.

BASIS OF FY 1988 ESTIMATE

In the applied aircraft control theory area, a key goal is to develop robust control algorithms which are resistant to vehicle or environment uncertainties. The prime technical challenge is to develop a completely restructurable controls algorithm for unanticipated failures. Future thrusts will be directed toward bringing viable theories into simulated flight environments for evaluation. Additionally, nonlinear modeling and system identification methods are being developed to support high angle-of-attack controls requirements.

Guidance and display concepts research includes the application of artificial intelligence technology to military and civil aircraft operations. One planned focus is the automated wingman program undertaken in cooperation with Defense Advanced Research Projects Agency. The automated wingman concept has the potential for making substantial improvements in the effectiveness of multiaircraft strike forces through the application of artificial intelligence technology. The approach for conducting flight research in this program, involving a ground computational facility and a remotely augmented vehicle, offers the potential for validating artificial intelligence flight systems and the capability for simulating complex aircraft and multiaircraft systems in a cost-effective manner.

In the flight-crucial systems area, research will stress validation techniques, assessment technology, software reliability, lightning effects, and advanced architectures. Recent software reliability research has indicated a potential fallacy in classical software reliability assumptions. Increased emphasis will be applied to develop a credible software reliability model based on validated assumptions. In the advanced architecture area, the' proof-of-concept hardware and software of the advanced information processing system, a distributed fault- and damage-tolerant architecture designed for real-time aerospace applications, will complete test and validation.

Controls and guidance research directed at subsonic transports includes advanced transport operating systems, highly reliable digital control systems architectures, and safety. The major focus in advanced transport operating systems will be evaluation of air traffic control automation aids for unequipped and four-dimensional (4-D) flight management system equipped aircraft operations within the national airspace system. Research will establish preliminary algorithms needed to allow a transport to automatically fly the optimized trajectory from cruise to the terminal area metering fix, flight crew interfaces, and ground controller procedures to intermix 4-D and non-4-D equipped aircraft. This research will be performed in close coordination with the Federal Aviation Administration.

Rotorcraft controls and guidance research involves the application of artificial intelligence and expert systems technology to the difficult military rotorcraft mission of all-weather NOE operations. The objective of this research is to develop flight path management and planning concepts for terrain following and terrain avoidance and manually controlled helicopter NOE flight, leading to automated flight. An expert system will be developed for onboard mission replanning during NOE flight, and concepts for providing the interface between the pilot and the system will be formulated. This research will be performed in cooperation with the U.S. Army.

Controls and guidance research directed at high-performance aircraft applications will stress development of a supermaneuverability technology base for high angle-of-attack research. Proposed design methods will be evaluated and honed in piloted simulation.

	1986 Actual	1987 Amended Budget	1987 Current Estimate	1988 Budget Estimate
		(Thousands of Dollars)		
Human factors research and technology..	21,360	24,000	24,000	26,000

OBJECTIVES AND STATUS

The objective of the aeronautical human factors research and technology program is to provide the capability to design effective crew-cockpit systems using advanced cockpit automation technologies which will properly integrate the diverse systems, operators, and procedures. This is necessary for safety, efficiency, and increased capability in transcentury rotorcraft and transports and, ultimately, in the national aero-space plane. This is accomplished by developing an understanding of crew capabilities, limitations, and tendencies in interacting with these systems and by delineating guidelines for implementing that understanding. There are four areas of emphasis: flight management, human engineering methods, rotorcraft, and subsonic transports.

The flight management research program continues to emphasize: (1) determination of the relationship between human performance and advanced automation, (2) information management for advanced cockpits, (3) computer-aided interface design tools, and (4) evaluation and modeling of pilot sensory and information transfer performance. Operational incidents, such as those collected by the Federal Aviation Administration (FAA)/NASA aviation safety reporting system, continue to provide researchers with guidance about the most critical areas requiring investigation. The rapid advancement of onboard computers has dramatically altered the nature of the piloting task.

An expert system which automatically detects crew procedure errors was completed and readied for testing in full mission simulation. The system contains information about expected behaviors, phase of flight, and other operational details. It is a key component in a more fully capable system which will be human error tolerant.

An intelligent cockpit aid was developed for fault monitoring and diagnosis utilizing a knowledge-based approach to system description.

The subsonic air carrier research program concentrates on: (1) determination of sources of pilot error in operational aviation environments and evaluation of systems and operating procedures, (2) improved pilot selection and training methods, and (3) investigation of methods for improving information transfer in the national airspace system. This year, a major, full-mission simulation study of the human factors aspects of the FAA's traffic alert and collision avoidance system (TCAS) was initiated at the request of the FAA and the Air Transport Association.

	1986 Actual	1987 Amended Budget	1987 Current Estimate	1988 Budget Estimate
	(Thousands of Dollars)			
Flight systems research and technology	17,891	21,500	21,900	26,100

OBJECTIVES AND STATUS

The objective of the flight systems research and technology program is to provide the necessary research and technology development for an improved and validated base of advanced technology for application by industry to future generations of the entire spectrum of aircraft. In many cases, joint funding is provided by NASA, Department of Defense, and Federal Aviation Administration (FAA). The program is organized into the following main categories: (1) aviation safety, (2) flight instrumentation and test techniques, (3) high-performance aircraft, and (4) flight support. The activities within this program encompass advanced engineering techniques and the establishment of the feasibility of concepts to ensure rapid application of promising new technology essential to meeting one or more of the following goals: (1) reducing aircraft accidents resulting from weather effects (heavy rain, wind shear, lightning, turbulence, and icing); (2) improving flight efficiency, enhancing data accuracy, and enabling the acquisition of previously unobtainable information; and (3) establishing a technology base for the design of future fighter aircraft with unprecedented maneuverability at high angle-of-attack (up to 90 degrees) flight conditions.

The objectives of the activities in aviation safety are to provide a better understanding of aeronautical safety hazards and their consequences and to provide criteria for design of aircraft systems and operating techniques. They involve the development of analytical models to predict ice accretion and its effects on aircraft handling qualities and airfoil performance for both rotary- and fixed-wing aircraft, development of ice protection concepts, establishment of a flight-validated lightning strike data base, and development of an understanding of the effects of heavy rain on aircraft aerodynamic and propulsion system performance. A program has been initiated to develop an intercollated graphite thermal anti-deicing concept for composite aircraft surfaces. Development of an airfoil ice accretion computer code has been completed, and research efforts related to advanced aircraft applications have been initiated. In the area of heavy rains, a critical design review was successfully completed for the planned use of the aircraft landing dynamics facility for heavy rainfall simulation using a large-scale wing model. The instrumented F-106 severe storms research aircraft completed its lightning strike flight research activity. The resulting first-of-a-kind data base is providing the basis for the development of lightning strike effects models for use by FAA and industry for materials and avionics protection. Wind tunnel investigations of heavy rain effects are providing an initial data base for modeling the resulting degradation of aircraft performance.

The objectives of the high-performance aircraft program are to refine and validate aerodynamic predictive tools at high angle-of-attack flight conditions and demonstrate the performance benefits and utility of propulsive flight control. Negotiations have been conducted with the United Kingdom for cooperative investigations of several design concepts for an aircraft with supersonic and advanced short takeoff and vertical landing (ASTOVL) capability.

The objectives of the flight support program are to provide a variety of support services to flight research projects using standard aircraft for chase, airspeed calibration, remotely piloted research vehicle air drops, and flight crew readiness training. Replacement of the aging F-104 high-performance support aircraft at the Dryden Flight Research Facility with Navy-loaned full-scale development F-18 aircraft has been initiated.

CHANGES FROM FY 1987 AMENDED BUDGET

The flight systems research and technology program has been increased by $0.4M, reflecting increased emphasis in high angle-of-attack and vortex flap technology.

BASIS OF FY 1988 ESTIMATE

In FY 1988, the aviation safety program will emphasize coordinated wind tunnel and analytical investigations of ice accretion and its effects on fixed- and rotary-wing aircraft performance and handling qualities. Research to establish a flight-validated severe storms and lightning effects data base will be completed and the results reported to the FAA and industry. Wind tunnel and analytical investigations will be continued to establish a data base for analysis and understanding of the effects of heavy rain on aircraft aerodynamic and propulsion system performance.

Wind tunnel and analytical research will be conducted to investigate the potential benefits and the aerodynamic, propulsion system, and structural interactions resulting from multiaxis thrust vectoring at high angle-of-attack. Simulator and design studies will be completed to establish a data base for the potential integration of aerodynamic and propulsive flight controls on the NASA F-18 high-alpha research vehicle. In the U.S./United Kingdom ASTOVL program, propulsion system and airframe design studies will be completed to identify the advantages and disadvantages of alternative propulsion system concepts for a supersonic ASTOVL aircraft. The study results will be used to guide the research activities required to develop the technology base for the most promising aircraft/propulsion system concepts.

Flight test support of flight research projects will continue using a variety of both fixed- and rotary- wing aircraft. In the main, these standard aircraft will be flown as chase aircraft in support of research aircraft described under high-performance aircraft systems technology (X-29A, F-15, F-18, YAV-8B) and rotorcraft systems technology (X-wing, XV-15 tilt rotor). The test support activity also provides for flight crew training, maintenance of flight data facilities, aircraft instrumentation, and flight data processing.

	1986 Actual	1987 Amended Budget	1987 Current Estimate	1988 Budget Estimate
		(Thousands of Dollars)		
Systems analysis......................	3,762	4,800	5,800	6,500

OBJECTIVES AND STATUS

The objective of the systems analysis effort is to identify and quantify the impact of emerging technologies in aerodynamics, materials, structures, propulsion, and systems that can lead to new plateaus or major improvements in civil or military aircraft of the future, create new markets, and provide potential economic benefits. Conceptual designs are performed incorporating new technologies, and sensitivity analyses and tradeoff studies are conducted to quantify the benefits of the emerging technologies.

Systems analysis studies of subsonic aircraft, which include general aviation, commuter, and transport aircraft, concentrate on the impact of very advanced materials and structures for propulsion systems on a 150-passenger class of transports powered by advanced turboprops and on a 500-passenger class of transports powered by turbofans.

In FY 1987, data collected from a joint program between the American Helicopter Society and NASA was used to identify the highest payoff technologies that enable helicopter noise reduction with minimum performance penalty. Also, conceptual studies were performed to quantify noise reduction achievable through advanced technologies, such as rotorcraft without tail rotors.

A major study effort has been initiated to identify the most promising vehicle and propulsion system concepts for high-speed civil transportation (from Mach 2.0 up to transatmospheric speeds). The studies address the advanced vehicle concepts enabled by emerging technologies, including those from the national aero-space plane program. These studies are being conducted by major airframe and propulsion system manufacturers with airline consultants.

An ongoing study effort is assessing the potential of new technologies for high-performance aircraft. In FY 1987, the studies focused on the advanced short takeoff and vertical landing (ASTOVL) aircraft. As part of a cooperative U.S./United Kingdom program, second-generation conceptual design studies were conducted with emphasis on advanced propulsion concepts and their integration into the vehicle. These in-house studies support major contractual efforts with propulsion system and airframe manufacturers that are funded in the flight systems area. Together these studies will form the basis for selecting the most promising concept for technology development in FY 1988.

Studies in FY 1987 for hypersonic vehicles consisted of in-house development of models to assess hypersonic propulsion systems and contractual development and assessment of unique propulsion concepts for both hypersonic cruise and transatmospheric flight.

CHANGES FROM FY 1987 AMENDED BUDGET

The systems analysis program reflects an increase of $1.0 million in the area of high-speed transportation.

BASIS OF FY 1988 ESTIMATE

In FY 1988, rotorcraft efforts will assess the impact of advanced technologies on high-speed tilt rotor configurations and X-wing concepts. For the tilt rotor, technology needs will be identified for folded tilt rotor configurations with speeds in excess of Mach 0.7. Also, the potential benefits and technology needs of autonomous remotely piloted rotorcraft will be studied.

The high-speed civil transportation studies will continue through FY 1988. Design criteria will be established, and sensitivity studies will be performed to assess the benefits and technical risks of configuration options in terms of civil potential. Also, for each configuration, issues such as environmental impact, safety, fuel, and airport infrastructure will be examined. The national-scale significance of these issues and their sensitivity to emerging technologies will be determined.

Systems studies for advanced high-performance aircraft will focus on new capabilities enabled by key technology developments in high thrust-to-weight ratio propulsion, propulsive control, and systems integration. The thrust-to-weight ratio of engines is expected to double over the next decade. Combined with advances in lightweight materials, advanced structural concepts, and reliable flight/propulsion controls, a small lightweight fighter with short takeoff and vertical landing capability that is supermaneuverable could result. In FY 1988, thrust vectoring and other propulsive control concepts will be assessed.

Hypersonic speed and high-altitude capability in both airplanes and missiles have obvious advantages for national defense, as well as hypersonic transports and transatmospheric vehicles. Vehicle concepts incorporating projected technology advances are required to determine the performance potential and technology needs. Prospective vehicles and their mission capabilities will be assessed, along with their sensitivity to technology options. In FY 1988, the emphasis will be on determining the most promising propulsion concepts and associated technology needs for hypersonic cruise and transatmospheric vehicles. These formulations will employ the synergistic integration of aerodynamics, aerothermal, propulsion, structural, and controls technologies.

BASIS OF FY 1988 FUNDING REQUIREMENTS

SYSTEMS TECHNOLOGY PROGRAMS

	1986 Actual	1987 Amended Budget	1987 Current Estimate	1988 Budget Estimate	Page Number
		(Thousands of Dollars)			
Rotorcraft systems technology..........	20,500	18,700	18,700	5,000	RD 13-36
High-performance aircraft systems technology..........................	17,800	26,000	26,000	14,600	RD 13-38
Advanced propulsion systems technology	42,200	28,400	28,400	30,500	RD 13-41
Numerical aerodynamic simulation.......	28,200	30,000	30,000	39,700	RD 13-44
Total............................	108,700	103,100	103,100	89,800	

	1986 Actual	1987 Amended Budget	1987 Current Estimate	1988 Budget Estimate
		(Thousands of Dollars)		
Rotorcraft systems technology				
Advanced rotorcraft technology.......	2,700	2,000	2,000	5,000
Technology for next generation rotorcraft.........................	17,800	16,700	16,700	---
Total................................	20,500	18,700	18,700	5,000

OBJECTIVES AND STATUS

The rotorcraft systems technology program consists of research conducted on two fronts. The first element focuses on advanced technology applicable to the broad class of rotorcraft, with a present focus on reducing noise and vibration and increasing the performance of helicopters. The second element consists of research leading to new, enabling rotorcraft concepts with vastly 'greater capabilities, such as triple the speed, range, and altitude of current generation helicopters. In FY 1987, the emphasis is on completing the initial flight investigations of an X-wing rotor on the rotor systems research aircraft (RSRA) under a joint program with the Defense Advanced Research Projects Agency (DARPA).

In the noise program conducted with U.S. industry, an updated, comprehensive noise prediction code was made operational. Accuracy is expected to be ± 3 decibels in most cases for existing designs. Broadband noise prediction was completed, and good correlation of blade-vortex interaction noise was made from a limited data base. A flight test of a two-speed rotor on a McDonnell Douglas 500E helicopter that dramatically demonstrated the importance of rotor speed control for low noise operation was conducted. In addition, since many helicopters have noise signatures dominated by the tail rotor, several promising concepts for tail rotor noise reduction are being analyzed for future testing.

In the joint DARPA/NASA RSRA/X-wing rotor investigation, the goal is to demonstrate a stoppable circulation-control rotor concept which could increase the operational capability for future rotorcraft into the high subsonic flight regime. The prime objective of this test program is to perform an X-wing conversion from rotary to stopped-rotor flight and return to rotary-wing flight. The flight research program will also investigate the dynamic stability, performance, and rotor control characteristics of the X-wing rotor system. The testbed aircraft modifications have been completed, and in FY 1987 the RSRA/X-wing basic flight test program for flight envelope clearance will be initiated. The program will also include obtaining ground-based piloted simulation data, conducting propulsion systems testbed evaluations, and generating vehicle management systems data in support of the flight investigation of the X-wing rotor on the RSRA. The RSRA/X-wing basic 40-hour flight test program will be initiated.

BASIS OF FY 1988 ESTIMATE

The NASA/American Helicopter Society (AHS) cooperative industry noise research program will conclude with the release of the operational version of the comprehensive noise prediction code called ROTONET. New subroutines for rotor loads, rotor wakes, and aerodynamic interference will be incorporated. Prediction accuracy is expected to approach $\pm$1.5 decibels for takeoff and flyover conditions for existing designs. A full-scale test in the 40x80-foot wind tunnel of a modified S-76 rotor designed for reduced blade-vortex interaction noise using technology developed in the NASA/AHS program will take place. A final task of this program will be a design exercise for a low noise rotor with practical operational limitations with a view toward validating improvements in the technology.

An effort will be accelerated to gather a modern data base on rotor airloads with comprehensive measurement of pressures, structural shears, pilot control activity, and acoustics. This effort is fundamental to the needs of noise and vibration prediction and will supplant the previous data base that is outdated in terms of airfoils, platform, and aeroelasticity and is limited in speed, fidelity, and depth. The flight data will be accompanied by full-scale and small-scale wind tunnel testing to correlate scaling laws and wind tunnel wall interference effects.

Active pitch control for improvements in vibration, noise, performance, and maneuvering has been demonstrated in small scale under applied aerodynamics basic research. A test is planned in the 40x80-foot wind tunnel to verify results and reduce uncertainty due to scaling effects. Simulation research will investigate the augmented control available with this approach. The use of active controls will also be investigated with a goal of enabling relaxed aeroelastic stability on a future tilt rotor to reduce wing thickness, hence drag, and push speeds from the current 300 knots to 400 knots. Additional efforts will examine blade airloads and more modern hub designs for speed and maneuverability. As a first step, a test will be conducted in the transonic dynamics tunnel for feasibility and proof of analysis.

In FY 1988, the RSRA/X-wing basic 40-hour flight test program will be completed. No further funding has been requested. These tests will concentrate on the flight mode in which the aircraft converts from rotary to stopped rotor at speeds near 200 knots. Ground-based tests and analysis of advanced X-wing technology, such as improved airfoils developed with computational flight dynamics and improved control laws, will be conducted.

	1986 Actual	1987 Amended Budget	1987 Current Estimate	1988 Budget Estimate
		(Thousands of Dollars)		
High-performance aircraft systems technology				
High-performance flight research.....	9,800	10,400	10,400	11,000
Turbine engine hot section technology........................	5,200	5,000	5,000	---
Ceramics for turbine engines.........	2,100	2,200	2,200	---
Oblique wing technology.............	700	8,400	8,400	3,600
Total...............................	17,800	26,000	26,000	14,600

OBJECTIVES AND STATUS

The objective of the high-performance aircraft systems technology program is to generate validated engineering methods and design data applicable to the development of advanced high-performance, high-speed aircraft applications. The program objectives are accomplished by analysis, ground-based simulations, wind tunnel experimental research, and flight research tests of advanced aircraft concepts and systems.

The F-18 high-alpha research vehicle has been modified to a research configuration for support of flight research operations in FY 1987, with the goal of obtaining a flight-validated data base for the design of highly maneuverable aircraft. Initial flight tests are focusing on the measurements of high angle-of-attack aerodynamics for correlation with wind tunnel and analytical predictions. In the NASA/Air Force advanced fighter technology integration (AFTI) program, the AFTI/F-111 mission adaptive wing project has completed envelope expansion and will initiate the flight test of an automatic camber control system for its variable camber airfoil to demonstrate the performance improvements which may be obtained in maneuvering flight. In the F-15 highly integrated digital electronic control (HIDEC) program, which builds on the capability developed during the digital electronic engine control and F-100 engine model derivative programs, flight research testing to validate 10- to 15-percent aircraft performance improvements through integrated digital electronic controls will be completed. Fuel flow reductions of 14 percent have been demonstrated in high-speed flight with afterburner and acceleration times to supersonic flight have improved substantially. Flight test data will be obtained on the F-106 aircraft equipped with leading-edge vortex flaps to validate the predicted improvements on aircraft takeoff, landing, and maneuvering flight performance. Flight testing of a YAV-8B Harrier is continuing for validation of wind tunnel, analytical, and simulator predictions of vertical/short takeoff and landing aircraft aerodynamic, propulsion, and control characteristics. In the NASA/DARPA X-29A forward-swept-wing flight demonstration program, the aircraft completed the envelope clearance flights in 1986, demonstrating the capabilities of the advanced technologies designed in the experimental aircraft.

During FY 1987, the turbine engine hot section technology (HOST) program continues to focus on the issues involved in engine durability. The objective is to establish predictive methods for the structural response and life of hot section components through developments in analysis, instrumentation, and verification methodology. The new high-temperature structures and fatigue laboratory at Lewis Research Center has completed its first year of operation. Studies of the turbine blade and burner liner materials under realistic, complex, thermomechanical loading conditions have led to accurate prediction of combustor liner failure. Improved analysis €or 3-D aerothermal flow interaction in turbine cascades has been developed and benchmark tests conducted. Constitutive laws have been developed and validated to predict single crystal turbine blade response. Improved theories of salt deposition on rotating airfoils are being developed, thus leading to better models for hot corrosion performance in the turbine environment. The environmental and average turbine engine stress effects on cyclic damage accumulation for life prediction models is continuing.

As part of the activity to develop higher performance, longer life turbine blade materials, the ceramics for turbine engines program has continued to make progress in FY 1987. The relationship between microstructure and properties for silicon nitride will be established and toughening mechanisms identified. Studies of high-temperature function and wear are ongoing. New fibers produced by chemical vapor deposition processes are being studied for higher performance ceramic composites. In FY 1987, an advanced brittle design code, developed in-house at Lewis Research Center, will be extended to include multiaxial response.

The objective of the joint NASA/Navy oblique wing technology program is to establish a flight-validated data base for application of the technology to future civil and military aircraft. For over forty years, NASA has investigated oblique wing technology, including wind tunnel tests, simulations, aircraft design studies, and low-speed manned and unmanned flight tests. These studies have indicated significant performance advantages for an oblique wing aircraft, as compared to a conventional swept wing, for missions requiring both efficient subsonic cruise and supersonic dash performance. In addition, the concept offers significant improvement in carrier spotting ratio for Navy operations.

The final step in the oblique wing technology program is the design, construction, and flight evaluation of an aeroelastically tailored composite oblique wing at transonic and supersonic speeds. The NASA F-8 digital fly-by-wire (DFBW) test aircraft will be utilized as the research testbed for the flight program. This aircraft provides for easy installation of the oblique wing, as well as a well defined, readily modifiable, highly flexible, digital flight control system. An oblique wing preliminary design contract has been awarded and will provide the basis for the final design of the wing and required modifications to the F-8 DFBW testbed. This activity will lead to the start of the flight test program in 1989.

BASIS OF FY 1988 ESTIMATE

The flight research activity in FY 1988 will involve a variety of high-performance aircraft to investigate advanced concepts. Several projects will continue their flight phases during this period. The F-15 HIDEC flight test validation of performance improvements resulting from propulsion system variable operating line control will be completed. A program to further develop the technologies for the integration of flight and propulsion controls will be initiated with the F-15. These performance seeking control flights will validate the performance potential of real-time, in-flight optimization. The NASA/DARPA X-29A aircraft program will be expanded to include Air Force participation in the follow-on flight research program. One of the X-29A aircraft will be modified to include a spin chute to enable flight research testing of the forward-swept wing technologies above 20 degrees angle of attack. The F-106 aircraft will conduct flight tests of the vortex flap concept for correlation with wind tunnel and analytical predictions. The YAV-8B Harrier flight test program will complete the baseline aerodynamic and engine bleed flow experiments and initiate flight investigations to support supersonic short takeoff and vertical landing aircraft control design studies.

In FY 1988, the contracts for final design, fabrication, and ground qualification testing of the oblique wing and F-8 DFBW aircraft system interfaces/modifications will be under way. In-house wing aerodynamic design and research and technology activities in support of the oblique wing program will be continued, including wind tunnel investigations, simulations, and the application of advanced aerodynamic and structural analysis computer codes.

In FY 1988, the turbine engine hot section technology element and the ceramics for turbine engines element have been combined and augmented to form the advanced high-temperature engine materials program in the Advanced Propulsion Systems Technology program. The programs were combined to focus the efforts on developing fundamental technology for revolutionary advances in high-temperature materials for advanced propulsion systems and will be reported under advanced propulsion systems technology.

	1986 Actual	1987 Amended Budget	1987 Current Estimate	1988 Budget Estimate
		(Thousands of Dollars)		
Advanced propulsion systems technology				
Advanced turboprop systems..........	40,000	26,000	26,000	18,000
General aviation/commuter engine technology.........................	2,200	2,400	2,400	2,500
Advanced high-temperature engine materials technology................	---	---	---	10,000
Total...............................	42,200	28,400	28,400	30,500

OBJECTIVES AND STATUS

The objective of the advanced propulsion systems technology program is to explore and exploit advanced technology concepts for future aircraft propulsion systems in high payoff areas through the focusing of fundamental research and technology efforts and integration of advanced propulsion components.

Activities in the advanced turboprop systems program are devoted to establishing concept feasibility and providing the broad research and technology analytical and experimental data base necessary for achieving the concept's full potential. Information on aerodynamic performance, aeroelastic stability, and acoustic environment will be obtained for verification of analysis codes and to support the gathering and analysis of experimental data under actual flight conditions using aircraft testbeds. The 9-foot-diameter large-scale advanced propeller was successfully tested in a wind tunnel for aeroelastic stability and cleared for flight test. The single-rotation flight propulsion system, which includes the large-scale advanced propeller, forward nacelle, gearbox, and gas generator completed a static ground test. The system passed functional tests and completed a 50-hour endurance test to complete its checkout for flight testing. In 1987, the propulsion system will be installed on a modified production aircraft to perform structural, aeroelastic, and acoustic verification for propellers at large scale. Additional small-scale experiments in support of the flight test included one-ninth scale model low-speed tests of the propfan test assessment flight test aircraft which determined the aircraft to have acceptable stability and control characteristics. A semispan version on the model is also being tested to gather detailed aerodynamic data behind the propeller to aid in the analysis of the large-scale results. Ground tests of the General Electric unducted fan engine, a gearless counter-rotation propfan concept, were successfully completed. The engine is currently undergoing flight tests on a modified production aircraft under industry sponsorship. Aerodynamic and acoustic data are being gathered for both gearless and geared counter-rotation concepts in a two-foot-diameter scale-model size. The performance results are good and the acoustic results show that the proper design of the propellers will result in acceptable noise levels for airport operations.

In the general aviation and commuter engine technology program, with the objective of raising the performance level of small turbine engines to more nearly match that of large engines, the work continues to be focused on providing fundamental experimental data to obtain a detailed understanding of the design parameters that affect component performance as size is reduced. Small engine component technology studies have been completed. It was determined that high-temperature materials, such as ceramics for the hot section, improved aerodynamics of components, and advanced cycles, including recuperators, have the potential of reducing small engine fuel use by 20–50 percent with a corresponding reduction in direct operating costs of 12–20 percent. The scaled centrifugal compressor program was completed, proving that after the effects of tip clearance, blade thickness, and surface roughness were properly accounted, the performance of small centrifugal compressors depended on Reynolds number, which is the nondimensional parameter used for aerodynamic scaling. In addition, the experimental evaluation of an advanced ceramic matrix combustor liner was completed and a full analysis of the data will be accomplished in 1987. Ceramics offer the potential of eliminating cooling requirements for combustor liners, thus increasing engine cycle efficiency. During 1987, the new small turbine facility checkout will be completed and subsequently used to evaluate turbine performance penalties associated with inlet boundary layer size and blade surface finish.

BASIS OF FY 1988 ESTIMATE

In FY 1988, advanced turboprop systems research will emphasize source noise, cabin environment, turboprop installation aerodynamics, and the development of advanced aerodynamic and structural analysis techniques for both single- and counter-rotation propellers. The results of the flight test of the large-scale advanced propeller will be fully analyzed and compared to small-scale results to confirm scaling techniques for structures, aerodynamics, aeroelastics, propeller source noise, and an untreated cabin environment. The combination of aerodynamic and aeroacoustic analysis will continue in order to accurately predict the source noise of the complex shapes and multitude of configurations available for counter-rotation propellers. Analytical and experimental ground and flight research will be performed cooperatively with industry to develop approaches and determine their effectiveness for controlling cabin noise in various turboprop aircraft configurations. Experimental installation aerodynamics research will be performed on a variety of turboprop/airframe configurations including single- and counter-rotation and wing and aft mounts. These experimental results will be used to verify Euler and Navier-Stokes analysis codes under development for predicting aircraft flow fields. Advanced propeller research will include code development and verification using three-dimensional viscous transonic methods that consider counter-rotation interaction and evaluation of advanced concepts.

The general aviation and commuter engine technology effort will continue to focus on developing fundamental understanding and obtaining an analytical and experimental data base for use in future advanced small engines. Advanced turbine technology will be emphasized in FY 1988, with the experimental evaluation of a cooled, high work radial turbine and a mixed-flow turbine. Radial turbines are capable of very high work capability per stage. Successful cooling of small radial rotors will yield a very high-power compact turbine that can be used in high-pressure-ratio engines which provide system efficiency improvements. In another approach, the need for cooling can be potentially eliminated by using high-temperature materials such as ceramics; however, ceramics have not as yet proven strong enough to be used in a radial turbine. A compromise would be a mixed-flow turbine with almost as high work per stage, while significantly reducing stress levels. A mixed-flow metal turbine rotor will be fabricated to evaluate the maximum stress levels during rig tests in preparation for fabrication and test of a ceramic rotor at a later date. In addition, a centrifugal compressor evaluation will be completed, yielding a detailed laser velocimetry flow field description of a high-speed rotor.

Advanced high-temperature engine materials technology research will develop fundamental technology to enable very high thrust-to-weight (20 to 1) gas turbine engines with durable, long-life hot section components. Key to these applications are materials capable of operating at much higher temperatures and strength levels than now possible. These advanced materials will provide for a 30-percent decrease in weight, while allowing an increase in maximum operating temperature and a doubling of life. Only minor performance gains are possible with the existing high-temperature materials, such as titanium and superalloys, which are currently being used. The key advanced materials include ceramics and ceramic composites, metal matrix composites, and carbon-carbon composites.

Two ongoing systems technology programs currently in high-performance aircraft systems technology, turbine engine hot section technology and ceramics for turbine engines, have been combined and augmented to form the advanced high-temperature engine materials program for FY 1988. The objective of this new program is to develop the necessary fundamental technology to provide for the revolutionary advances in high-temperature materials for high-performance propulsion systems. These advanced materials will enable higher turbine inlet temperatures for sustained supersonic cruise, high thrust-to-weight engines for advanced high-performance concepts, and engine hot section component operations without cooling air for higher fuel efficiency. The program includes process development and research to understand how these materials respond to the complex thermomechanical loads encountered to allow determination of their life in service. Development of the technology to improve structural ceramic reliability to permit its use in engines will be continued, as will development of the analytical tools and experimental data base necessary for accurate life prediction and durability assessment of turbine blades, vanes, and combustors using current materials systems.

	1986 Actual	1987 Amended Budget	1987 Current Estimate	1988 Budget Estimate
		(Thousands of Dollars)		
Numerical aerodynamic simulation.......	28,200	30,000	30,000	26,700
NAS operations.........................	---	---	---	13,000
Total..............................	28,200	30,000	30,000	39,700

OBJECTIVES AND STATUS:

The numerical aerodynamic simulation (NAS) program objective is to significantly augment the nation's capabilities in computational fluid dynamics and other areas of computational physics by developing a preeminent capability for numerical simulation of aerodynamic flows. This program will provide the computational capabilities required to obtain solutions to problems which are currently intractable. Ongoing research and technology base efforts in computational aerodynamics will benefit significantly from the advanced computational capabilities to be provided by the NAS program. The combination of these programs will provide pathfinding aeronautical research for the future, allowing solutions of the full Navier-Stokes equations, providing first-principle prediction of viscous flow about simple aeronautical shapes, and enabling the prediction of performance of complete aircraft. The NAS program will develop an extensive, user-friendly system to assist engineers and scientists in all aspects of problem solution from problem formulation through graphical presentation of results. The heart of this system is the high-speed processors, which will be upgraded when new supercomputer systems at least four to six times more powerful than existing machines become available. These machines will provide the large-capacity/high-speed computational capability required in advanced fluid dynamic research and applications.

Since NAS is both a development and an operational system, two high-speed processors are necessary. One processor will be devoted exclusively to production computing. The second, newer and more powerful machine, will be integrated into the system while software for production use is being developed. The first high-speed processor (HSP-1), a Cray 2 supercomputer, reached operational status in the NAS initial operating configuration (IOC) on July 21, 1986. For IOC operations, over 180 researchers nationwide used the NAS resources to numerically simulate complex flow phenomena. Construction of the NAS facility has been completed, and occupancy began in the first quarter of FY 1987. Full operations commence in the second quarter of FY 1987 when the NAS system relocation into the NAS facility is completed. During FY 1987, the second high-speed processor will be acquired in preparation for achieving the planned extended operating configuration (EOC).

BASIS OF FY 1988 ESTIMATE

FY 1988 will be an important year in the development of the NAS system, The second high-speed processor (HSP-2), which will be four to six times more powerful than HSP-1, will be installed and integrated into the NAS system. Secure (classified) processing will be initiated with the completion of the secure processing area in the new building. The addition of HSP-2, which constitutes the NAS EOC, will reach the full planned architecture of the NAS system. The major subsystems will be expanded as appropriate to support EOC operations. The mass storage subsystem will be expanded to handle the additional archival storage required for support of the HSP-2. The advanced graphics subsystem development will be completed to accommodate both high-speed processors. During this period, system software development will continue, and all new components will undergo extensive test and integration. Application software developed during IOC will continue to be modified to provide pathfinding viscous flow solutions for advanced configurations. In FY 1988, NAS operations support funding has been consolidated in the NAS program from the Research and Technology Base. This consolidation of funding simplifies management and reporting of NAS progress.

TRANSATMOSPHERIC
RESEARCH AND
TECHNOLOGY

RESEARCH AND DEVELOPMENT

FISCAL YEAR 1988 ESTIMATES

BUDGET SUMMARY

OFFICE OF AERONAUTICS AND SPACE TECHNOLOGY | **TRANSATMOSPHERIC RESEARCH AND TECHNOLOGY**

SUMMARY OF RESOURCES REQUIREMENTS

	1986 Actual	1987 Amended Budget	1987 Current Estimte	1988 Budget Estimte	Page Number
		(Thousands of Dollars)			
Transatmospheric research and technology..........................	---	35,000	45,000	66,000	RD 14-2

Distribution of Program Amount by Installation				
Ames Research Center....................	---	4,900	1,000	1,000
Langley Research Center................	---	17,900	2,000	2,000
Lewis Research Center.................	---	12,200	2,000	2,000
Headquarters	---	---	40,000	61,000
Total..............................	---	35,000	45,000	66,000

OFFICE OF AERONAUTICS AND SPACE TECHNOLOGY **TRANSATMOSPHERIC RESEARCH AND TECHNOLOGY**

PROGRAM OBJECTIVES AND JUSTIFICATION

The national aero-space plane (NASP) program is a joint effort between NASA and the Department of Defense to accelerate the development of critical enabling technologies for this revolutionary class of hypersonic/transatmospheric vehicles. Such vehicles could be capable of taking off from and landing on conventional runways, using airbreathing propulsion up to, or near, orbital speed, and providing rapid and low-cost access to space. The program will accelerate the development and validation of key technologies through application of analytical prediction methods coupled with testing in ground-based facilities. The critical technologies being pursued in the current phase of the program include efficient airbreathing propulsion systems, with emphasis on scramjet performance that provides the necessary thrust from takeoff to near orbital speeds; reusable thermal structures that can withstand repeated combinations of extreme peak heating and long-duration heat loads; and complete integration of the propulsion system with the airframe for a minimum weight system with good performance throughout a broad range of accelerating, cruising, and maneuvering flight conditions. A necessary precursor to the development and flight validation of an experimental vehicle (X-30), these technologies will form the critical data base required for design and integration of complex propulsion and structural systems into a vehicle configuration capable of transatmospheric flight.

This program is an outgrowth of the ongoing aeronautics and space research and technology programs. It is a multicenter effort (Ames, Langley, and Lewis) directed at generating the technologies required to provide the variety of options afforded by airbreathing transatmospheric vehicles. The opportunities for exploiting this regime for advancement of national interests are broadly recognized -- including launch vehicles, hypersonic transports, and military applications.

CHANGES FROM FY 1987 AMENDED BUDGET

This program reflects an increase of $10.0 million from the FY 1987 amended budget. $5.0 million was added consistent with Congressional direction and an additional $5.0 million increase resulted from reallocation within the NASA budget. This increase was necessary in order to restore critical program activities.

BASIS OF FY 1988 ESTIMATE

Ongoing activities in the national aero-space plane program include technology development in subsonic, supersonic, and hypersonic hydrogen-fueled propulsion technology; advanced high-temperature materials and lightweight, high-strength, thermal structural concepts; and computational fluid dynamics, which remain the three critical technologies for all transatmospheric vehicle applications. The engine and airframe contracted efforts will be supported by an extensive focused technology effort at NASA centers (Ames, Langley and Lewis) and other government laboratories. Work will continue on computational fluid dynamics calculations, including the refinement of computer models based on test data. Modeling using supercomputers will include external/internal aerodynamics, aerothermodynamics, kinetics and thermal-structural considerations, and nozzle/plume computer codes for analyzing chemically reacting hypersonic nozzle/plume flows. Work will continue on development of, and manufacturing technology for, lightweight, high-temperature advanced materials. For example, processing techniques for fabricating ceramic matrix composite panels will be demonstrated. Engine component and subsystem testing will continue over the wide speed range of interest, and flight research vehicle test planning will be initiated. Tests will be conducted on subscale component integration models of scramjet concepts over the speed range of Mach 3.5 to Mach 8. Contractors will concentrate on developing and refining their vehicle concepts, the construction and testing of critical structural components of the airframe cryogenic tankage and vehicle, and propulsion/airframe integration of both engines into their respective vehicle configurations. In addition, the airframe contractors will focus on critical technologies including nose cap and leading-edge materials, actively cooled structures, computational fluid dynamics code validation, and flight instrumentation.

Due to the nature of this national program, a significant portion of the funding will be the responsibility of the Program Management Office which will distribute the funds to support the critical technology maturation contracted activities. NASA research center personnel will be responsible for the technical management of these technology efforts.

SPACE RESEARCH AND TECHNOLOGY

RESEARCH AND DEVELOPMENT

FISCAL YEAR 1988 ESTIMATES

BUDGET SUMMARY

OFFICE OF AERONAUTICS AND SPACE TECHNOLOGY | **SPACE RESEARCH AND TECHNOLOGY**

SUMMARY OF RESOURCES REQUIREMENTS

	1986 Actual	1987 Amended Budget	1987 Current Estimte	1988 Budget Estimte	Page Number
	(Thousands of Dollars)				
Research and technology base..........	124,200	133,600	133,600	115,900	RD 15-5
System technology programs...........	27,200	37,400	37,400	---	RD 15-36
Civil space technology initiative (CSTI) program......................	---	---	---	134,100	RD 15-40
Total..............................	151,400	171,000	171,000	250,000	

Distribution of Program Amount by Installation

	1986 Actual	1987 Amended Budget	1987 Current Estimte	1988 Budget Estimte
Johnson Space Center..................	6,981	10,500	8,700	12,000
Kennedy Space Center..................	---	---	---	500
Marshall Space Flight Center..........	14,378	19,000	19,200	49,400
Goddard Space Flight Center...........	5,541	6,200	5,100	9,000
Jet Propulsion Laboratory...............	21,633	23,800	19,500	27,000
Ames Research Center..................	16,084	18,900	19,400	29,100
Langley Research Center................	43,971	47,500	52,300	64,400
Lewis Research Center.................	35,788	37,400	40,200	51,900
Headquarters...........................	7,024	7,700	6,600	6,700
Total..............................	151,400	171,000	171,000	250,000

RESEARCH AND DEVELOPMENT

FISCAL YEAR 1988 ESTIMATES

OFFICE OF AERONAUTICS AND SPACE TECHNOLOGY — **SPACE RESEARCH AND TECHNOLOGY**

PROGRAM OBJECTIVES AND IFICATION

Th goal f the c research and technolog program is to retai nationa p in space by advan the technology base that supports th civ space program. The i ect e to provide a broad base f advanced technology r ehicl a s concepts, s devices and software; to develop the underlying methods, t t and technologies; and to perform and experiments to pr ide basic data and ify ts through ground and in iments so that new technology can be utilized th confidence.

An enhanced technology progam is required to assure that advanced space transportation system provide reliable access to, and operations in, space; that science missions can continue to expand understanding of the universe through missions of increased capability; and that human presence in space expands systematically within and beyond earth orbit.

CHANGES FROM FY 1987 AMENDED BUDGET

The FY 1987 funding for the space research and technology program has not changed from the estimate submitted in the hnded Budget last year. However, funding adjustments within disciplines have been made in response to changing requirements in the program and are explained within the individual program statements.

BASIS OF FY 1988 ESTIMATE

In FY 1988, the program will continue to support agency goals in space transportation, space station, and space science and applications, as well as to provide synergistic support to military and commercial space user needs. In FY 1988, the space research and technology program has been restructured into two parts. The first part, which retains the space research and technology base title, contains the generic, fundamental research aspects of the program. The second part, the Civil Space Technology Initiative (CSTI) program, includes focused system technology program supporting transportation, operations, and science consistent with the goals of the U.S. space program. The CSTI supports research in propulsion, vehicle concepts, information systems, large structures and control, power, and automation and robotics. CSTI contains research activities from the former research and technology base and system technology program, which have been reoriented and augmented toward the goals of the CSTI program.

The research and technology base portion of the program is conducted in the disciplines fundamental to space endeavors. In aerothermodynamics, increased emphasis will be given to obtaining the data base for code validation/verification covering the entire atmospheric spectrum from continuum to rarefied/free molecular flows. Continued emphasis will be placed on investigating aerodynamic and aerothermodynamic performance of hypersonic and entry vehicle configurations. The space energy conversion program will explore concepts which increase the capability and life of small and large utility-type power systems and for spacecraft and rover applications. Propulsion technology will increase the performance, life, and reliability of liquid oxygen/liquid hydrogen and liquid oxygen/hydrocarbon propulsion systems for earth-to-orbit and orbit transfer vehicles, stressing components, integrated diagnostic instrumentation, and fault-tolerant concepts. Research on auxiliary propulsion will develop concepts for gaseous oxygen and hydrogen propellant systems for growth stations and vehicles. Electric propulsion will address low-thrust propulsion applications, with attention on fundamental life- and performance-limiting features. Materials and structures activities will investigate the static and dynamic response of large-area space structures, including erectable and deployable construction concepts and analysis of dynamic response and controls interaction. The work on thermal protection systems and related thermal-structural analysis methodology for advanced transportation vehicle concepts will continue. The effects of the space environment, particularly atomic oxygen interaction on lightweight materials for spacecraft and platforms, will continue as a major thrust. In space data and communications, emphasis will be on advanced memory concepts, fault-tolerant general purpose computer architectures, and microwave and optical communications technology. The information sciences program will emphasize software technology, reliable computing, concurrent processing, radiation-tolerant electronics, and sensing technology for spacecraft and space station applications. Controls and guidance research will lead to the ability to precisely control large, flexible space structures; precision pointing of large spacecraft; and adaptive guidance concepts for future transportation systems. Human factors efforts are aimed at the enhancement of astronaut productivity through crew stations with "human engineered" information management techniques and extravehicular work stations.

Efforts in space flight research and technology will be focused on: (1) orbiter experiments to validate experimental and predictive techniques for the design and development of future space transportation systems, (2) a cryogenic fluid management flight experiment, and (3) in-space experiments. The systems analysis area will focus on the identification of high-leverage technologies for future space missions.

The CSTI program will focus on technology development in propulsion, vehicle concepts, information systems, large structures and control, power, and automation and robotics.

The CSTI propulsion program includes earth-to-orbit (ETO) and booster technology. Research on ETO propulsion will be expanded to assure a mid-1990 capability to enable development of reusable, high-performance, liquid oxygen/hydrogen, and high-density fuel propulsion systems for next-generation space transportation vehicles beyond shuttle. A booster technology program will develop the options for both pressure-fed liquid rocket propulsion and large-scale hybrid (solid propellant with liquid oxygen) systems. For vehicle technology, analytical and wind tunnel research on aerobraking and aeromaneuvering will be expanded to include the design, development, and flight of an aeroassist flight experiment (AFE). The AFE will be conducted by delivering a highly instrumented aerobrake configuration to earth orbit with the shuttle, accelerating the vehicle propulsively into the atmosphere at geosynchronous entry velocity, performing the atmospheric drag braking maneuver, and skipping back to low earth orbit for shuttle recovery. The information science program is focused on sensor devices for earth and astrophysical observations in spectral bands where present measurements cannot be made. The program also will build an optical disk buffer breadboard and demonstrate unique computer architectures for processing high-speed and large-volume radar and imaging sensing data. These computer capabilities will exploit applicable Department of Defense (DOD) and commercial processor technology to enable the effective management of the exponential growth of data from future science missions.

In large structures and control, the control of flexible structures **(COFS)** program will emphasize development of the first and second flight configurations and definition of the third configuration. A new element, precision segmented reflector technology, will be conducted in parallel. It will be directed at validating design concepts for lightweight composite, multisegment, precision reflectors. This technology program will include structural concepts for segmented surfaces, assembly methods, advanced material development and characterization, and control methods for multisegmented surfaces leading to tests of a seven-element subassembly. In the **CSTI** power program, enhancement of the high-capacity, high-efficiency, thermal-to-electric power conversion program will accelerate the development of components and subsystems for a ground test of the conversion systems to verify efficiency and life potential. The **CSTI** program in automation and robotics will build on the ongoing program directed at spacecraft and platform systems to develop and apply expert systems technology to prelaunch and in-space transportation operations.

BASIS OF F 1988 NDING REQUIREMENTS

TECHNOLOGY 3

	1986 Actual	1987 hnded Budget	1987 Current Estimate	1988 Budget Estimate	Page Number
		(Thousands of Dollars)			
Aerothemdynamics research and technology..........................	10,490	11,200	11,400	11,100	RD 15-6
Space energy conversion research and technology.,........................	19,955	20,400	20,400	14,600	RD 15-9
Propulsion research and technology.....	18,156	21,000	21,000	14,500	RD 15-12
Materials and structures research and technology............................	18,126	18,900	18,900	17,900	RD 15-16
Space data and communications research and technology......................	15,384	13,600	13,600	8,900	RD 15-19
Information sciences research and techno1ogy...........,...............	12,462	10,200	10,200	8,000	RD 15-22
Controls and guidance research and technology..........................	7,035	7,500	7,500	6,300	RD 15-25
Human factors research and technology..	2,100	2,300	2,300	4,900	RD 15-27
Space f1ight research and technology...	14,054	22,400	22,200	23,200	RD 15-30
Systems analysis......................	6,438	6,100	6,100	6,500	RD 15-33
Total...............................	124,200	133,600	133,600	115,900	

	1986 Actual	1987 Amended Budget	1987 Current Estimate	1988 Budget Estimate
		(Thousands of Dollars)		
Aerothermodynamics research and technology............................	10,490	11,200	11,400	11,100

OBJECTIVES AND STATUS

Future aerospace vehicles, such as aeroassist orbit transfer vehicles (AOTV), the aero-space plane, and hypersonic cruise and maneuver vehicles, must be capable of sustained hypervelocity flight in rarefied atmospheres. The design of these vehicles presents some formidable performance prediction challenges. To meet these challenges, the aerothermodynamics program is pursuing the following objectives: (1) development of advanced numerical algorithms for the whole range of continuum, transitional, and rarefied flow regimes; (2) development of accurate and detailed finite-rate chemistry and turbulent flow models; (3) establishment of benchmark quality, experimental data for code validation/verification; (4) correlation of calculations with ground and flight (shuttle orbiter experiments) experimental data; (5) establishment of a detailed aerothermal loads data base and development of integrated analysis techniques; and (6) provision of integrated aerospace vehicle design and analysis capability to support future vehicle/mission requirements.

For the continuum flow regime, significant progress recently has been made for three-dimensional viscous flows about hypersonic flight vehicles. An upwind differenced viscous flow code was developed for slender, winged flight vehicles and demonstrated for Mach numbers up to 25. This code provides the base for the analysis and prediction of aerodynamic and aerothermodynamic flows about transatmospheric vehicles. Additionally, a three-dimensional viscous flow code was developed and demonstrated for blunt aeroassist vehicles. The code was used to analyze the flow and heat transfer to the base region of the aeroassist flight experiment (AFE) vehicle under simulated reentry conditions where it was determined that flow reattachment in the base region caused localized high heating areas.

For rarefied flow regimes, the direct simulation Monte Carlo (DSMC) technique continues under development to better understand and model complex flow problems as represented by the interaction of vehicle airframe, ambient rarefied atmosphere, propulsion system exhaust, and material outgassing. Recently completed modification to the DSMC computer codes allows for the modeling of nonequilibrium thermodynamics under rarefied conditions. This improvement enables the prediction of nonequilibrium heating to aeroassist and planetary return vehicles operating at high speeds at high altitudes. The DSMC technique has been used to explain the shuttle glow phenomena experienced on shuttle flights STS-3, -4, and -5. Excellent qualitative agreement between the DSMC calculations and flight data supports the hypothesis that the glow is due to collisionally excited molecules (N_2) from the free stream and not to surface contamination effects.

Computational chemistry, in which the chemical and physical properties of matter are computed from first principles, is making significant contributions to the fundamental understanding of the chemical and physical processes that occur in the low-density shock layer gases that surround the airframes of high-altitude high-speed vehicles. In FY 1987, the exact production mechanism of excited molecular species by electron impact was established through application of first principle calculations. It is now understood that these excited molecular species are the principal source of nonequilibrium radiation expected to dominate AOTV designs.

The development of a fully integrated fluid-thermal-structural analysis technique is essential to permit proper vehicle structural design while avoiding the tendency to overdesign, which can result in significant mass/volume penalties. In FY 1987, the program achieved a significant milestone with the unique demonstration of a single calculation which successfully coupled fluid dynamics, thermal analysis, and structural response for shock-induced localized high heating on a simulated scramjet engine strut.

CHANGES FROM FY 1987 AMENDED BUDGET

The increase of $0.2 million in aerothermodynamics research and technology reflects primarily a realignment of hypersonic technology funding from space flight research and technology.

BASIS OF FY 1988 ESTIMATE

Continued emphasis will be placed on developing computer codes capable of simulating external flows relevant to aerospace transportation systems and on providing analysis and design capability with respect to aerodynamic and aerothermodynamic loads. Toward this end, in FY 1988, chemical nonequilibrium real-gas models will be incorporated into the viscous, three-dimensional, continuum flow codes for blunt bodies, allowing for accurate prediction/simulation of the high-altitude high-velocity thermal environment encountered by aeroassist orbit transfer vehicles during atmospheric maneuvers. In addition, real gas equilibrium thermodynamic properties will be incorporated into the slender hypersonic winged vehicle viscous flow codes to enable accurate high Mach number, moderate altitude flight conditions to be simulated. These codes will then be utilized to analyze the thermal environment encountered by transatmospheric vehicles during both ascent and reentry flight.

Software will be developed in FY 1988 to enable establishment of a readily accessible national data base for the storage of aerodynamic and aerothermodynamic data. Existing and newly acquired ground- and flight-test results will be incorporated into this data base. This will provide the validated technology required to rapidly evaluate future conceptual aerospace vehicle configurations. The experimental data base for verifying the predictive capability of the fluid-thermal-structural analysis technique will be completed in FY 1988. Predictions will be compared to data obtained both at Langley Research Center (Mach 6.3/8-foot high temperature tunnel) and at CalSpan (Mach 6.3 to 18).

In FY 1988, the reliability of the nonequilibrium flow radiatian models that have been developed for the direct simulation Monte Carlo method will be established. This will be accomplished by comparing the calculated results with available laboratory and flight data.

Additionally, benchmark hypersonic experiments will be carried out in FY 1988 in the newly reactivated 3.5-foot tunnel from Mach 7 to 12 in order to establish an accurate data set with which hypersonic winged-body flow codes can be validated. These tests will provide the first comprehensive data set for a generic but realistic hypersonic configuration that can be easily modeled by recently developed computational codes.

	1986 Actual	1987 Amended Budget	1987 Current Estimate	1988 Budget Estimate
		(Thousands of Dollars)		
Space energy conversion research and technology...........................	19,955	20,400	20,400	14,600

OBJECTIVES AND STATUS

The objectives of this program are to explore concepts and components to improve the performance, lifetime, and cost effectiveness and to reduce the size and weight of power and life support systems for large manned space systems, small earth-orbiting and planetary exploration spacecraft, and other ambitious future space missions.

In FY 1986, two significant advances in photovoltaic cell technology were achieved. A gallium arsenide (GaAs) solar cell demonstrated over 23-percent efficiency when exposed to a 100-to-1 solar concentration of air mass zero (AMO) spectrum at 25 degrees centigrade. This is the highest performance yet achieved for a space photovoltaic cell, and, when combined with data indicating that GaAs degrades less than half as much as silicon to radiation damage, this shows the near-term potential for a considerable decrease in solar array areas. An indium phosphide (InP) cell with an efficiency of 14.2-percent AMO was demonstrated and shows potential for considerably higher efficiencies. These cells also have demonstrated a substantial improvement in ability to maintain efficiencies in a radiation environment relative to either silicon or gallium arsenide. Because some spacecraft operate for extended periods in regions of high natural radiation, the ability to achieve relatively high efficiencies with good resistance to damage by radiation is more important than just high efficiency. An advanced photovoltaic array design was completed which demonstrated an array power-to-weight ratio in excess of 130 watts per kilogram, and a technology demonstration contract was awarded. This would be over a twofold increase in the power-to-weight ratio of 60 watts/kilograms demonstrated in the shuttle array experiment as recently as late 1984. Doubling of the power-to-weight ratio of photovoltaic power systems will provide additional scientific capability on weight-limited geosynchronous and planetary spacecraft. Integrated pressure vessel (IPV) nickel-hydrogen batteries with energy densities two times those of conventional nickel-cadmium batteries achieved cycle life in excess of 20,000 hours at 80 percent depth of discharge, leading to their selection as the electrical energy storage device for the initial operating configuration (IOC) space station.

In the power management and distribution area, a facility was put on line for the evaluation of newly developed high-power (100 kilowatts) 20-kilohertz electrical components, such as transformers, capacitors, transmission lines, and radiation-hardened high-temperature electronics.

As part of the space nuclear power research effort, the largest free-piston Stirling engine ever built demonstrated 22.5KWe, which is over 90 percent of full design power. The free-piston Stirling engine, in conjunction with a linear alternator, offers the potential to provide high efficiency and long life. The testing of the Stirling engine developed a valuable data base from which design codes were updated and validated. Deep impurity double-injection $(DI)^2$ silicon devices have been shown to exhibit insignificant electrical degradation after gigarad level irradiations 100 times that tolerated by conventional silicon devices. These devices also exhibit a high-temperature stability at temperatures twice those of conventional silicon devices. Dramatic improvements in both the fundamental understanding and the demonstrated lifetimes were made in the porous molybdenum electrodes used in the alkali metal thermoelectric converter (AMTEC). AMTEC is a thermally regenerative electrochemical conversion device, which is both static and modular and which has had experimentally measured efficiencies of up to 20 percent. An important first step was made in the development of technology for high-efficiency liquid-droplet and liquid-belt radiator concepts by demonstrating continuous generation of uniform droplets with low vapor pressure fluids. High-strength graphite fiber-reinforced copper matrix composites, which have the potential to substitute for beryllium in radiator panels, have been fabricated and tested. A low-power reusable organic iodide laser has been successfully operated to demonstrate power transmission at power levels commensurate with those achievable with a solar concentrating parabolic dish.

BASIS OF FY 1988 ESTIMATE

Prior to FY 1988, the space energy conversion program had the broad focus of addressing the technology needs of all advanced space applications. In FY 1988, a systems program in high-capacity nuclear power will be established as part of the new CSTI program. Nuclear technologies needed to meet the high-capacity power systems requirements for evolutionary space station(s), lunar and planetary bases, and for high-power demand electric propulsion systems will be developed in this program. The FY 1988 space energy conversion research and technology program will develop concepts and component technologies that will: (1) dramatically reduce the weight of relatively low-power spacecraft power systems; (2) enable substantial reduction in the size and weight of high-capacity, nonnuclear power systems; and (3) increase the degree of closure, reduce power requirements, and increase the life of environmental control and life support systems.

For photovoltaic spacecraft power systems technologies, the goal is to improve the total system performance enough to permit a 50-percent increase in payload weight. Techniques for increasing the purity of indium phosphide crystals will be investigated and are expected to yield indium phosphide cells with a 30-percent improvement in efficiency relative to current indium phosphide cells, while maintaining a high resistance to radiation damage. Experimental efforts, started in FY 1987, to improve doping techniques for amorphous silicon materials will be continued in FY 1988. Amorphous silicon can be produced in very thin sheets, and consequently, very lightweight photovoltaic materials could be produced if planned efforts to improve the efficiency and life are successful. In FY 1988, testing of a spacecraft silicon photovoltaic array with a power-to-weight ratio of 130 watts per kilogram (more than twice the current state of the art) will be completed. Experimental studies to understand the life-limiting mechanism of electrode erosion in very high energy density lithium batteries will continue. Finally, new ways of integrating components with lightweight structures into a long-life, low-weight, reliable, and efficient solar power system will be demonstrated. Work initiated in FY 1987 on a small reactor spacecraft power system will continue in FY 1988. Dynamic conversion concepts and high-temperature rare-earth chalcogenides and boron carbide thermoelectric materials suitable for use with a small, lightweight, reactor power system will be evaluated to establish their current-producing capability as a function of temperature ratio. Design and materials development efforts for high-strength metal matrices, lightweight heat pipes, and radiation-hardened electronic components will be continued.

Technologies being pursued to Improve the performance of high capacity power systems (greater than 50 kWe) include advanced solar dynamics, photovoltaic concentrator arrays, and high capacity batteries. In FY 1988, a compact Stirling engine, with a high-temperature, heat pipe heater head suitable for use with a solar concentrator, will be fabricated and performance testing will be initiated. Efforts to design high-performance solar concentrators, including new concepts such as prismatic designs, will continue. Techniques to reduce thermal distortions and off-pointing losses in concentrator photovoltaic systems will continue, as will efforts to develop very high efficiency (greater than 30 percent) photovoltaic cells for operation at concentration ratios greater than 100. In the energy storage area, long-life, very high energy density batteries such as bipolar nickel-hydrogen batteries are being developed.

In the life support area, work will continue on the development of hollow fiber membranes as a low energy approach to humidity condensate removal. Performance testing of reverse osmosis/hyperfiltration technology for wash-water recovery will be initiated as an alternative to the energy intensive phase change technology. The development of a basic technology associated with supercritical water oxidation, which would permit further closure of the life support loop by recovery of organic wastes, will be continued and feasibility tests initiated.

	1986 Actual	1987 Amended Budget	1987 Current Estimate	1988 Budget Estimate
		(Thousands of Dollars)		
Propulsion research and technology...........................	18,156	21,000	21,000	14,500

OBJECTIVES AND STATUS

The objective of the propulsion research and technology program is to establish a base of design concepts and analytical tools that will allow the design and development of advanced propulsion systems with the known performance, life, and operational characteristics essential for next generation space transportation systems. This base will also reduce the risk of costly, unanticipated design deficiencies and schedule delays during the development and certification of flight hardware. Specific objectives include developing a sound understanding and broad base of knowledge in the area of reusable engine component life prediction and extension; improving high-pressure ignition/combustion performance, stability, heat transfer, and cooling models; developing unique, nonintrusive diagnostic sensors for use in interactive engine condition monitoring/control systems; establishing an understanding of the chemical and physical processes associated with very high-performance, low-thrust propulsion systems, as well as developing corrosion-resistant high-temperature materials necessary for achieving extremely long life and reliability; and evaluating potential breakthrough propulsion concepts and related research and technology issues that could lead to quantum leaps in future propulsion capabilities.

For life prediction/extension, the effort has been primarily directed toward the turbomachinery to understand and analytically simulate the hostile environments to which these components are subjected. The program includes developing techniques for reducing the severity of those environments by analytically simulating them and determining configuration changes that will reduce thermal and mechanical loads resulting from the environments. Advanced design concepts that can provide greatly increased fatigue life are also being developed. Advanced materials and coatings which will contribute to the reduction of thermal transients to aid in increasing life expectancy of turbomachinery components and systems are also in the program. A rotordynamics model has been developed for investigating design changes, such as dampers on space shuttle main engine (SSME) rotors €or alleviating vibration and for studying interactions and resulting failure mechanisms. A bearing model has been completed which has enabled the analytical determination of SSME bearing problems. This model has revealed that in addition to wearing problems, thermal loading has also contributed to failure mechanisms. Thus, analytical redesigns, using various contact angles in conjunction with new and augmented cooling techniques, are being investigated. Damping seal analytical models have led to the design of new concepts and will be evaluated in the size and speed range of interest for the SSME using a unique test facility. Advanced computational fluid mechanics techniques are being used to define the flow of hot gases through the turbine blades and to define the resultant thermal and mechanical stresses on the blades. The results of such analyses will provide inputs to structural analyses as well. Probabilistic structural analysis theories have been developed and are being used by both NASA and industry to predict the fatigue life of highly stressed turbine blades. Such models for turbopump blades are operational and are currently being validated. Advanced single-crystal blade materials and improved design concepts show that approximately 80 percent higher strength may be attainable using these new techniques as compared to current materials.

Experimental data for high-pressure combustion stability and heat tranfer has been obtained for liquid oxygen (LOX)/methane and LOX/propane in both subscale main combustor hardware and in turbine-drive gas generators and is being used to update analytical models developed for low-pressure operating conditions. Studies of the incompatibility of hydrocarbon fuels with copper alloys (combustor materials) have been initiated.

Optical diagnostic sensors for measuring bearing wear, turbine blade temperature, and shaft speeds have been successfully demonstrated in the laboratory and are scheduled for verification testing on the technology testbed engine. Nonintrusive cryogenic flow meters and hot gas temperature sensors are currently being evaluated in laboratory tests.

Auxiliary, or low-thrust propulsion technology, is aimed at improving our capabilities in electrothermal thrusters; arcjets; ion thrusters; small gaseous oxygen/gaseous hydrogen motors; and long-life, efficient, storable propellant motors. Successful firings of three 25- to 50-pound thrust hydrogen/oxygen motors were accomplished for a total burning time of approximately 32 hours. Successful firings of a thin-walled rhenium chamber with storable bipropellants in which the chamber temperature stabilized at over 4300 degrees Fahrenheit occurred. More efficient combustion resulted, giving a 10-percent increase in performance, a significant amount for planetary spacecraft which may be over 50-percent propellant by weight. In electric propulsion, a platinum-alloy resistojet was successfully operated using the anticipated waste gases from the space station. On the basis of these tests, the resistojet has been selected for the space station drag make-up, and this will utilize waste that otherwise would have to be returned to earth. Small arcjets are now starting and operating smoothly, and specific impulses of over 700 seconds have been delivered with storable propellants. This is more than double the performance of current systems for controlling satellites. Ion thruster progress includes the tripling of the thrust levels at a given size and the successful computer operation of a two-thruster system to investigate component interactions.

Advanced propulsion studies continue to investigate promising concepts beyond today's capabilities. The potential of such advanced concepts as antimatter and fusion plasma is being considered, as well as nearer term concepts, such as on-site production and use of propellants on the moon and planets. Magnetoplasmadynamic (MPD) testing has been advanced by the development of a capability to operate thrusters for extended durations at relatively low power. Forty-minute tests were performed with thrusters at 20-kilowatt levels, giving the first extended operational experience with MPD units. Performance was promising, and higher power testing is planned.

BASIS OF FY 1988 ESTIMATE

In FY 1988, some of the propulsion research program on LOX/hydrogen and LOX/hydrocarbon research concerning analysis methods and components experiments formerly in the research and technology base program will become part of the CSTI program in earth-to-orbit propulsion. Fundamental efforts in reusable engine research and technology, which are aimed at establishing the technology base for component life extension and prediction, will continue in the research and technology base program. Bearing model verification testing (utilizing an advanced cryogenic-fluid lubricated bearing tester) will be nearing completion, and previously developed analytical techniques will be used to initiate the design and fabrication of advanced, longer life, rolling-element bearing concepts. Computational fluid dynamic analyses will continue to be used to define and improve internal engine hot gas flows and resulting aerothermodynamic loads. The full-scale SSME testbed facility, appropriately instrumented, will be used to validate the probabilistic structural analyses theories that have been developed in this program. Diagnostic sensors will be developed, with emphasis on sensors that will be able to detect fatigue life degradation of component parts and on the remote sensing of leak detection. Both types will be used in the SSME testbed. An optical bearing deflectometer will be used to detect bearing failures, and an optical pyrometer will be used to measure blade temperatures and temperature profiles across a blade. Isotope wear detectors will be used to measure radiation loss in bearings which can be correlated to the amount of wear in the bearing.

The orbit transfer propulsion technology program will provide the design and analysis tools for the future design and development of a reusable, space-based, high-performance, throttleable, oxygen/hydrogen expander cycle engine. Ribs will be provided on hot gas side walls and fins will be included in coolant channels thus providing more surface area and a resultant increase in heat transfer rates. High-efficiency, variable-flow turbomachinery enhancements will be achieved through the investigation of losses in the pump, diffusing losses in the crossover passages, and seal technology to reduce recirculation losses. An understanding of flow processes in high-expansion-ratio nozzles will be developed so that the contributions of viscous and kinetic losses in the boundary layer can be accounted for. Such losses will be measured using both probes and schieleren photography methods. To promote life expectancy in very small high-speed rotating machinery, hydrostatically-supported bearing systems and the rotor dynamics of such bearings will be investigated, as will hydrodynamic lift seals to promote increased life with less contact. High-strength combustor liner materials capable of transferring very high ratios of heat transfer will be developed using rapid solidification rate powder metallurgy technology. Such materials have the potential for unique properties in strength and conductivity with improved, low-cycle fatigue life. Diagnostic sensors will be developed to provide the basis for integrated condition monitoring/engine control systems leading to automated, fault-tolerant flight operations and between-flight hands-off inspection, servicing, and checkout. One potential sensor would consist of a spectrometer used to analyze exhaust gas plumes to search for the existence of microscopic metals and other component materials which will provide information about possible malfunctioning of the turbomachinery and/or allow for appropriate conditioning of engine operating parameters as required. Other sensors will be developed which can determine the condition of the thrust chamber materials and detect cracks prior to the development of catastrophic failure modes. Advanced eddy-current probes will be investigated to allow for monitoring wear and misalignment in turbomachinery system.

For auxiliary and low-thrust propulsion, the design of a high-temperature storable bipropellant thruster will be established and life tests performed to verify its candidacy for planetary missions. Small hydrogen/oxygen thruster designs to increase performance versatility over a wider fuel/oxidizer range will be evaluated. Resistojet and arcjet efforts will be aimed at improving materials and developing understanding of the complex internal flow conditions to improve lifetime and specific impulse. Ion propulsion work will be directed at simplifying the design while increasing the thrust-per-unit area, characterizing inert gas propellants, and studying component interactions through system tests. Advanced concept work with MPD thrusters will be at power levels up to 100 kilowatts for extended periods to understand, model, and minimize cathode erosion. Advanced concept studies will continue with the objective of identifying promising areas and establishing experiments necessary to prove their potential.

	1986 Actual	1987 Amended Budget	1987 Current Estimate	1988 Budget Estimate
		(Thousands of Dollars)		
Materials and structures research and technology............................	18,126	18,900	18,900	17,900

OBJECTIVES AND STATUS

The objective of the materials and structures program is to provide technology that will allow the development of future spacecraft, large-area space structures, and advanced space transporation systems with significant improvements in performance, efficiency, durability, and economy. Major technical areas of emphasis in materials include fundamental understanding of the properties and behavior of advanced space materials; characterization of long-duration space environmental effects on materials; development of computational chemistry for predicting the fundamental properties of materials and their interaction with the space environment; and the development of ceramic, metallic, and advanced carbon-carbon thermal protection systems. Structures technology focuses on the development of erectable and deployable structural concepts; efficient and reliable methods for erection/deployment, monitoring, maintenance, and repair of space structures; new structural and cryogenic tank concepts for advanced earth-to-orbit rockets, hypersonic vehicles, and orbital transfer vehicles; and efficient analysis methods for design and evaluation of advanced space structures, including integrated structure/controls analysis and design optimization.

Materials research concentrates on fundamental material science and the development of space durable materials. Emphasis is placed on the basic understanding of the nature and behavior of advanced polymeric, metallic and ceramic composites; nondestructive evaluation and testing methods; effect of the space environment, such as thermal cycling, atomic oxygen, radiation, and high energy particles on materials; and development of dimensionally stable materials resistant to the space environment and debris impact. Examples of recent major accomplishments include the achievement of an equivalent 30 years' damage accumulation of electron exposure on graphite-epoxy composites using accelerated test methods, performance verification of aluminum-coated graphite-epoxy tubes under thermal cycling loads, prediction of surface-gas interaction effects and spontaneous ignition temperature for hydrogen on nickel, and enhanced understanding of the effect on processing and crystallinity of high-temperature thermoplastics.

The structures program continues to focus on the development of advanced space structural concepts and dynamics of flexible structures. Research in the advanced space structural concepts area includes the development of erectable and deployable concepts and design technology for large-area space structures, validated multidisciplinary analysis and optimization methodology for large-area space structures, and design and analysis methods for advanced space mechanisms. Recent major advances in the structural concepts program include an integrated interdisciplinary optimization procedure successfully applied to a 55-meter generic antenna design; space construction methods for erectable large space structures, successfully demonstrated by the assembly concept for construction of erectable structure (access) flight experiment performed on shuttle mission 61-B; an integrated multidisciplinary study for the space station structure design, which resulted in the selection of the 5-meter bay size; and a comprehensive space shuttle solid rocket motor joint analysis and the development of an alternate joint design for the solid rocket motor case.

Research on the dynamics of flexible structures emphasizes the development of advanced system identification technology, analytical methodology for predicting coupled dynamics of large flexible space structures, validated active and passive vibration damping of large space structures, and efficient and reliable techniques for ground testing of large space structures. Major recent accomplishements in this area include active damping of flexible structures using piezoelectric devices, prediction of vibration frequencies for large flexible structures with nonlinear joint behavior, demonstrated methodology for assessing on-orbit structural damage, and completion of a comprehensive study which defined the ground-based test facility requirements for large space structures.

Work in the aerothermal materials and structures technology area continues to focus on the development of advanced, efficient, thermostructural and thermal management concepts for future space transportation systems and hypersonic vehicles; an integrated fluid-thermal-structural analysis methodology and aerothermal loads data base; and new reusable thermal protection systems using metallic, ceramic and advanced carbon-carbon materials. Recent progress includes the development of new "hard hat" thermal protection tiles, a demonstrated three-dimensional woven silicon-carbide reusable thermal insulation blanket concept suitable for aeroassist orbit transfer vehicle ballute applications, and verified prediction of the combined fluid-thermal-structural analysis code using benchmark high-temperature wind tunnel data.

The hypersonics program proceeds with the development of efficient, durable, and lightweight materials and structural concepts for applications at both high and cryogenic temperatures; materials and thermal structural concepts for airbreathing launch and sustained hypersonic cruise vehicles; and analysis and testing methods for advanced structural concepts evaluation and validation. An advanced, efficient, lightweight, and reusable cryogenic tank concept has been developed which incorporated a recently developed high-temperature foam insulation system.

BASIS OF FY 1988 ESTIMATE

In FY 1988, the materials program will continue to focus on the effect of the space environment on structural materials for spacecraft, large-area space structures, advanced space transportation systems, and orbital transfer vehicles; development of lightweight, impact-resistant, environmentally durable, and thermally and dimensionally stable composite materials and protective coatings; and test methods for nondestructive evaluation of ceramic flaw detection and strength characterization. Strong emphasis will continue in computational chemistry. Research will be focused on the prediction of atomic oxygen and radiation effects on space materials through a fundamental understanding of physical properties of atomic clusters and gas/atom interactions, such as between atomic oxygen and hydrocarbon molecules. This focused effort will be coordinated with the ongoing activity in computational chemistry described under aerothermodynamics research and technology where the focus is on the dynamics of rarefied gas flows.

In FY 1988, research to develop and verify lightweight erectable and deployable structural concepts, including modification and repair technology for large-area space structures and for large high-precision antennas and reflectors with high-dimensional stability, will continue as a major thrust. Development of mobile manipulator systems for efficient construction will be evaluated by ground test. Three-dimensional modeling and simulation of a multijointed, flexible, 20-meter beam will be performed to establish the technology base for the control of dynamic response predictions. The activity will concentrate on analytical methods to predict model characteristics, transient response, and deflection behavior. Active and passive damping methodology will be developed to reduce unwanted structural vibration during space operation. Particular emphasis this year will be on innovative active structural damping methodology. Novel piezoelectric devices will be developed and embedded into structural components to obtain the needed damping forces. The associated control law algorithms will be generated and experimentally verified using simulated large space structures.

In support of advanced space transporation systems, research to develop an advanced integrated fluid-thermal-structural analysis capability will con inue in FY 1988 with focus on generic configurations to allow for the development of highly efficient, reliable hot structures for hypervelocity flight. Concurrent with this activity, innovative concepts for extremely lightweight structures utilizing advanced foil gage joining techn ques will be explored. Development of advanced processing, including weaving techniques and coating procedures for carbon-carbon composites for stable long-life structures, will be investigated.

In FY 1988, the dynamics of large space structures effort will be conducted under the large structures and control portion of the CSTI program.

	1986 Actual	1987 Amended Budget	1987 Current Estimate	1988 Budget Estimate
	(Thousands of Dollars)			
Space data and communications research and technology..............	15,384	13,600	13,600	8,900

OBJECTIVES AND STATUS

The space data and communications research and technology program is directed toward developing the advanced ability to control, process, store, manipulate, and communicate space-derived mission data and enabling new communications concepts.

The objective of the data systems research is to provide the onboard computing technology needed for new classes of data systems that will enable and make affordable future NASA missions with challenging computing requirements. The work is concentrating on system-level development. These systems are largely based upon existing or newly emerging components and integrated circuits. A multiple processor computer using very high speed integrated circuits has been assembled and is now being combined with NASA high-reliability and fault-tolerant architectures and software. This unit is being evaluated as a candidate for space applications. Other work, with longer term objectives, is underway to produce a complete computer using gallium arsenide technology for the the first time. Gallium arsenide components have the potential of replacing the existing silicon technology devices because of the increased speed and improved radiation tolerance. New architectures are being developed with the objective of providing dramatic increases in performance and reliability. Increased emphasis is being placed on enhancing software reliability while also reducing the cost.

The communications technology effort is directed toward maintaining and ensuring the U.S. preeminence in satellite communications and providing the necessary technology to enable future reliable data communication links for ultra-high data generation rate dependent missions, such as the earth observation satellite, the large deployable reflector, and the Mars rover. Fundamental materials research has led to high-emission current long-life reservoir cathodes. These cathodes will have applications in high-frequency/high-power tubes for space communications and high-frequency submillimeter backward oscillators for remote sensing. Other materials research has led to a technique to apply a pyrolitic graphite coating to a copper electrode in a multistage depressed collector. This technique has extended the efficiency of traveling wave tubes by producing a surface with extremely low secondary electron emission properties. A digital filter processor, integrated on a silicon chip, has been developed which replaces the cumbersome and unreliable series-parallel tracking loop capacitors found in past transponders. It will provide numerical control of the voltage controlled oscillator frequency by command, is radiation hard, and is a generic technology which can provide other functions such as automatic signal acquisition and ranging. The mathematics have been developed to yield the necessary information for correcting a phased-array antenna feed for distortion in the reflector given a random distribution of measurements of the far-field antenna pattern. An Intelsat 24-phased array horn feed has been obtained for experiments on the 15-meter hoop colum antenna to investigate the correction of the far-field pattern of a distorted reflector by reconfiguring the phase and anplitude of the feed. This technology will allow for less active control of the large structure antennas. A 30-gigahertz integrated gallium arsenide receiver module which provides the basic receiver functions such as low noise anplification, phase shifting, down conversion, intermediate frequency anplification, and output power control, has been fabricated. The next generation of communications will employ laser optics. Efforts under way have indicated that it may be possible to have a two-dimensional surface emitting semiconductor diode laser array. Each individual laser beam may be individually controlled in both anplitude and phase, making it theoretically possible to electronically steer the laser beam like that of a microwave phased-array antenna. Research is continuing on an artificially layered solid-state device with a built-in staircase electric potential which may enable a solid-state device with the equivalent properties of a photomultiplier tube, but without the associated reliability problems. The device will find immediate application as a receiver for optical communication links.

BASIS OF FY 1988 ESTIMATE

Prior to FY 1988, the space data and communications program had the broad focus of addressing the technology needs of all advanced space applications. In FY 1988, a systems program in information technology will be established as part of the new CSTI program. Technologies needed to meet the high-rate/capacity data requirements for the earth observing system, large deployable reflector, evolutionary space station, and future missions will be developed in that program. The remaining space data research and technology program will emphasize general purpose, fault-tolerant carputing. All space communications research and technology will remain in this research and technology base program.

In FY 1988, work will continue toward developnent of onboard processors that provide the canbinations of performance, weight, power, and very high reliability needed for future NASA missions. The developmental computer, using very high-speed integrated circuits, will continue to be used to evaluate the performance of those circuits in combination with new architectural and software concepts. Elements of this work could benefit upcoming missions, such as the space station and earth observing system. The developnent of gallium arsenide-based computers will continue to be aimed at more advanced carputers for missions and payloads further in the future. The evaluation of data flow architectures will move fran the study and design phases into testing. Work using simulation to design and evaluate alternative intercomputer communications approaches will continue. Work to provide high-capacity onboard data links using very fast and multichannel fiber optic approaches will continue. Chip level developnent will be conducted in very specific areas, such as communications channel coding, data compression and radiation-tolerant microprocessors where NASA's needs are not being met by products from industry. Work initfated in FY 1987 to develop an erasable associative memory will be continued. Work will be initiated on theoretical exploration of the use of optical processing technology in conjunction with the ongoing computer research. The 14-inch space-qualifiable optical disk recorder, together with parallel real-time optical processing technology, will be included in the CSTI program.

In FY 1988, because of advances in photolithography, the possibility of micro-fabricating slow wave circuits with application to field emission cathodes will be tested. Advantages include low-beam voltage and low-power consumption with one-watt output. Part of the monolithic microwave integrated circuit effort will be focused on Ka-band integrated gallium arsenide transmitters for eventual upgrade of the deep space communications network. Also, experiments will be done on the development of the technology to enable the development of an efficient 32-gigahertz traveling wave tube. The Intelsat 24-reconfigurable horn feed and a 20-gigahertz integrated microwave feed will be tested on the 15-meter Langley Research Center hoop-column antenna in an appropriate near-field antenna pattern measurement facility. The mathematical concept of reconfiguring the phase and amplitude of the feed to compensate for distortions in the reflector surface will be experimentally tested. Also, the mathematical concept of nonuniform sampling of the far-field will be experimentally tested. Research will begin to develop a monolithic gallium arsenide microwave module which will provide an interface for an optical-fiber carrying control network with performance goals of one gigabit of information, 16 parallel outputs, and 50 milliwatts power consumption for receiver and control logic.

Research will continue on laser power summing techniques to sum the power from multiple individual devices to increase the total transmitted power, flexibility, and reliability of semiconductor diode lasers for deep space and planetary optical communications applications. This will enable the laser sources, beam diagnostics, tracking, and imaging and steering optics to be tested singly or in a system environment. For deep space communications, power is important. Experimental work will begin on a semiconductor laser diode end pumped neodymium yittrium iron garnet laser as a possible source. For low earth applications, the semiconductor laser diode phased array will be demonstrated with a single-lobed far-field pattern while remaining stable at high power and high modulation rates.

	1986 Actual	1987 Amended Budget	1987 Current Estimate	1988 Budget Estimte
		(Thousands of Dollars)		
Information sciences research and technology...........................	12,462	10,200	10,200	8,000

OBJECTI

The objectives of the ion sciences resea and technology program are to discover advanced , t and t algorithm and t invent , dwar ces and components, d sof in order to enable viable and producti spac information systems.

I computer science, the of Ada as the chosen p language for station has d a point for the of to develop and manage large software jects A new set of software management tools, called software automation, and strati (SAGA), have been elop d to or and pr requir assis managers in the control of s twa projects. ndings fran software management research are the topic of a NAS s workshop. Algorithm for processors have been developed to efficiently deal with the general problem of eff allocation of tasks to the individual in t ocessor systems. Research in data t ogic has esulted impro to allo s ienti ic investigators to access space-derived data that i stored i various at var locations in the country. The center onautics and space inf sciences at Stanford nivers continues to identify telescience as a cal point for the fundamental work in carputing.

In the sensor technology program, major advances have been made through NASA-sponsored research at industrial, academic, and NASA laboratories in titanium-doped sapphire as a viable candidate as laser material for active remote sensing. In particular, the anomalous self-absorption losses seen in these crystals have been discovered to be caused by impurities in the material. Subsequent crystal growth has been successfully tailored to rectify this problem.

In the detector device area, a direct read-out 58x62-pixel antimony-doped silicon array has been successfully tested in the important scientific wavelength region of 24 to 31 micrometers.

In the area of devices for heterodyne detection in the far infrared portion of the spectrum, a mercury- cadmium-telluride alloy frequency mixer at 28 micrometers in wavelength has been successfully built with possibilities for extension out to 118 micrometers. In addition, preliminary experiments on a superconducting-insulating-superconducting junction employing a new material, miobium nitride, show promise as a mixer at 500 gigahertz and above in frequency.

In the area of sensor materials research, a new artificial material, an indium arsenide/indium-gallium arsenide strained layer superlattice, which shows promise as a new candidate material for sensing, has been grown for the first time in the world by molecular beam epitaxy at the Jet Propulsion Laboratory.

BASIS OF FY 1988 ESTIMATE

Prior to FY 1988, the information sciences research and technology program had the broad focus of addressing the technology needs of all advanced space applications. In FY 1988, a systems program in information technology will be established as part of the new CSTI program. Technologies needed to meet the science sensor requirements of the earth observing system and large deployable refector will be developed in this program.

A reduction in the FY 1988 budget from that of FY 1987 reflects the fact that portions of the submillimeter passive sensing program, together with portions of the active sensing program, have been incorporated in the information section of the CSTI program. All computer science research will remain in this program.

In computer science, major emphasis is being placed on software engineering research leading toward improved techniques and tools to produce, document, and manage large and complex tasks for development of highly reliable software. NASA software development will continue to be coordinated with comparable Department of Defense (DOD) work via the DOD software technology for adaptable reliable systems program and the DOD Software Engineering Institute. The pioneering use of the Ada programming language on space station will be used to evolve improvements in the language and its associated support environment. Research to provide a common tool to access a variety of scientific data bases will move from demonstrations with homogeneous data bases to demonstrations with heterogeneous data bases. Work will continue in the development of algorithms to use the unique capabilities of the NASA-developed massively parallel processor to solve space-related problems, such as defection of stars and galaxies in images, ocean dynamics modeling, and space plasma simulation. The center for aeronautics and space information sciences at Stanford University will continue as a center of excellence in aerospace computing, conducting fundamental research and educating students in concurrent processing, networking, information management, and large-scale system architecture.

In the sensors technology area, work will continue in active remote sensing on the problems associated with making lasers space qualifiable. This includes increasing the number of shots over the total lifetime of the laser to at least 100 million, tuning the laser to the frequencies of scientific importance, getting enough energy in the laser pulse, and assuring the frequency purity of the pulse. Associated technologies, such as semiconductor diode laser arrays for pumping laser amplifiers and materials research, will continue. Solid-state technology for pumping lasers with semiconductor laser diode arrays will be included in the CSTI program.

In passive remote sensing, heterodyne detection is the method of choice for spectroscopic measurement applications in the submillimeter portion of the electromagnetic spectrum. Devices research in frequency sources and mixers in the submillimeter region will be pursued. The advanced coherent detector concepts, including revolutionary heterodyne arrays, which will enable both spatial and spectral instrument resolution, will be included in the CSTI program together with advanced tube oscillater concepts. The area of the growth of artificial layered structures by means of molecular beam epitaxy shows great promise for providing materials for detectors and mixers in the near- and far-infrared portion of the electromagnetic spectrum. Methods will be investigated for growing electro-optic materials on silicon in order to integrate the detecting and electronics on one chip, thereby reducing unwanted electronic noise. New materials will be investigated for extending the response of detectors out into the far infrared and upper portions of the submillimeter region for space-based background-limited astronomical observations.

	1986 Actual	1987 Amended Budget	1987 Current Estimate	1988 Budget Estimate
		(Thousands of Dollars)		
Controls and guidance research and technology...........................	7,035	7,500	7,500	6,300

OBJECTIVES AND STATUS

The controls and guidance research and technology program goals are to generate the practical design methods and techniques required to enable precise pointing and stabilization for future NASA spacecraft and payloads; to maintain precise structural shape control for highly flexible large space systems; and to guide, navigate, and control advanced space transportation vehicles. Emphasis is being placed in two areas: (1) advancing the methodology of combining both ground-based testing and future space-based testing with modern control theory to validate advanced flexible-body modeling techniques and control laws; and (2) providing advanced guidance, navigation, and control algorithms combined with real-time fault-tolerant distributed control architectures and validation and reliability tools.

Recent program accomplishments include the successful performance of distributed active control algorithms in the spacecraft control laboratory experiment program. These results are important in defining the active controls experiments for the 60-meter control of flexible structures experiment and the three-dimensional antenna flight experiment currently under definition. These successful ground tests and subsequent flight validation experiments will also be important to implementing the NASA-planned pinhole occulter and mobile communications satellite ventures and will supply valuable control algorithms for large flexible astrophysical reflector telescopes. Refined system identification techniques have been developed which can accurately determine, on orbit, the vibration modes in large space systems, such as growth space station. A precision position measurement sensor useful in determining the shape of large antennas and other large space systems has successfully demonstrated millimeter accuracy in a multitarget ranging test. Advanced guidance and navigation concepts and flight experiments were generated supporting a wide range of aeromaneuvering orbital transfer vehicles. Also, in the transportation system vehicle controls area, the initial advanced information processing system architecture was demonstrated. It provides reliable, long-life, low-cost controls capability for a wide spectrum of transportation vehicles, including the aerobraking orbital transfer vehicle, Shuttle 11, and the heavy lift launch vehicle.

BASIS OF FY 1988 ESTIMATE

In FY 1988, all controls research that directly supports the control of flexible structures experiment has been transferred to the large structures and controls section of the CSTI program.

FY 1988 controls and guidance research and technology activities will continue theoretical exploration of modern control theory methods associated with both system identification and distributed and adaptive control. The goal is to identify and develop promising advanced control concepts for future large space systems. The unique piezoelectric payload mounting and isolation device, useful for eliminating space station induced instrument motions, will be carried to the breadboard stage. A three-dimensional millimeter accuracy shape and motion sensor will demonstrate combined range and lateral displacement functions.

For advanced transportation systems, theoretical research will be carried out to provide guidance and navigation algorithms for aeromaneuvering vehicles undergoing skip trajectories, synergistic plane changes, and precise landings involving large down-range and cross-range capability. Theoretical approaches for adaptive guidance, navigation, and control algorithms and software will be developed for next generation earth-to-orbit transportation vehicles to enable lower cost and higher efficiency launch operations. Integrated function solid-state optical processing chips will be tested in the fiber-optic rotation sensor testbed, to provide transportation vehicles and interplanetary spacecraft with long life and highly reliable navigation devices. To meet extremely demanding future transportation vehicle mission requirements, the advanced information processing system control architecture will be developed and experimentally validated in the avionics integration research laboratory. Prevalidation performance and reliability tools and methodology will be developed. Guidance, navigation, and control flight experiments will be defined and analyzed for the proposed aeromaneuvering vehicle flight experiments.

	1986 Actual	1987 Amended Budget	1987 Current Estimate	1988 Budget Estimate
		(Thousands of Dollars)		
Human factors research and technology..........................	2,100	2,300	2,300	4,900

OBJECTIVES AND STATUS

The objective of the space human factors research and technology program is to provide the technology base for productivity, efficiency, and safety in increasingly complex manned space operations, including the space station and a potential national aero-space plane. The research is focused on crewstation design and productivity enhancements for extravehicular activity (EVA). The objective of the crewstation design effort is to determine the requirements for effective interfaces between human operators and advanced automation. This issue has become very challenging due to the increasing levels of machine intelligence and autonomy sought by system designers. Instead of performing low-level sensor integration and determining actuator positions, the human operator is becoming a supervisor of intelligent systems. Thus, a major goal of the crewstation research and technology program is to ensure effective information transfer between the system and the operator, which is fundamental to the operation of highly automated systems. Increased EVA capability can be achieved by developing high-pressure suits and gloves which are comfortable, durable, and maintainable on orbit and by introducing EVA electronic information displays which provide flexibility and rapid information access.

Research in **FY** 1987 emphasized crew workstation design and a focused effort in EVA suits and displays. A comprehensive set of human factors guidelines that are specific to NASA's missions were developed and will be distributed to space station contractors in **FY** 1987. Prototype workstation mockups have been fabricated, and more detailed and functional ones are being built. These facilities are supporting rapid prototyping, in which advanced research concepts are brought in for integrated evaluation, operational simulations, and comment by users.

Research on the wide field-of-view stereo display, called the virtual visual environment display (VIVED), last year formed the basis of the virtual workstation project in **FY** 1987. This workstation is a major leap beyond current human-computer interfaces, since it allows computer-generated graphics and text to be displayed anywhere in the user's workspace. This greatly improves information transfer in applications, requiring the user to be spatially oriented relative to the displayed information, such as in telerobotics monitoring and control. Currently, higher resolution liquid crystal displays and cathode ray tubes are being integrated into the design. Improved support electronics have been fabricated which will allow replication and improve reliablity. Application-specific spatial data bases are under development.

Expert system interfaces is a key area of study since the level of interaction is far higher than in traditional systems. In these more intelligent systems, communication is in terms of goals, intentions, and problem-solving, rather than in terms of knobs, dials, and a few numerical parameters. Several teams of leading designers in NASA, industry, and universities are cooperating to develop the paradigms on which this kind of system should be built. The payoff will be rapid and accurate decision-making in highly complex automated systems, even as the total number of operators is reduced. Expert system interfaces, which incorporate graphical information, improved explanation capability, and enhanced reasoning, are being built for experimental evaluation.

Since EVA is physically demanding, it is important to understand the strength and motion capabilities of humans in zero-gravity conditions. This information is essential to guide the design of EVA tools, suits, and gloves. Progress in FY 1987 includes the development of quantitative models of strength and motion, and these are being combined with powerful computer graphics tools for use by designers. Software improvements are enabling scientists to combine graphical and physical data. Preliminary strength experiments in zero gravity have been accomplished in aircraft flying parabolic arcs. Strength measurement equipment for later shuttle flights is being developed.

Display hardware has been developed for demonstration and evaluation of helmet-mounted information displays in EVA space suits. This display will greatly add to flexibility in presenting mission-critical information to EVA astronauts. The current alternative is a book of information mounted on the astronaut's arm, whose content must be finalized well before the mission. A helmet display would not only add real-time update capability but would also enable substantial improvement in the display of system status of the suit, life support, and manned maneuvering unit. Two prototypes have been completed. One uses state-of-the-art helmet-mounted display technology and is designed for integration with current space helmets. The second uses advanced wide-angle optics and is used for more far-term studies of formats and operational uses.

Two high-pressure hard space suits have been constructed and pressure tested. As a result of this accomplishment, considerable interest has been shown by space station designers. Further work on the gloves is in progress, since it is critical that gloves be flexible at high pressure and not interfere with astronaut manual performance. On-orbit experiments indicated severe problems with manual work and, because of this, among other reasons, the space station has been redesigned to reduce EVA requirements. Improved EVA systems are being studied so that later space systems are not similarly constrained.

BASIS OF FY 1988 ESTIMATE

Workstations for proximity operations will be evaluated. The virtual workstation will undergo hardware integration and display upgrade. A demonstration of the virtual workstation in telerobotic applications is planned for FY 1988. Expert systems studies will focus on specific subsystems and users. Subsystem specialists, software designers, and cognitive psychologists will work together to analyze the key features of an expert system interface needed to support the user. Graphical strength and motion models of EVA astronauts will be refined to include mass, inertia, and other physical properties. The models will also be used to evaluate such intravehicular activities as the change-out of modular racks in space station. Testing of the hard EVA space. suit will be conducted in weightless environment test facilities (neutral buoyancy water tanks). Glove design will receive particular attention in the area of materials and manufacturing processes. EVA helmet displays will be evaluated for use, and a summary report on the status of this effort and further technology needs will be written. Format research based on head-up display studies by aeronautical human factors researchers will be conducted.

The productivity of humans in space is critically important to the success of NASA's missions, and an increase of the space human factors research and technology base is planned in FY 1988. As part of the planning for this augmentation, NASA and the National Research Council (NRC) of the National Academy of Sciences will conduct a space human factors symposium in FY 1987 which will bring together leaders of industry, government, and academia in order to survey human factors research which would most likely benefit NASA's manned space goals. The space human factors research program will integrate the NRC guidance with NASA's strategic plan to determine the additional FY 1988 research activities which will enable NASA's visionary missions. Key elements will include: (1) supervisory control of autonomous space systems (e.g., rovers, orbital transfer vehicles, and life support subsystems); (2) teamwork and interaction between automation/robots and humans; and (3) automation-augmented human physical and intellectual capability.

	1986 Actual	1987 Amended Budget	1987 Current Estimate	1988 Budget Estimate
		(Thousands of Dollars)		
Space flight research and technology...	**14,054**	**22,400**	**22,200**	**23,200**

OBJECTIVES AND STATUS

The ecti **of** this program **is** to **ovide** research-quality **flight** data supportive of **d** research and technology **eff** **for** the ; and **operation** of **utur space stems. This objective** is **d through** the **utiliz** lo of **urrent** and **it space fac t** such as in-space research **laboratories.** Data obtained from t effort support the **deve opm nt** and **ification** of l **theori** and verification of ground facility performance, test **s** and techniques. This g mp tl ; development and t test of **peri** and the s t of **special urp** ; **reusabl flight** research **ties** for use in space.

The cryogenic fluid management flight experiment will provide the basic understanding of the storage, acquisition, and transfer of cryogenic fluids in zero gravity. This technology .is critical to the design of future cryogenically fueled orbital transfer vehicles (OTV) and for the on-orbit supply and resupply of cryogens to both spacecraft and platforms. In FY **1987,** procurements were initiated for component development of liquid hydrogen flowmeters and valves and gaseous hydrogen/gaseous helium flowmeters and pressure regulators. In addition, analytical models were developed and/or refined to provide the design data base for the heat and mass transfer during nonvented fluid transfer and an understanding of low-gravity fluid behavior.

Under the orbiter experiments program, first flight was completed for three key aerodynamic and aerothermodynamic experiments. Significant contributions were made to the aero/aerothermodynamic data base, although anomalies occurred during experiment operations which reduced the planned data return. Subsequently, the causes of these anomalies have been determined and modifications or repairs have been or are in the process of being made in preparation for an additional five flights upon resumption of theorbiter flight schedule. The orbital acceleration research experiment, which will provide a better understanding of vehicle aerodynamics and aerothermodynamics in both the molecular and continuum flow regimes, as well as expand the data base for orbital drag predictions, has completed critical design review and is in process of hardware fabrication. Fabrication of flight test panels for the advanced thermal protection system experiments was completed, and certification of test materials initiated. This experiment will provide actual flight data on durable, high-performance material concepts which could become candidates for future aerospace vehicles.

The outreach program, to provide leadership and funding support to the aerospace industry and university communities to better utilize the potential of space for technology development, was initiated in FY 1986. The solicitation and selection of experiments will be completed during FY 1987, followed by the initiation of experiment definition/development activities.

The development of a space technology experiments platform (STEP) initiated in FY 1985 was continued in FY 1986 with the fabrication of mission peculiar hardware and the completion of the preliminary design of the required avionics element. STEP is configured to accommodate a wide variety of space experiments in the microgravity and low disturbance environment of space over broad thermal excursions, Functionally, STEP, as a reusable payload support system and standard shuttle interface, will provide a cost-effective means for routinely conducting a variety of shuttle unique in-space experiments. In FY 1987, a critical design review was conducted on the avionics elements for STEP; fabrication and testing of a quarter platform was completed; and a pyrotechnic separation system was developed.

The capillary pump loop experiment, successfully flown in January 1986, provided systems and component research data for future development of two-phase heat-pipe systems. The results of this experiment lend confidence to the potential for the early application of two-phase technology to space station and future spacecraft. The long-duration exposure facility awaits retrieval by the shuttle and subsequent data analysis. The LIDAR in-space technology experiment, to evaluate the capability of making measurements of aerosols and other atmospheric parameters from a spaceborne platform, has completed preliminary design review. Also, the ion auxiliary propulsion system remains in flight-ready status for flight on an Air Force satellite. Fabrication and flight certification have been completed on the heat-pipe radiator experiment which is awaiting an early shuttle flight. In FY 1987, efforts focused on the identification and definition of new space experiments required for the enhancement or enablement of future space endeavors was initiated. These experiments are being defined for the shuttle or the future space station.

CHANGES FROM FY 1987 AMENDED BUDGET

The reduction of $0.2M in space flight research and technology reflects primarily the realignment of hypersonic technology funding to aerothermodynamics research and technology.

BASIS OF FY 1988 ESTIMATE

In FY 1988, under the orbiter experiments program, key aerodynamic, aerothermodynamic, and thermal protection system experiments will resume flights for completion of the previously planned six-flight series for these experiments. Early fiscal year activities will be in preparation for these flights, including completion of material sample fabrication flight certification and instrument installation into the orbiter.

In FY 1988, preliminary design activities will be initiated with concept design planned for completion in mid-year and a design review scheduled for FY 1989. Ground-based tests to support component development and analytical models development will continue.

The outreach program, initiated in FY 1987 to expand flight opportunities to the industry and the university communities, will continue with experiment definition/development activities.

The LIDAR in-space technology experiment effort will include the critical design review of the instrument, followed by the initiation of hardware development in preparation for a planned 1991 flight.

	1986 Actual	1987 Amended Budget	1987 Current Estimate	1988 Budget Estimate
		(Thousands of Dollars)		
Systems analysis......................	6,438	6,100	6,100	6,500

OBJECTIVES AND STATUS

The objectives of the systems analysis program are to: (1) conduct systems analyses to identify technology requirements for spacecraft systems, space transportation systems, and large space systems for the national space program; (2) integrate these requirements into a comprehensive technology plan; and (3) provide data to establish the ability to develop these technologies in a timely manner. Close coordination with NASA flight program offices and other users is maintained to ensure proper prioritization of enabling and high–leverage technologies.

Spacecraft systems analysis is concentrated in four science and application areas: astrophysics, earth science, communications, and solar system exploration. In FY 1987, the critical technology tradeoffs for the large deployable reflector and the earth observing system have been completed, and the results will be transitioned into the discipline technology programs. In earth science, a series of studies will be initiated to understand the critical technologies associated with geosynchronous earth science observations. A comprehensive series of studies on the technologies required for a Mars surface sample return mission will be continued. Emphasis will be on the detailed technologies required for robotic sample collection, including the robotic mobility system and the alternatives for electrical power. A Mars rover workshop was held to stimulate detailed analysis of rover requirements with respect to the current state of the art and future directions of the automation and robotics program. Working through the spacecraft 2000 government/industry steering group, a joint strategic plan was developed for future spacecraft technology development and transition into specific missions and applications.

The space transportation systems analyses are focused in three areas: advanced earth–to–orbit (ETO) vehicles, aeroassist orbit transfer vehicles (AOTV), and advanced space transportation systems conceptual design and analysis methods. More specifically, the FY 1987 studies/analyses focus on the generic architecture from the ongoing space transportation architecture studies (STAS). The earth-to-orbit (ETO) studies include the technology to support a second generation fully reusable manned vehicle (Shuttle II), an advanced heavy–lift launch vehicle, and very advanced (post–2010) future space transportation systems. The ETO studies also include the definition of nonintrusive flight instrumentation and measurements applicable across the speed range during ascent and entry of an ETO vehicle. Shuttle II efforts will identify and prioritize enabling and high–leverage technologies required for a transportation vehicle that operates between earth and the space station for logistics, crew change-out, up and down payloads, and, in some cases, platform and satellite servicing. Liquid oxygen/hydrocarbon (LOX/HC) engines/vehicle integration and design studies include the impact on reusable transportation vehicle performance and cost. The use of LOX/HC engines, which require very high density propellants and thus significantly smaller propellant tanks, has the potential for large reductions in dry weight and in cost per pound of payload to orbit. AOTV technology and environment studies are continuing in FY **1987** but are concentrated on cislunar transportation systems -- in particular, on the identification of the class or classes of AOTV's that will be required to operate between lunar orbit and low earth orbit (LEO). The analyses emphasize performance, reusability, and space basing. These studies are consistent with the renewed interest in lunar and planetary colonization and mining. Finally, conceptual design and analysis methods are being developed to conduct required trade studies in a most efficient and cost-effective manner. This involves the update and development of the necessary analytical and numerical tools including the computer-aided engineering software and the technology and cost data base.

In the area of large space systems, both manned and unmanned, the focus of the analysis program is on technology for evolutionary space stations and the space infrastructure that they will support. Analysis activities will continue to examine the technology implications for designing a lunar base with emphasis on power systems and habitat facilities. Also, the definition of support hardware necessary to use the space station for in-space research and technology experiments will be completed.

In FY **1987**, three specific activity study areas will be continued in the large space systems analysis program: (1) systems analysis methods; (2) future space systems, including the evolutionary space station/infrastructure, large unmanned platforms, and a manned lunar base; and (3) in-space research, technology, and engineering planning. The objective of the systems analysis methods is to develop and maintain advanced analytic simulation/emulation computer-based capabilities for determining the operational characteristics of large space systems, predicting nominal and worst-case failure modes, and identifying critical system/subsystem interfaces. The objective of the second activity area, future space systems, is to address mission and system requirements and to identify their associated technology needs and trends. Specifically, efforts will continue for developing generic space system models to permit the conduct of sensitivity trade studies incorporating advanced technology concepts and options. Additional tasks will investigate advanced power system technology for evolutionary space stations and a lunar base, low-gravity structures for the moon, propellant and oxygen production from lunar oxides and Martian permafrost and atmosphere, and food production and enhanced human capability for extended space missions. The activities in the third area are associated with developing a sound technical basis for conducting in-space research and technology experiments using the space station as a laboratory facility. This FY **1987** activity includes the preliminary definition of experiment support equipment for an aggressive in-space experiments program across the spectrum of such technical areas as fluids, power, environmental effects, and structures and control.

BASIS OF FY 1988 BUDGET ESTIMATE

In FY 1988, the Mars rover ii will be completed, and emphasis will be redir toward an outer p s stati study. Wi the ast focus, t will center on the chnol requirements for inter r observatori across a c f av he definition study of a s flight testbed for i l industry gy development will be Work will t ini to synthesize the analytical techniques d f st studies into a general purpose ft systems analysis capability.

The transportation system ly effort FY 1988 ill the tion of key areas for og growth in t transfe vehicl and advanced system for delivery of payloads to l rb The analyses wil focus on concepts and technology requirements for a lunar orbit tr vehicle, a -l launch h and the shuttle lac The continued elop of design and analys ls and the technology base for anc transportation vehicles will enable the elopment a space in the future.

In large systems, the of the t y focus from the initial p tation to an d mission perspective, lutionary space stations, lunar bases, and l durat manned space ips, will be thrust of the extended perspect is to ensur that the research and technology base program is ucture to enable and support the needs of missions in the future. , the FY 1988 program will continue to include planning for the use the space ion as a facility t support research and technology.

BASIS OF 1988 FUNDING REQUIREMENTS

SYSTEMS TECHNOLOGY PROGRAMS

	986 Actual	1987 Amended Budget	1987 Current Estimate	1988 Budget Estimate
	(Thousands of Dollars)			
Chemical propulsion systems technology	5,800	8,100	8,100	---
Space flight systems technology	11,200	11,300	11,300	---
Automation and robotics	10,200	18,000	18,000	---
Total	27,200	37,400	37,400	---

	1986 Actual	1987 Amended Budget	1987 Current Estimate	1988 Budget Estimate
		(Thousands of Dollars)		
Chemic 1 propul ion systems techn logy				
Advanced earth-to-orbit systems technology...........................	5,800	8,100	8,100	

OBJECTIVES AND STATUS

The objective of the advanced earth-to-orbit systems technology program is to verify life, performance, and operations technologies that have been developed under the space propulsion research and technology program by utilizing a testbed engine which has been assembled from existing space shuttle main engine components. This will provide experimental data with which to verify advanced design concepts in true internal engine environments and to validate analytical models created to simulate these internal environments. Initial testing will be conducted with an engine instrumented with research-quality instrumentation to accurately measure both transient and steady-state pressures, temperatures, flow rates, stresses, and strains. Experimental data from this testing will be used to anchor simulation codes. Advanced subcomponent hardware items, including advanced single-crystal hollow turbine blades, 'advanced longer life bearing designs, and improved rotordynamic damping seals, are currently being fabricated for installation into engine component hardware for later hot-fire testing. Diagnostic sensors, including a bearing wear deflectometer, a fiber optic pyrometer blade temperature sensor, an optical hot-gas temperature sensor, a nonintrusive shaft speed sensor, a plume anomaly detector, and a brushless torquemeter, are all being similarly fabricated for later installation and testing.

The testbed engine program will generate the experimental data needed to provide final verification of advanced design and analysis tools that will lay the foundation for advanced high-performance, reusable earth-to-orbit engines. These engines are essential for future national space transportation needs. The Office of Aeronautics and Space Technology program funds the analyses, design, and fabrication of advanced technology instrumentation, subcomponent hardware, new diagnostic sensors, and the analysis of the test results. The Office of Space Flight provides engine component hardware, installs advanced technology items, assembles the testbed, and conducts test operations. Testing of the instrumented engine is scheduled to begin in FY 1988, followed by initial technology evaluation testing beginning in FY 1989.

BASIS OF FY 1988 ESTIMATE

In FY 1988, this program will be absorbed into and become an integral part of the propulsion program under the CSTI program.

	1986 Actual	1987 Amended Budget	1987 Current Estimate	1988 Budget Estimate
		(Thousands of Dollars)		
Space flight systems technology				
Space flight experiments.............	6,200	---	---	---
Control of flexible structures.........	5,000	11,300	11,300	---
Total..............................	11,200	11,300	11,300	---

OBJECTIVES AND STATUS

The objective of the control of flexible structures (COFS) program is to provide experimental validation of analytical methods for predicting coupled structural dynamics and controls response for complex multibody space structures with flexible components, interfaces, and dissipative mechanisms.

In order to meet the requirements of the program, a comprehensive research activity which includes analytical methods development, ground-based testing, and in-space experiments was initiated in 1985 to provide a focus for control structures interactive technology. An in-space experiment program is planned, building progressively from modeling and dynamic characterization of large space structures to more complex flexible-body interactive controls/structure issues. The approach provides for structural dynamic functional complexity in a baseline configuration that has fundamental frequencies below one hertz, complex nonlinear joint effects, structural dynamic/control systems interactions, and inherent low structural damping effects. This test article will be tailored to validate discipline research objectives addressing the major concerns of large space system spacecraft, independent of any specific configurations ultimately chosen for new missions. The first flight article, COFS I, a large 60-meter deployable/stowable structure (termed Mast) will be dynamically tested in space cantilevered from the shuttle. The second flight article, COFS 11, is a Mast with a three-dimensional appendage to study the structural dynamics and controls of large, flexible spacecraft configurations.

BASIS OF FY 1988 ESTIMATE

This program is incorporated in the CSTI program in FY 1988.

	1986 Actual	1987 Amended Budget	1987 Current Estimate	1988 Budget Estimate
	(Thousands of Dollars)			
Automation and robotics................	10,200	18,000	18,000	---

OBJECTIVES AND STATUS

The objective of the automation and robotics program is to exploit the potential of artificial intelligence and telerobotics to increase the capability, flexibility, and safety of space and ground operations while decreasing associated costs. In FY 1987, the preliminary design and development of the telerobot demonstration facility with a two-arm manipulator was completed, and a sequence of demonstrations for FY 1988 defined. The facility has a suspended spacecraft (Solar Max) which the robot will acquire, despin, and service, with two cooperating robot manipulator arms mounted on tracks to accomplish these tasks, and a third arm with a mounted television camera which supplies the vision for the robot system. In systems autonomy, a comprehensive plan was developed and the management structure put into place. A prototype knowledge base for a thermal control system (TCS) was demonstrated on a symbolic 3640 computer, using the artificial intelligence (AI) development tools KEE and Simkit. Demonstrator targets include the TCS; prelaunch ECS, power, and pneumatics; the space station power system; and the shuttle communication system.

In the associated core research area, several outstanding achievements were attained. In sensing and perception, an intermediate-level computer vision system called PIFEX (programmable image feature extractor) has been developed which can detect hardware edges and vertices. In the operator interface area a six degree-of-freedom force-reflecting controller has been developed. In task planning, an artificial intelligence planner has been developed which, given a set of goals and a knowledge base of relevant actions, can generate a sequence of actions in a satellite's payload to implement those goals. Other accomplishments include rudimentary learning by the expert system planner deviser, telerobotic operation of fuel transfer/strut node coupling, verification of the smart hand and force reflecting controller, and the development of a computer graphics display for that controller.

BASIS OF FY 1988 ESTIMATE

In FY 1988, the automation and robotics program has been incorporated into the CSTI program.

BASIS OF 1988 FUNDING REQUIREMENTS

CIVIL SPACE TECHNOLOGY INITIATIVE (CSTI) PROGRAM

	1986 Actual	1987 Amended Budget	1987 Current Estimate	1988 Budget Estimate
		(Thousands of Dollars)		
Propulsion	---	---	---	39,200
Vehicle	---	---	---	15,000
Information	---	---	---	17,400
Large structures and control	---	---	---	22,800
Power	---	---	---	14,000
Automation and robotics	---	---	---	25,700
Total	---	---	---	134,100

	1986 Actual	1987 Amended Budget	1987 Current Estimate	1988 Budget Estimate
		(Thousands of Dollars)		
CSTI - Propulsion				
Earth to orbit........................	---	---	---	28,200
Booster technology....................	---	---	---	11,000
Total................................	---	---	---	39,200

OBJECTIVES AND STATUS

The objective of the CSTI propulsion program is to develop and demonstrate, in full-scale component and system tests, main engine and booster propulsion technology which will enable the development of the next generation of earth-to-orbit vehicle.

The earth-to-orbit propulsion technology program will verify the design and analysis tools developed with laboratory scale and subscale test hardware in the research and technology base program and demonstrate their performance under large-scale hot-fire engine environment. These validated analytical techniques will become the basis for the design and development of advanced, reusable, high-performance earth-to-orbit propulsion systems. These design and analysis tools will be generalized to accommodate both hydrogen and high-density propellant engine systems for broad application and operating conditions. Candidate propellant combinations include oxygen/hydrogen (at space shuttle main engine (SSME) and oxygen rich mixture ratios) oxygen/propane, oxygen/RP-1, and oxygen/methane. The program initially includes the SSME testbed engine which will provide comprehensive operating data for the SSME and a large-scale liquid oxygen/hydrocarbon (LOX/HC) main chamber to explore stability limits associated with high-pressure operation. The testbed will also be used to verify the performance of advanced technology components in a system-level environment, including advanced bearings, hollow and single-crystal turbine blades, and diagnostic instrumentation. A LOX/HC research engine will be assembled for subsequent system-level testing of the gas-generator turbomachinery.

The booster technology program will develop technologies for alternate propulsion concepts for the space shuttle booster. Two types of systems are to be considered, solid-liquid hybrid boosters and pressure-fed bipropellant liquid boosters. Performance models will be generated and verified with data from a number of increasing size static firings. Thrust levels of up to a million pounds will be considered. A single system will be selected for large-scale demonstration of performance and the safe abort capability.

BASIS OF FY 1988 ESTIMATE

In FY 1988, the CSTI propulsion program will include earth-to-orbit technology for both LOX/hydrogen and LOX/hydrocarbon propulsion systems. CSTI will also include LOX/hydrocarbon specific technology tasks to verify high pressure ignition, combustion performance and stability, and heat transfer and cooling. The CSTI propulsion program incorporates some of the effort formerly in the research and technology base and the chemical propulsion systems technology program.

The LOX/HC effort will be focused on the design and fabrication of large-scale (750,000-pound-thrust class) oxygen/hydrocarbon combustor hardware in preparation for conducting hot-fire tests to accumulate experimental data to upgrade and finalize analytical models for combustion performance, stability, heat transfer, and cooling. Models and design concepts developed in the subscale research and technology base program will be used for the design of the large-scale hardware. The overall objective of the program is to develop a set of generalized design and analytical tools that can be used for the design of advanced high-density propellant engine systems of any thrust class functioning under any desired set of operating conditions.

The SSME testbed effort will include the final assembly of the testbed engine and the initial hot-fire operations utilizing the newly activated S1C test stand at the Marshall Space Flight Center. The research-quality diagnostic instrumentation, including selected advanced technology sensors, will be installed and .calibrated. Advanced technology components (turbine blades, dampers) will be prepared for installation for the second hot-fire test sequence.

For the hybrid booster system, tasks include evaluating candidate fuels, establishing burning characteristics and a propellant configuration, selecting an oxidizer pump concept, evaluating spray concepts, and establishing the mechanisms for a safe abort option. For pressure-fed liquid booster systems, tasks include propellant selection, combustion stability characterization, pressurization systems, design, nozzle size and number optimization, and structural design and material evaluation.

	1986 Actual	1987 Amended Budget	1987 Current Estimate	1988 Budget Estimate
		(Thousands of Dollars)		
CSTI - Vehicle				
Aeroassist flight experiment........	---	---	---	15,000

OBJECTIVES AND STATUS

The aeroassist flight experiment **(AFE)** will investigate the critical vehicle design and environmental technologies applicable to the design of an aeroassisted orbital transfer vehicle (AOTV). The technology areas that will benefit from the AFE are categorized into environmental and vehicle design technologies. The environmental technologies include nonequilibrium heating (radiative and convective), wall catalysis, and real gas aerodynamics. Vehicle design technologies involve thermal protection materials, structural loads, avionics, and guidance and control. Design technologies are strongly influenced by the variations associated with the upper atmosphere.

In FY 1987, preliminary advanced development activities were completed under the space flight research and technology program in preparation for initiation of the final design and long-lead hardware procurements in FY 1988. Also a ground-based testing program was conducted in support of the definition and design efforts to establish the aerodynamic and aerothermodynamic data base for the vehicle systems and mission design. Both arc-jet and wind-tunnel tests were performed in support of the instrumentation layout for the aeroshell. Supported by the above tests, the development of analytical codes for the design of the AFE has been initiated.

BASIS OF FY 1988 ESTIMATE

Development of the AFE will be initiated in FY 1988. Final systems design and instrument design efforts will be initiated. Ground-based activities will be continued to support these design activities. Long-lead procurements will be initiated where required to meet the scheduled 1992 planned launch date and will include major hardware items, such as the propulsion system and the thermal protection tile for the aeroshell. Integration activities will be initiated to support the definition of shuttle interface requirements, system and component certification requirements, and a preliminary assessment of flight operational requirements.

	1986 Actual	1987 Amended Budget	1987 Current Estimate	1988 Budget Estimate
		(Thousands of Dollars)		
CSTI - Information				
Science sensor technology..	---	---	---	8,000
Data: high rate/capacity............	---	---	---	9,400
Total..............................	---	---	---	17,400

OBJECTIVES AND STATUS

The objective of the information systems technology program is to discover and develop new materials, devices, and components in order to enable viable and productive detection, imaging, and storage systems for future space and planetary missions in the next century.

The high rate/capacity data efforts are directed toward maintaining U. S. preeminence in collection and productive utilization of space-derived data. The work will enable a new generation of smart onboard information systems that will increase the return of scientific information from space. The science sensor efforts concentrate on visual and infared scanning and imaging instruments and radar and optical surface mapping instruments. The utilization of both classes of instruments can be greatly improved by using onboard artificial intelligence to manage the instrument operation. Smart instruments could be taught to look for particular features or events and transmit only data of interest.

The next revolutionary impact on instrumentation will be submillimeter detectors utilizing a heterodyne array for missions such as the large deployable reflector. This particular instrument concept will be able to accomplish both spectral and spatial imaging. Parts of the ongoing sensor technology base have been focused onto this problem, namely materials which can incorporate mixing arrays. In addition, a heterodyne frequency source with enough power to illuminate the entire array is needed. Ongoing work in novel backward oscillator tubes at the submillimeter frequency and with promise of ample power will continue to be focused from the ongoing base to this systems technology thrust area. Millimeter and submillimeter wave heterodyne radiometer front-ends employing planar antenna structure and quasi-optical coupling have been investigated.

Research to enable active laser sensors is being conducted. Solid-state materials and pump device advances have contributed toward extending laser operational lifetimes. One approach transferred from the research and technology base is pumping the laser material with laser diode arrays. The objective is to develop two-dimensional semiconductor laser diode arrays with ample output power density. Materials studies into problems such as heat dissipation, frequency stability, and efficiency are in progress. In addition, a research effort is being initiated to develop sub-Kelvin cooler technology to improve and extend infrared sensor performance and life.

BASIS OF FY 1988 ESTIMATE

Onboard computing and optical disk memory technology elements of the space data and communications program have been incorporated into the CSTI program in FY 1988 to focus on the high-ratelcapacity data requirements of future NASA missions. Submillimeter and laser sensor technology elements of the information science research and technology program have been incorporated into the CSTI program in FY 1988 to focus on science sensor technology for earth observing system and large deployable reflector.

Future onboard imaging instruments operating in the visual and infared regions that create images of much higher spatial and spectral resolution than now in use are being developed. These instruments enable an exciting new scientific exploration capability. However, the volume of raw data from these instruments will be enormous. Onboard processing work is targeted at reducing the data by a factor of 1,000 with equivalent science return. Improvements in the useful information from surface mapping instruments, such as synthetic aperture radars and light-detecting and -ranging devices, will be obtained by using onboard processing. Remote sensing of surface features could be automaticaly configured for the scene (ocean, mountains, ice fields, etc.) which would both increase information return and reduce the operations support staff needed on the ground.

In the high-rate data area, work concentrates on the development of onboard processing techniques for surface mapping measurements and visual and infared scanning instruments. These instruments share the common characteristic of being voluminous producers of data. Early work in the area of surface mapping will concentrate on elimination of data with no information content from the communications channel. Adaptive processes will be developed so that data is collected only at times and places of interest. In a like manner, onboard processing of focal plane image data will delete unneeded information before transmission. This processing will be done in coordination with the scientific users of the data. There is work underway to demonstrate onboard processing techniques to automate the identification of surface minerals.

The development of a 14-inch optical disk recorder that is space qualifiable continues. This provides the very large onboard storage needed to do onboard calculations that are based on historical comparisons. The applications of the optical disk storage also extend into spacecraft automation where trend data must be stored. There are also expected to be applications for the optical recorder in the area of pattern recognition for vision systems.

New devices will be developed to enable scientific observations in the submillimeter region of the electromagnetic spectrum. Techniques for making square (NxN) mixing arrays using superconducting-insulating-superconducting junctions will be investigated together with quasi-optical methods for illuminating the device. In addition, the backward oscillator tube will be tested to determine whether it oscillates in band and to measure output power. The NxN mixing array will necessitate inventing devices for doing an NxN signal analysis. Promising candidates such as a two-dimenstional acousto-optic receiver will be investigated.

In laser remote sensing, research will be focused on developing critical technology to enable space-based light detection and ranging (LIDAR) capability to meet the science requirements of the earth observing system. Research into promising two- and three-dimensional semiconductor laser diode arrays for maximum pumping efficiency will continue. In addition, methods for tuning the solid-state laser amplifiers into the science frequency regions of interest will continue. Technologies for a 10-Joule per pulse with a 10-pulse per second duty cycle and a 100-million-pulse lifetime carbon dioxide laser to enable a doppler planetary and tropospheric wind field measurement instrument will be initiated. Studies include preionization electrode and cavity optics degradation, gas recycling, and isotopic operation. Active cooler technology to enable the earth observational and astronomical missions requiring low instrument temperatures will be initiated. Non-contact Stirling cycle mechanical refrigerators will be developed to provide cooling down to $45^{o}K$ and adsorption coolers will be developed to provide sensor cooling to less than $1^{o}K$.

	1986 Actual	1987 Amended Budget	1987 Current Estimate	1988 Budget Estimate
		(Thousands of Dollars)		
CSTI - Large structures and control				
Control of flexible structures.......	---	---	---	17,800
Precision segmented reflectors.......	---	---	---	5,000
Total.......................,......	---	---	---	22,800

OBJECTIVES AND STATUS

The objective of the large structures and control program is to provide experimental validation of analytical methods for predicting coupled structural dynamics and controls response for complex multibody space structures with flexible components, interfaces, and dissipative mechanisms. As the agency initiates planning and implementation for large space systems (space station/platforms/antennas), there are basic unknowns in the areas of structural dynamics, controls, structural interaction, structural performance, and deployment dynamics which must be resolved in order to develop this new class of spacecraft with the assurance of meeting safety, performance, and cost goals. The size and flexibility of these systems require development of analysis and test methods and a space-based experiment activity addressing the key technology unknowns through graduated testing of flexible elements. The research data base will allow the design and development of integrated complex control systems and structural configurations for future generation large spacecraft.

The control of flexible structures (COFS) program, a comprehensive research activity which includes analytical methods development, ground-based testing, and in-space experiments, was initiated in FY 1985 to provide a focus for large structures and control technology. The first flight article, COFS I, a large 60-meter deployable/stowable structure (termed Mast) will be dynamically tested in space cantilevered from the shuttle. In 1986, fabrication of the subsystems of COFS I was initiated, and a conceptual design review was completed. In FY 1987, the preliminary and critical design reviews were completed, and development testing has been initiated on actuators and instrumentation required for the excitation, measurement, and control of the low-frequency modes of the Mast. The structural design characteristics, representative of large space structures, have been carefully integrated into a beam design for safe experimentation. An experiment requirements document has been completed which initiates the rigorous integration activities required to place an experiment onboard the shuttle. Also, in FY 1987, the avionics subsystems were defined for a fault-tolerant flight control system and a high-volume data acquisition system. A guest investigator program was developed, and participants from several universities and industrial firms were selected for the COFS I in-space experiments.

The second flight article, COFS 11, is a Mast with a three-dimensional appendage to study the structural dynamics and controls of large, flexible spacecraft configurations. Key technology elements include maneuver control, articulation, pointing, shape control, alignment, system identification, deployment dynamics and adaptive controls. In FY 1987, a project plan for COFS II was developed with rigorous involvement of industry, universities, and other government agencies, and a competitive procurement process was started for the test hardware. A guest investigator program to leverage the technology impact of the COFS II program was also initiated.

Further technology advancement required for the COFS program is included in the COFS III activity. The focus of COFS III is on the validation of control-structure interactive analysis and design methodology for multibody, flexible spacecraft, a step beyond space station. For COFS 111, a project plan was defined for analytical development for multibody dynamics and controls, ground test methods and capabilities, and flight test to validate in space the analytical methodology and ground-based experiments.

The precision segmented reflectors (PSR) program will develop a large-size segmented reflector structure that is lightweight, low cost, thermally stable, and structurally stiff in order to meet stringent optical precision requirements and to develop an accurate system necessary for pointing, vibration, and wavefront figure control. The overall system requirements for large precision segmented reflectors include large aperture for very faint astronomical signals, narrow field of view to focus on single targets, minimal slow rate and structural dynamical response, and low radiation temperature environment. The required technology does not currently exist and must be developed systematically.

Optical design, reflector materials, fabrication, and controls are essential technologies for precision segmented reflectors to be used in NASA's space science missions. The stringent pointing and low jitter required for such systems, together with its optical figure precision requirement, impose very challenging demands on sensing and control technology.. Graphite-epoxy composites and metal-core structures need to be evaluated and developed as candidate materials. Precision replication of segments is essential. The primary reflector structure is a driver in the overall systems design. Its mass, surface accuracy, and thermal behavior affect most of the other subsystems. Long-term dimensional stability, which includes moisture effects, microcracking, ultraviolet degradation, and active oxygen erosion, will also be investigated.

BASIS OF FY 1988 ESTIMATE

Prior to FY 1988, the COFS program was included in the space flight systems technology program, and the supporting structural dynamics and controls technologies were included in the research and technology base materials and structures and controls and guidance programs, respectively. Since the principal focus of the COFS program is to develop new design options for future generations of large, flexible spacecraft, this program is included in the large structures and control area of the CSTI program.

Ground-based elements initiated earlier will be continued in FY 1988 for the COFS I and II structures. Analysis and ground-based experiments will focus on qualifying these in-space experiments for flight on the shuttle. Additional analysis and ground-based experiments will focus on expanding the newly developed technology for application to more complex multibody and three-dimensional structures. The delivery of the COFS I flight test article is scheduled for 1989. The characteristics of the Mast truss-beam flight test article will be defined with an analytical model to be validated in the ground-based experiments and finally in the COFS I in-space experiments manifested for 1991-1992.

In FY 1988, plans for a phased competitive procurement for the development of COFS II experimental configurations will be completed. A related ground test program will be developed. Guest investigators from universities and industry will be invited to participate in the development of this technology.

In FY 1988, the COFS III scaled-model analytical and ground-based studies will be focused on the space station initial operating configuration (IOC). The space station offers an inexpensive means of obtaining flight data as the components of the station IOC are assembled. Precise location and definition of required instrumentation for the space station will be determined in COFS III scaled-model experiments, and a systematic mission plan to acquire structural dynamics and control data on the assembly configurations of the space station IOC will be established.

During FY 1988, research in the precision segmented reflectors program will focus on developing new concepts for very lightweight and dimensionally stable panels. Both erectable and deployable concepts will be considered along with mechanisms and control systems for maintaining very accurate alignment and stability. Tests on advanced materials and fabrication methods will be conducted to support the selection of initial concepts and to define specific areas for advanced materials development to be performed under this program. Prototype mechanisms for erecting/deploying/aligning the panels will be designed, and fundamental control laws for controlling these processes will be developed and tested. This activity will directly support a seven-panel reflector ground demonstration test program planned for FY 1992.

	1986 Actual	1987 Amended Budget	1987 Current Estimate	1988 Budget Estimate
		(Thousands of Dollars)		
CSTI - Power				
High capacity power..................	---	---	---	14,000

OBJECTIVES AND STATUS

The objective of this program is to develop the technology needed to meet the high-capacity power systems requirements for evolutionary space station, lunar and planetary bases, and for high-power-demand electric propulsion systems.

For high-capacity power systems, power levels of interest are greater than tens of kilowatts to multimegawatts. An advanced technology program was initiated in FY 1986, as part of the space energy conversion research and technology program, with emphasis on significantly improving the SP-100 power conversion efficiency to take advantage of the reactor's estimated thermal output capability of eight megawatts. In the thermoelectric converter area, identification and the laboratory characterization of the physical, thermal, and electrical properties of potentially stable, higher efficiency, rare earth chalcogenide junction material candidates, e.g., lanthanum telluride, has resulted in good progress toward achieving the desired higher level figure of merit. Recent experimentation and micro-structural analyses of the silicon germanium junction materials have shown that favorable phase precipitation changes can occur at particular annealing temperatures during material processing. The net positive effect of this newly discovered interrelationship would be an improved electrical activity characteristic without detrimentally affecting desired thermal conductivity characteristics for the material. Couple efficiency could then be improved threefold or more for the baseline silicon germanium material. For a dynamic conversion system alternative, the development of the free-piston Stirling engine technology for use with advanced nuclear reactor power systems is continuing. Testing of the initial 25-kilowatt space power demonstration engine was concluded with near achievement (91 percent) of the design power goal. Preliminary engineering design of the next generation developmental engine with a higher hot-side temperature capability has been completed. Advanced radiator configuration concept studies are in progress with supporting research and technology in heat pipe modeling and analyses, testing of improved high-temperature radiator materials, and advanced surface emissivity treatments. Tests of a new family of semiconductors have substantiated the materials tolerance capability for resisting without failure extremely high levels of radiation exposure. These significant improvements in radiation tolerance of dielectric electrical insulating materials have been measured in repeated laboratory tests. The broad-based SP-100 advanced technology program has been highly successful in identifying potential component/subsystem improvements and in developing solutions for those nonnuclear technology areas critical to successful development and application of high-capacity space nuclear reactor power systems.

BASIS OF FY 1988 ESTIMATE

Prior to FY 1988, funding for high-capacity space power systems was contained within the space energy conversion research and technology program. The principal focus of the high-capacity space power program was support of the SP-100 nuclear reactor power technology development program primarily in the advanced conversion component technology developments area and in the directed support of the SP-100 ground engineering systems program in selected nonnuclear technology areas. In FY 1988, an aggressive dynamic conversion systems technology development and verification program will be initiated. The fabrication and assembly of a space prototypical free-piston Stirling engine capable of 1050°K hot-side temperature operation will be well underway. Advanced heat pipe configurations for heat transport, as well as advanced regenerator/heat exchanger concepts, will be incorporated into this design. Test plans for the performance mapping and endurance testing of this advanced Stirling engine will be developed. The reactor being developed in the SP-100 program would provide the heat source for the Stirling dynamic converter in a flight power system. In the Stirling engine development ground tests, however, a simulated heat source will be used. Thermoelectric materials research for the N-leg and the P-leg will continue for the alternative static converter system, seeking experimental substantiation of a 3- to 5-fold increase in cycle efficiency with stable, repeatable, single cell and multicell couple performance. In parallel with these efforts, other key power system technology elements will be pursued, both analytically and experimentally. Advanced waste heat radiator concepts incorporating lighter weight heat pipes and innovative surface conditioning techniques for greatly improving the emissivity of the candidate surface materials will continue to be investigated. Component testing will be initiated to confirm performance predictions. The waste heat radiator is a critical item, not only from a thermal performance standpoint, but also from a weight standpoint, for the space nuclear reactor power system. Supporting research and technology activities (i.e., analysis, fabrication, testing) will be conducted in the area of high-temperature, high-strength, long-life materials and thermal management modeling and analyses. Laboratory-scale tests of candidate advanced power conditioning and control components will proceed into FY 1988. A diagnostics/fault-tolerant system technology assessment and advancement effort for the high-capacity power system will be initiated.

	1986 Actual	1987 Amended Budget	1987 Current Estimate	1988 Budget Estimate
		(Thousands of Dollars)		
CSTI - Automation and robotics				
Robotics..............................	---	---	---	11,700
Autonomous systems...................	---	---	---	14,000
Total.................................	---	---	---	25,700

OBJECTIVES AND STATUS

The objective of the automation and robotics program is to exploit the potential of artificial intelligence and telerobotics to increase the capability, flexibility, and safety of space and ground operations while decreasing associated costs. Specifically, the objectives of the robotics element are to evolve the level of autonomy of remote operations from teleoperation to robotics and to increase the operational capability of remote manipulation from its current state as a crane on the shuttle orbiter to the capabiilty for on-orbit assembly, servicing and repair, and for planetary exploration. The objectives of the autonomous systems element are to reduce the size of the ground control and operations crew and to automate control of appropriate subsystems aboard the space station, spacecraft, or transportation vehicles. Goals of the program are to replace 50 percent of extravehicular activity (EVA) with telerobotics, decrease mission operations manpower by 60 percent, and reduce the manpower required to do routine housekeeping functions aboard the spacecraft by 50 percent.

A series of evolutionary ground demonstrations is planned for both robotics and autonomous systems elements. Underlying the sequence of demonstrations in both programs are five core technology areas: sensing and perception, control execution, task planning and reasoning, operator interface, and system architecture and integration. Integrated plans have been developed for the demonstration sequences, and research is underway in the five core technology areas. Coordination with the Defense Advanced Research Projects Agency (DARPA) assures leverage of relevant technologies being developed under their strategic computing initiative. Intercenter memoranda of agreement have been signed to facilitate the transfer of technology from the technology development centers to the user centers.

In FY 1987, the preliminary design and development of the telerobot demonstration facility with a two-arm manipulator was completed, and a sequence of demonstrations for FY 1988 defined. The facility has a suspended spacecraft (Solar Max) which the robot will acquire, despin, and service, with two cooperating robot manipulator arms mounted on tracks to accomplish these tasks, and a third arm with a mounted television camera which supplies the vision for the robot system. A notable accomplishment was the establishment of the hierarchical computer architecture which will allow artificial intelligence planners to control this robot.

In FY 1987, in the systems autonomy area, a comprehensive plan was developed and the management structure put into place. A prototype knowledge base for a thermal control systems (TCS) was demonstrated on a symbolic 3640 computer, using the artificial intelligence (AI) development tools KEE and Simkit. Demonstrator targets include the TCS; prelaunch ECS, power, and pneumatics; the space station power system; and the shuttle communication system.

In the associated core research area, several outstanding achievements were attained. In sensing and perception, an intermediate-level computer vision system called PIFEX (programmable image feature extractor) has been developed which can detect hardware edges and vertices. Such a visual system will be necessary to enable autonomous recognition of objects from a well defined data base, as well as autonomous capture and despin of tumbling satellites. A prototype of PIFEX, which provides the real-time acquisition, feature tracking, motion stereo, stereo matching, and processing of the visual system for the robot, was demonstrated. This system is capable of performing 100 billion arithmetic operations per second. Two stand-alone expert systems including an error diagnostician and an execution monitor, which monitors and predicts the behavior of the system, were integrated using a communications blackboard. This is the first time two separate expert systems have been made to cooperate using a common or shared knowledge base. In control execution, computer vision and force/torque feedback have been used to automatically guide a pin to a close tolerance hole and insert it. This is necessary for autonomous module insertion when the telerobot is operating under conditions of communications time delay. In operator interface, a six degree-of-freedom force-reflecting controller has been developed. Using this technology, the same controller can be used with a number of different space arms. In task planning, an artificial intelligence planner has been developed which, given a set of goals and a knowledge base of relevant actions, can generate a sequence of actions in a satellite's payload to implement those goals. Other notable accomplishments include rudimentary learning by the expert system planner deviser, telerobotic operation of fuel transfer/strut node coupling, verification of the smart hand and force reflecting controller, and the development-of a computer graphics display for that controller.

BASIS FOR FY 1988 ESTIMATE

The automation and robotics program in its entirety has been incorporated into the CSTI program in FY 1988. In addition, the program has been augmented to include pre-launch and post-launch operations, including pneumatics and power pre-launch subsystems and the shuttle communications subsystem.

Development and advancing technologies in telerobotics are described by a sequence of evolutionary ground demonstrations scheduled from 1987 to 1996. The initial demonstration will be of a two-armed remote manipulator for satellite module replacement and fluid transfer tasks. Autonomy will be implemented in terms of preplanned sequences of task primitives, e.g., open, close, screw in, etc. The second demonstration (1990) will include automatic acquisition and despin of a spacecraft and servicing it using dexterous cooperative arms, automatic sequence planning, and autonomy at the task element level, e.g., remove panel. The 1993 demonstration will comprise task level (e.g., replace module) commands, automated replanning for error conditions, and automated planning using a computer-assisted design (CAD) data base. The 1996 demonstration will extend to repair tasks involving cutting and fabrication.

The FY 1988 telerobot demonstration will incorporate dual arm control, AI-based planning, smart end effectors, force reflecting controllers, and vision-based robotic control for simple servicing tasks.

Research and development in each of the five core technology areas associated with telerobotics will continue. In sensing and perception, research on multiple-class three-dimensional object recognition and tactile/proximity sensing will be conducted in order to reduce reliance on the human operator's vision system. In task planning, experiments will be conducted on spatial planning of manipulator trajectories and on reasoning about nonstandard procedures in order to reduce reliance on the .human operator's cognitive capabilities in task planning. In control execution, telerobot control of flexible manipulators and control of multiple-arm degrees of freedom will be developed to enable telerobot servicing of a wider class of spacecraft and payloads. In operator interface, perdictive displays and simulation aids for anticipated failures will be developed to permit the operator to take over when the autonomous system encounters difficulty. In systems architecture and integration, the focus will be on developing techniques for expert systems to control an entire system by coordinating the needs and tasks of a number of subsystems.

Integration of advancing technologies in systems autonomy is described by a sequence of evolutionary ground demonstrations scheduled from 1988 to 1996. The initial demonstration (1988) is of a rule-based expert system for control of a single-mission operations subsystem in which reasoning is limited to standard procedures, and knowledge of the task world is complete and unambiguous. The second demonstration (1990) will be of a model-based expert system for coordinated control of multiple subsystems, and it will be capable of reasoning about nonstandard procedures and of diagnosis of anticipated failures. The third demonstration (1993) will be of hierarchical control of multiple subsystems and will be capable of reasoning about emergency procedures, planning under uncertainty, and recovery from unanticipated failures. The 1996 demonstration will consist of distributed control of multiple subsystems and will have the capability for fault prediction, real-time replanning, and learning.

The initial systems autonomy demonstrations will take place early in FY 1988. The initial demonstration will comprise automated control (i.e., an intelligent aide) for the space station thermal control subsystem. Demonstrations using expert system control will be developed and demonstrated for pre-launch and post-launch ground system operations. The consoles and programs for demonstrating the expert system using real-time shuttle data in an off-line (parallel) mode to actual subsystem control by human controllers will be developed.

Research and development in each of the five core technology areas associated with systems autonomy will continue. Anticipated research achievements include the development of an expert system with the capability of learning by example and a prototype spaceborne symbolic processor with two 32-bit numeric processors and two 40-bit symbolic processors, using **VLSI/VHSIC** technology. This combined processor uses a reconfigurable, fault-tolerant multiprocessor architecture and is capable of 10-mega instructions per second execution rate. It will support the LISP, Ada, **PROLOG**, and **C** software environments.

SYSTEM RELIABILITY
AND QUALITY
ASSURANCE

RESEARCH AND DEVELOPMENT

FISCAL YEAR 1988 ESTIMATES

BUDGET SUMMARY

OFFICE OF SAFETY, RELIABILITY, MAINTAINABILITY AND QUALITY ASSURANCE

SAFETY, RELIABILITY AND QUALITY ASSURANCE PROGRAM

SUMMARY OF RESOURCES REQUIREMENTS

	1986 Actual	1987 Amended Budget	1987 Current Estimte	1988 Budget Estimate	Page Number
	(Thousands of Dollars)				
Safety, Reliability and Quality Assurance..........................	7,600	9,200	9,200	16,200	RD 16-2

Distribution of Program Amount by Installation

	1986 Actual	1987 Amended Budget	1987 Current Estimte	1988 Budget Estimate
Johnson Space Center...................	345	315	265	1,090
Kennedy Space Center...................	200	50	125	100
Marshall Space Flight Center...........	402	350	314	415
Goddard Space Flight Center............	780	830	1,067	1,485
Jet Propulsion Laboratory..............	2,431	4,057	2,207	2,350
Langley Research Center................	745	920	1,147	1,120
Lewis Research Center..................	140	462	173	185
Headquarters...........................	2,557	2,216	3,902	9,455
Total..............................	7,600	9,200	9,200	16,200

OFFICE OF SAFETY, RELIABILITY, MAINTAINABILITY AND QUALITY ASSURANCE — **SAFETY, RELIABILITY AND QUALITY ASSURANCE PROGRAM**

PROGRAM OBJECTIVE AND STATUS

The objective of the Safety, Reliability and Quality Assurance (SR&QA) program, formerly the Standards and Practices Program, is to support NASA's goals through activities in safety, productivity, reliability and quality assurance, maintainability, software assurance, systems engineering, and program practices which reduce program risk; to inprove product confidence; and to encourage good program procedures in the technical execution of NASA programs.

During FY 1986, efforts to inprove NASA's software management, assurance and productivity have continued. Emphasis was placed on developing validated procedures to ensure the integrity of the systems to be put into service. Exploration of non-destructive evaluation techniques continued, with emphasis on composites and advanced metals problems using probing energies, such as sonic and thermal, and electromagnetic techniques to examine material properties. The results of this effort will ensure that material and fabrication specifications can be non-destructively verified and quantitatively documented.

In FY 1987, work continues in concert with the NASA Centers and industry in the areas of materials, treatments and processes; integrated circuit product assurance; microcircuit radiation effects evaluation; aerospace and system safety related matters; and other areas in support of NASA-wide programs. In the near-term, the Non-Destructive Evaluation (NDE) Program will place special emphasis on NDE techniques for Solid Rocket Motors. The program will be expanded to include electronics, and will explore and develop qualitative and quantitative inspection and quality control techniques for microcircuits and semiconductors. The Software Management and Assurance Program will develop standards, specialized training, distributed software, corporate memory data bases, and guidebooks to facilitate inproved software business practices and resources sharing by NASA projects. In response to the findings and recommendations contained in the Report of the Presidential Commission on the Space Shuttle Challenger Accident (Rogers Carmission), an effort is underway to develop a system to address the reporting and documentation of problems, problem resolution, and trends. The initial effort will define the goals that the systems must achieve, the criteria by which success will be judged, and a plan for system support of the next Shuttle flight. Efforts to inventory available data sources, determine information flow incompatibilities and constraints, and obtain other data necessary to develop a detailed system architecture are currently underway.

BASIS OF FY 1988 ESTIMATE

In FY 1988, the SR&QA program will continue to conduct activities in support of the objectives of the agency. The increase in funding fran the FY 1987 level reflects an increase in safety related activities and the creation of a Technical Assessment Program. The Technical Assessment Program will develop systems that monitor the status of equipmnt; validate technical designs; report and analyze problem; analyze trends; and judge system acceptability in agencywide program.

The Technical Assessment Program will address the reporting and documentation of problems, problem resolution and trends, and other safety system as required. One component of the assessment program is a ccnputerized, real-time, agencywide problem reporting and corrective action system which will allow an assessment of SR&QA problem. As currently planned, the system will contain data on failures, nonconformance anomalies, and unsatisfactory conditions for problem analysis and resolution, remedial and preventive actions, and trend analysis for flight and critical ground hardware, as well as certain generic program hardware. The information resulting fran the system will be used for design, flight, and test reviews. It will be specifically designed to provide a broad data base which will be accessible by NASA and its contractors on an iterative basis. It will provide a means whereby effective trend analysis can be accomplished, thus providing early and mre complete illumination of problems to management.

Efforts are being planned that will revitalize the basic NASA safety program. Major activities will be focused on increasing the safety of high hazard operations, better understanding the failure mdes of highly stressed wind tunnel components and pressure systems, and quantifying the hazard potential of new, exotic propellants, existing cryogenic propellants, and new composite materials. The existing effort to autamte mishap reporting will be expanded to include the capability for trend analysis and generation of multimedia, generic lessons-learned from the central data base. Critical policies, procedures, practices, regulations, guidelines, and directives will be reviewed and revised, or developed, as appropriate. Risk assessments of hazards identified in NASA activities will be conducted to determine the implied risks to people and property.

TRACKING AND DATA
ADVANCED SYSTEMS

RESEARCH AND DEVELOPMENT

FISCAL YEAR 1988 ESTIMATES

BUDGET SUMMARY

OFFICE OF SPACE TRACKING AND DATA SYSTEMS — **TRACKING AND DATA ADVANCED SYSTEMS**

SUMMARY OF RESOURCES REQUIREMENTS

	1986 Actual	1987 Amended Budget	1987 Current Estimte	1988 Budget Estimte	Page Number
	(Thousands of Dollars)				
Advanced systems.......................	15,500	17,100	17,100	18,100	RD 17-2
TOTAL................................	15,500	17,100	17,100	18,100	

Distribution of Program Amounts by Installation

	1986 Actual	1987 Amended Budget	1987 Current Estimte	1988 Budget Estimte
Goddard Space Flight Center............	4,500	5,000	5,000	5,300
Jet Propulsion Laboratory...............	10,799	12,100	12,100	12,800
Ames Research Center..................	7	---	---	---
Headquarters..........................	194	---	---	---
TOTAL................................	15,500	17,100	17,100	18,100

BASIS OF FY 1988 FUNDING REQUIREMENTS

ADVANCED SYSTEMS

	1986 Actual	1987 hnded Budget	1987 Current Estimte	1988 Budget Estimte
		(Thousands of Dollars)		
Advanced syst........................	15,500	17,100	17,100	18,100

OBJECTIVES AND STATUS

The objecti of the Advanced System Program is to form es and provide of tracking and data and techniques required to: (obtain new and inproved and data i capabilities that will me t the needs of d new missions d near term new starts; and (2) impr the cost fect and iabi needed for overall pp of the total mi of spacef t missions.

This activity is a small but vital part of the Tracking and Rita System Program whi continues to focus on ssing and making use of technologi advances in te t electronic itry and the computer sciences. ffort is essential for the cost effect ication of new technology and r planning future t work the investigat f the ta data sf r a ocessing needs missi and studies of gr systems and telecommunication links to determine design approaches and all tradeof for h lowest ife cycle costs to or future space missions.

BASIS OF FY 1988 ESTIMATE

Activities planned for FY 1988 to location accuracies within the one meter level for Eart ing wh would make possible a new class of high ion Earth observatory mis on the Shuttle, Space Station on flying . The techniques to be analyzed for include the of Global Positioning System and Very Baseline Interferometry Work will tinue on the of extreme precise radiometric techniques for determining angular direction of future missions to an accuracy of fi nano-radians. Such t a to spacecraft igat and ondu of science experiments not previ Studies will continue on ground navigation strategies, demonstrati for Galileo, Ulysses, and Mars Observer.

Efforts to improve communications between the ground and spacecraft will continue in such areas as development of a K-band terminal for TDRSS user spacecraft; use of millimeter wave frequencies on large diameter antennas; development of more efficient transmitters and highly reliable, low noise telemetry receivers; and, antenna feed systems capable of multiple frequency operation, including millimeter waves. Such improvements in space-to-ground communications can benefit future missions by reducing spacecraft weight and power requirements and increasing the amount and quality of the data returned. Optical tracking and communications technology to meet telecommunications needs in the decades ahead will also be investigated both for its cost-performance advantages over microwave technology and for its potential in space data relay applications.

The use of high density magnetic tape and optical disk storage’with automated quality control of recorded data is being investigated to meet future high-rate image data processing requirements as the data handled from earth-orbital missions increases from a current peak of 50 megabits per second to the TDRSS design limit of 300 megabits per second. These future requirements result from high resolution sensors such as multispectral scanners and synthetic aperture radars. New techniques and systems will be developed for the transfer and processing of these high data rates. These developments include new techniques for signal coding and decoding of data; advanced technology for on-board recording; digital processing of high volume data, improved man-machine interfaces, and a commmunications network using an optimal mix of fiber optics, satellites, and local area networks to distribute data to processing centers and users.

Investigations will continue on achieving more efficient operation of the mission control facilities and providing for the necessary real time interaction between the spacecraft experimenters and their experiments. Other investigations are being carried out in the areas of expert systems applications, greater use of distributed command terminals and the performance of orbit and attitude computations on board the spacecraft.

SPACE FLIGHT
CONTROL AND DATA
COMMUNICATIONS

NATIONAL AERONAUTICS AND SPACE ADMINISTRATION

SPACE FLIGHT, CONTROL AND DATA COMMUNICATIONS

FISCAL YEAR 1988 ESTIMATES

GENERAL STATEMENT

The objective of the National Aeronautics and Space ministration program of space flight, control and data communications is to provide for the operational activities of the Space Transportation System and tracking and communication system support to all NASA flight projects. This objective is achieved through the following elements:

SHUTTLE PRODUCTION AND OPERATIONAL CAPABILITY: A program to provide a fully capable fleet of Space Shuttle orbiters, main engines, launch site and mission operations control requirgnents, initial spares, production tooling, and related supporting activities.

SPACE TRANSPORTATION OPERATIONS: A program to provide the standard operational support services for the Space Shuttle and the expendable launch vehicles. Within Shuttle operations, external tank and solid rocket booster flight hardware is produced; operational spare hardware is provisioned, overhauled and repaired; and manpower, propellants, and other materials are furnished to conduct both flight and ground (launch and landing) operations.

SPACE AND GROUND NETWORK, COMMUNICATIONS AH) DATA SYSTEMS: A program to provide vital tracking, telemetry, command, and data acquisition support to meet the requirgnents of all NASA flight projects. This support is currently provided by a worldwide network of NASA electronic ground stations interconnected by a communications system using ground, undersea, and satellite circuits. The Tracking and Data Relay Satellite System (TDRSS) will become the primry system for supporting upcoming Earth orbiting missions.

NATIONAL AERONAUTICS AND SPACE ADMINISTRATION

SPACE FLIGHT, CONTROL AND DATA COMMUNICATIONS
FY 1988 BUDGET ESTIMATES

	1986 Actual	1987 hnded Budget	1987 Current Estimte	1988 Budget Estimte
		(Millions of Dollars)		
SHUTTLE PRODUCTION AND OPERATIONAL CAPABILITY	1,365.3	884.4	1,005.1	1,229.6
REPLACEMENT ORBITER	---	250.0	2,100.0	---
SPACE TRANSPORTATION OPERATIONS	1,640.2	1,345.7	1,847.0	1,885.a
SPACE AND GROUND NETWORKS, COMMUNICATION AND DATA SYSTEMS	660.4	862.9	862.9	948.9
TOTAL	3,665.9	3,343.0	5,815.0	4,064.3

NATIONAL AERONAUTICS AND SPACE ADMINISTRATION PROPOSED APPROPRIATION LANGUAGE

SPACE FLIGHT, CONTROL AND DATA COMMUNICATIONS

For necessary expenses, not otherwise provided for; in support of space flight, spacecraft control and communications activities of the National Aeronautics and Space Administration, including operations,. production, services, minor construction. maintenance, repair, rehabilitation. and modification of real and personal property: tracking and data relay satellite services as authorized by law; purchase, hire. maintenance and operation of other than administrative aircraft; [$3,317,000,000] *$4,064,300,000*. to remain available until September 30. [1988] *1989. (Additional authorizing legislation to be proposed.)*

Note.—Public Laws 99-500 and 99-591, section 101(g), provide funds to the extent and in the manner provided for in the conference version of H.R. 5313, Department of Housing and Urban Development-Independent Agencies Appropriations Act, 1987.

[*Provided*, That. notwithstanding any other provision of this joint resolution, including section 102, in addition to the funds otherwise made available in this subsection. the following amounts are made available: (2) an additional $2,398,000,000, to remain available until expended, in hereby appropriated for the National Aeronautics and Space Administration. "Space flight, control and data communication-" including (a) $2,100,000,000 for orbiter production only, which amount shall not become available for obligation until August 1, 1987, and (b) $265,000,000 for space shuttle operations, which amount, together with $266,000,000 otherwise made available for this account by thin subsection (or by enactment into law of the above named Act) shall not become available for obligation until January 15. 1987.] (Public *Laws 99-500 and 99-591, providing continuing appropriations for the fiscal* year *1987, section 101(g).)*

NATIONAL AERONAUTICS AND SPACE ADMINISTRATION

Space Flight, Control and Data Communications

Reimbursable Summary
(In thousands of dollars)

Space Flight, Control and Data Communications	Budget Plan FY 1986	FY 1987	FY 1988
Shuttle Production and Capability Development	364,934	105,100	134,800
Space Transportation Operations	277,574	-180,000	---
Expendable Launch Vehicles....................................	230,423	236,000	70,700
"racking and Data Acquisition..................................	36,821	45,500	38,300
Total...	909,752	206,600	243,800

NATIONAL AERONAUTICS AND SPACE ADMINISTRATION

FISCAL YEAR 1988 ESTIMATES

DISTRIBUTION OF SPACE FLIGHT CONTROL AND DATA COMMUNICATIONS BUDGET PLAN BY INSTALLATION AND FISCAL YEAR

(Thousands of Dollars)

Program		Total	Johnson Space Center	Kennedy Space Center	Marshall Space Flight Center	National Space Technology Laboratories	Goddard Space Flight Center	Jet Propulsion Laboratory	Ames Research Center	Langley Research Center	Lewis Research Center	NASA Headquarters
Space Transportation Systems	1986	3,005,500	988,300	448,500	1,514,000	8,500	1,800	600	5,500	100	3,000	35,200
	1987	4,952,100	2,453,400	620,800	1,194,700	15,000	1,700	1,500	4,700	100	3,000	657,200
	1988	3,115,400	868,700	609,700	1,213,800	17,300	1,800	1,500	6,000	100	3,000	393,500
Shuttle Production and Capability Development	1986	1,365,300	460,300	99,600	776,000	7,500	200	600	—	—	3,000	18,100
	1987	3,105,100	1,979,000	150,000	597,900	14,000	—	1,500	—	—	3,000	359,700
	1988	1,229,600	344,800	123,700	437,300	15,300	—	1,500	—	—	3,000	304,000
Space Transportation Operations	1986	1,640,200	528,000	348,900	738,000	1,000	1,600	—	5,500	100	—	17,100
	1987	1,847,000	474,400	470,800	596,800	1,000	1,700	—	4,700	100	—	297,500
	1988	1,885,800	523,900	486,000	776,500	2,000	1,800	—	6,000	100	—	89,500
Tracking and Data Acquisition	1986	660,400	8	—	29,655	—	329,436	115,588	9,900	—	—	175,813
	1987	862,900	—	—	35,800	—	433,500	126,600	11,800	—	—	255,200
	1988	948,900	—	—	34,700	—	514,000	131,800	10,200	—	—	258,200
Total	1986	3,665,900	988,308	448,500	1,543,655	8,500	331,236	116,188	15,400	100	3,000	211,013
	1987	5,815,000	2,453,400	620,800	1,230,500	15,000	435,200	128,100	16,500	100	3,000	912,400
	1988	4,064,300	868,700	609,700	1,248,500	17,300	515,800	133,300	16,200	100	3,000	651,700

SPACE
TRANSPORTATION
SYSTEMS

FISCAL YEAR 1988 ESTIMATES

BUDGET SUMMARY

OFFICE OF SPACE FLIGHT — **SPACE TRANSPORTATION SYSTEM PROGRAM**

SUMMARY OF RESOURCES REQUIREMENTS

	1986 Actual	1987 Amended Budget	1987 Current Estimte	1988 Budget Estimate	Page Number
	(Thousands of Dollars)				
Shuttle production and operational capability........................	1.365. 300	1.234. 400	3.105. 100	1.229. 600	SF 1-1
Space transportation operations.......	1.640. 200	1.345. 700	1.847. 000	1.885. 800	SF 1-2
Total............................	3.005. 500	2.580. 100	4.952. 100	3.115. 400	

Distribution of Program hunts By Installation

	1986 Actual	1987 Amended Budget	1987 Current Estimte	1988 Budget Estimate
Johnson Space Center..................	988. 300	705. 600	2.453. 400	868. 700
Kennedy Space Center..................	448, 500	415. 800	620. 800	609. 700
Marshall Space Flight Center..........	1,514, 000	829. 300	1.194. 700	1.213. 800
National Space Technology Lab.........	8, 500	8. 900	15. 000	17. 300
Goddard Space Flight Center...........	1,800	1.700	1.700	1.800
Jet Propulsion Laboratory.............	600	1.500	1.500	1.500
Lewis Research Center.................	3, 000	500	3.000	3. 000
Langley Research Center...............	100	100	100	100
Ames Research Center..................	5, 500	4. 900	4. 700	6. 000
Headquarters..........................	35. 200	611. 800	657. 200	393. 500
Total............................	3.005. 500	2.580. 100	4.952. 100	3.115. 400

SPACE FLIGHT, CONTROL AND DATA COMMUNICATIONS

FISCAL YEAR 1988 ESTIMATES

OFFICE OF SPACE FLIGHT **SPACE TRANSPORTATION SYSTEM PROGRAM**

PROGRAM OBJECTIVES

The primry program objective of current activity in the Space Transportation System is to complete the safe return to Space Shuttle flight activities. The Space Shuttle is the key element of a versatile Space Transportation System **(STS)** that is available to a wide variety of national users and certain international users. The Space Shuttle is the first reusable space vehicle and is configured to carry many different types of space apparatus, spacecraft scientific experiments, and national security payloads. In addition to transporting materials, equipnent and spacecraft to orbit, the Shuttle offers unique capabilities that cannot be achieved with expendable launch vehicles (ELV)--to retrieve payloads from orbit for reuse; to service and repair satellites in space; to transport to orbit, operate, and return space laboratories; and to perform rescue missions.

Shuttle Production and Operational Chpability provides for the national fleet of Shuttle orbiters including the replacement orbiter which is fully funded in **FY 1987.** Funding also provides for the launch site facilities, initial spares, production tooling, and related supporting activities This line item also includes the design, test, analysis and certification associated with the recovery actions necessary, as a result of the Challenger accident to verify the flight hardware and mission support processes necessary for return to flight.

This line item contains five subdivisions: Orbiter Qerational Capability, Orbiter Replacement, Propulsion, Launch and Mission Support, and Changes and System Upgrades. Orbiter Operational Chpability includes flight hardware design mdifications and system inprovements, mission kits, the procurement of a spares inventory for the operational orbiter fleet, the residual development tasks for the orbiter and the necessary safety modifications identified by the **NASA** investigation and the Rogers Commission during the post Challenger accident review process and the initiation of a new set of structural spares to maintain the capability to produce orbiter vehicles. Propulsion Systems provides for Space Shuttle main engines (SSME), external tank (ET), and solid rocket booster (SRB) design inprovements, safety modifications, capability investments, and rate tooling. Launch and Mission Support provides the Johnson Space Center (JSC) mission operations capability developnent, the equipment provisioning of the facilities for launch and landing at the Kennedy Space Center **(KSC)** and the initial lay-in of spares and ground support equipment. Changes and Systems Upgrade provides funding for potential changes and systems mdifications as well as unanticipated new requirements not covered in the budget estimates for the above activities and other program elements. Orbiter Replacement reflects the funding provided in **FY 1987** for the replacement Challenger.

Shuttle Operations provides the standard operational support services for the Space Shuttle. Within Shuttle Operations, flight hardware is produced, refurbished and repaired; and manpower, propellants, and other mterials are furnished to conduct and support both flight and ground operations. The Shuttle Operations program provides for the launch of NASA missions, DOD, other U.S. Govermnt and certain commercial and international missions on a reinbursable basis. The launch schedule calls for 4 flights in FY 88 (the first launch after the Challenger accident is scheduled for early 1988), 9 flights in FY 1989, and 11 flights in FY 1990.

The Shuttle provides launch services to non-NASA users on a reinbursable basis to satisfy Department of Defense and civil government requirements. A limited number of foreign and cannercial launches are planned following the resurption of flights based on ministration policy decisions.

The ELV program is currently totally funded through reimbursements fran users. Privatization of these system continues to be actively pursued. The only planned NASA launch at this time is for the Cosmic Background Explorer spacecraft which will utilize a Delta launch vehicle acquired with reimbursements for replacement of residual assets.

STATUS

In Orbiter Operational Capability the primry thrust of the current effort is to complete the review, evaluation, production and installation of modifications to enable a safe return to flight. In addition, the logistics program continues to procure lay-in and rate spares and establish repair capability to fully support the flight program. Improvement programs for the orbiter flight hardware which were initiated prior to the Challenger accident are well on the way to completion. Work continues on the Remote Manipulator System to upgrade a test article to flight status and on flight software to incorporate all required changes for return to flight and introduction of the upgraded computers.

In August 1987, efforts will begin to produce an additional orbiter to replace Challenger utilizing the existing structural spares. This replacement orbiter will provide a significant increase to the national space launch capability which is necessary to fly off the backlog of national security, certain international and civil missions resulting fran the Challenger accident.

At KSC, Wifications to mjor facilities and launch site equipnt are underway to provide for more efficient and reliable launch processing. For example, the Launch Complex 39 permanent weather protection modifications were recently completed on Pad B and similar Wifications on Pad A will be completed in FY 1988. Installation of the new Operational Television System (OTV) will also be completed this year to provide inproved vehicle monitoring during the various stages of launch processing. In addition, several modifications to the launch facilities have been identified as mandatory for carpletion prior to the next launch. Most of these modifications are underway and include: redesign of the external tank venting system on the launch pad to preclude potential interference with the vehicle during launch; upgrade of the emergency egress system for use by flight crew and support personnel; and, modification of the payload changeout room to improve the environmental conditions surrounding the payload. Equipment continues to be procured for installation into the Orbiter Maintenance and Refurbishment Facility (OMRF) which will provide a minimal maintenance and storage capability by 1989. Other efforts underway include continued development of the Digital Operational Intercomm System (OIS-D), initial study and design of the replacement Launch Processing System (LPS), and extension of the Launch Equipment Test Facility (LETF) to support testing of the facility modifications.

At JSC, modifications to on-going activities have been approved to satisfy post Challenger accident program requirements. Weather prediction and reporting capabilities are being expanded and runway end barriers are being developed for possible installation at the primary and contingency landing sites, with the latter being expanded in number as well as capability. Readiness of those landing sites associated with polar orbit missions have been deferred consistent with the planned launch schedule fran the Vandenberg launch site. In addition, fidelity and reliability inprovements to the training simulators are being given high priority with replacement of the host computers and selected software models underway. Procurement of a spare engine for the shuttle carrier aircraft (SCA) is complete and acquisition of a modification "kit" for a second SCA commences in FY 1987. Rewinging of the T-38 aircraft will be completed in 1987.

Development and life certification of the Space Shuttle Main Engine (SSME) is continuing in support of the flight and ground test program. Design modifications on the high pressure pumps and the hot gas manifold are directed at increasing the SSME operating margins, reducing the SSME operating costs, and determining the hardware life and replacement requirements through a certification extension test program. A major near term effort is to continue to develop design improvements to the high pressure turbopump blades and bearings to enhance the operating margins and extend their operational life. The long range plan is to replace the high pressure turbopumps with redesigned pumps fran an alternative source. A contractor was selected in August, 1986 for this effort. Redesign of the hot gas manifold is continuing with the design goal of inproving flow conditions which will extend engine life by decreasing systems resistance and reducing pump loads. These manifold changes and the alternative source turbopumps will be introduced into the fleet during the early 1990's. The SSME program also includes an advanced technology effort which will provide a technology test bed for detailed SSME environment characterization, and will evaluate potential SSME canponent and system level improvements, as well as evaluate technical advances arising fran the Office of Aeronautics and Space Technology program.

The solid rocket motor joints were identified as the specific cause of the Challenger accident. A mjor redesign activity is now being conducted to resolve deficiences in the previous design and to insure the safety and operational viability of the **STS.** During **FY 1987,** the re-design and certification of the boosters for return to flight **will** be progressing to support a return to flight in early FY **1988**. Extensive testing **will** continue in order to certify the solid rocket booster and the redesigned solid rocket mtors.

Tooling and production streamlining activities are continuing on the solid rocket booster and external tank program. No mjor design changes are anticipated in the External Tank as the result of extensive reviews following the Challenger accident.

The first filament wound case **(FWC)** flight articles delivered to Vandenberg are being de-stacked. During the FWC **140% compressive** structural load test to simulate loads at SSME ignition, the aft skirt failed at about 130%. Failure of the aft skirt and methods to structurally load the FWC segments to 140% are being evaluated. Completion of the FWC program **will** be deferred until the baseline SRB designs are certified and the operational readiness dates of the Vandenberg launch site are firmly established.

The Shuttle Operations budget provides funding in three principal areas: Flight Operations, Flight Hardware, and Launch and Landing Operations. Flight Operations includes training, mission control, flight operations planning, payload and system analytical integration, mission analysis, post-flight anamly resolution, sustaining engineering and launch support services. The consolidated operations contract covering most of the flight operation functions performed at JSC has completed transition. The period prior to resurption of flight is being utilized to correct deficiencies identified either by previous experience or by the accident investigation and redevelopnent analyses. Training exercises continue at the minim necessary level.

Flight Hardware includes the procurement of orbiter flight spares, SSME spares and refurbishnt, **ET's** and the interface hardware with the orbiter, solid rocket motors and booster hardware, and propellants; engineering and logistics support for external tank/solid rocket booster/main engine hardware elements; and maintenance and operation of flight crew equipnent. The consolidated operations contract covering most of the crew equipnent support at JSC has been awarded and transition completed in **1986.** The funding for the ET and solid rocket motors and boosters includes long lead time raw mterials, subassdlies, and subsystem required to sustain production.

The Launch and Landing operations budget provides funding for processing of the elements of shuttle flight hardware as they flow through the ground processing stations at KSC. The Shuttle processing contractor (SPC), in conjunction with the base operations contractor (BOC), are conducting operational training during the standdown period as well as providing support to vehicle testing and development of improved procedures and processes. Competition for the payload ground operations contract (PGOC) is completed. The PGOC contractor will be responsible for integration and processing of Shuttle payloads as well as for spacelab and space station payload processing at KSC.

BASIS OF FY 1988 FUNDING REQUIREMENT

SHUTTLE PRODUCTION AND OPERATIONAL CAPABILITY

	1986 Actual	1987 hnded Budget	1987 Current Estimate	1988 Budget Estimate	Page Number
	(Thousands of Dollars)				
Orbiter Operational Capability........	396,400	211,000	373,000	403,200	SF 1-4
Orbiter Replacement....................	-	250,000	2,100,000	-	SF 1-7
Launch and mission support............	180,000	161,000	148,200	249,300	SF 1-8
Propulsion systems.....................	788,900	338,400	463,900	552,100	SF 1-11
manges and system upgrading..........	---	274,000	20,000	25,000	SF 1-14
Total..............................	1,365,300	1,234,400	3,105,100	1,229,600	

Distribution of Program hunts by Installation

	1986 Actual	1987 hnded Budget	1987 Current Estimate	1988 Budget Estimate
Johnson Space Center..................	460,300	210,500	1,979,000	344,800
Kennedy Space Center....................	99,600	105,500	150,000	123,700
Marshall Space Flight Center..........	776,000	318,500	597,900	437,300
National Space Technology Laboratories	7,500	7,900	14,000	15,300
Lewis Research Center.................	3,000	500	3,000	3,000
Goddard Space Flight Center...........	200	---	---	---
Jet Propulsion Laboratory..............	600	1,500	1,500	1,500
Headquarters..........................	18,100	590,000	359,700	304,000
Total..............................	1,365,300	1,234,400	3,105,100	1,229,600

PRODUCTION
AND OPERATIONAL
CAPABILITY

OBJECTIVES AND STATUS

The objectives of this program are to provide for the conpletion of the modifications required to return the Space Transportation System to a safe flight status and the completion of the national fleet of Shuttle orbiters, including building a replacement orbiter for the Challenger; the developnt and production of the propulsion system; preparation of launch site capabilities; and, the potential changes and upgrading of the Space Transportation System (STS).

With the loss of Challenger in January 1986 the orbiter fleet was reduced to three vehicles until a replacement orbiter, which was approved by Congress in 1986, can be delivered. The existing post-Challenger accident orbiter fleet includes Columbia, the orbiter developed and flown on four test and evaluation flights, and two orbiters of a lighter-weight configuration, Discovery and Atlantis. The budget provides funding for necessary inprovements, hardware fixes and mission kits for the orbiter fleet to satisfy flight requirements. In addition, the provisioning of orbiter spares at the Kennedy Space Center is an on-going activity to support the requirements for the initial lay-in of spares to support the flight rate buildup.

Launch and Mission Support provides for the required investment in Launch Operations and Flight Operations capability to meet STS program objectives which include returning safely to flight and supporting the operational flight rate. At KSC, the second line of facilities allow simultaneous processing and checkout of orbiters and associated flight hardware from landing through launch. At JSC, the Mission Support budget provides collateral hardware, principally the extra-vehicular mneuvering units (EMU) while the Mission Operations Capability budget provides for inprovements in the flight support system. The flight support system funded by this budget include training and carrier aircraft, additional landing aids and runway end barriers at the primry and contingency landing sites, and replacement/upgrade of equipnt in the mission support complex such as the Shuttle mission simulator, software production facility and the mission control center.

Propulsion System provide for the production of the Space Shuttle Main Engine (SSME) and the developnt of the capability to support operational requirements established for the SSME, Solid Rocket Booster (SRB), and External Tank (ET). The SSME program includes: production of the main engines necessary to outfit and provide spares for the orbiter fleet, ground testing in support of engine developnt, anomaly resolution, and an advanced developnt effort. The SRB production and capability developnt activities include: the redesign and recertification efforts necessary as a result of the Challenger accident and the procurement,of tooling and equipment to support the revised flight rate; selected studies to continue investigative, analytical and problem-solving activities; and, the conpletion of the filament wound case structural testing. In the ET program, the objectives are to support the recovery activities and return to safe flight efficiently.

Changes and Systems Upgrading provides funding for potential changes and system modifications as well as unanticipated new requirements not covered in the budget estimates for the above activities and other program elements.

BASIS OF FY ! FUNDING REQUIREMENT

ORBITER OPERATIONAL CAPABILITY

	1986 Actual	1987 Amended Budget	1987 Current Estimte	1988 Budget Estimate
		(Thousands of Dollars)		
Orbiter...............................	216,100	82,400	201,300	241,200
Systems integration..................	22,000	---	12,100	4,100
Orbiter spares.......................	158,300	128,600	159,600	157,900
Total..............................	396,400	211,000	373,000	403,200

OBJECTIVES AND STATUS

With the recent loss of Challenger (OV-099), our pr objective is to return the three orb t fl t to safe flight in FY 1988. will ide safe and reliable access to space for NASA the of D and c tain me and i t users space. In support of this objecti orb production activiti include the necessary safety modi fied the ge mi and the p Challenger accident review process and the lopment and installa , ft and p cations Also work inues on improvements to achieve greater tional b iti reduce ational sts, and meet system q irements. These improvements include i t purpose p (GPC), inertial measurement uni (IMU) and a propulsion units (APU). The b and h nose wheel steering tems are undergo fi to improve landing In oncert w these mjor to the hardware ther are modifications to the fl g and d software. In n to these changes, there are num mi and fica i requested for i n payloads

The structura program init ated in FY 1983 provided the foundation for the pr of a replacement er with a ivery date p for mid A new set f structural es will be initiated in FY 1988. This new effort wil s n the i to oduce t vehicle in add tion to additional f i Structura assemblies lude wings, aft structure engine compartment, crew dul luding the nose and cockpit), mid and aft fuselage sections, bay ors vertical l, and the bital r system

The procurement and fabr on f the orbi inventory A concerted effort has been to better define the spares qui and production ty at various vendors. A study is underway to determine logistics depot and mintenance requirements. *An* interim depot system is being implemented utilizing NASA and contractor facilities while the study is being completed and a long-term configuration identified.

CHANGES FROM FY 1987 AMENDED BUDGET

Funding for orbiter production and support activities increased $162.0 million. Additional funding was required to implement and certify changes necessary for the safe return to flight of the Shuttle program and to ensure a viable operational program as the flight rate increases. Activities included in the additional funding are the system design reviews and the resulting hardware, software and processing modifications to the flight system, Funding will also be utilized for the continuation and improvement of flight software, acquisition of an additional tail cone for ferry operations, and the continued investigation of crew escape system. Logistic support to the Shuttle program has been accelerated to inprove our inventory of orbiter flight spares and ground support equipnent spares prior to return to flight. In addition, funding is included to retain critical subcontractors and to support production planning for the replacgnent orbiter until August 1987 when funding appropriated in the FY 1987 Continuing Appropriations Bill (P.L. 99-591) will be available to begin production.

BASIS OF FY 1988 ESTIMATE

Orbiter funds provide for the procurement of a logistics capability including establishing an inventory of spares to support operations requirements, the continuation of previously approved systems improvement program, necessary safety modifications identified as a result of the Challenger accident review process, completing the existing set of structural spares to support the production of a replacement orbiter, initiating manufacture of a replacement set of structural spares, and the engineering analysis and integration support for the increasing flight rate. Orbiter funding also provides for orbiter support activities such as the remote manipulator system, the on-board flight software, and potential implementation of a crew escape system during Orbiter controlled gliding flight.

The orbiter logistics capability program in FY 1988 is continuing the lay-in of line replaceable units, shop replaceable units, and repair parts to support the flight rate buildup. The funding covers flight hardware spares, ground equipment spares, scheduling, provisioning docmentation, and mintenance training. In addition, funding is included to provide maintenance test equipnt and special test equipment for the intermediate, depot level and selected vendor repair sites.

The developnent, qualification and production of flight units for an inproved auxiliary power unit (APU) and the upgrade of the general purpose computers (GPC) will be completed in 1988. The inproved APU will have longer life and higher reliability and will require substantially less ground servicing. This configuration will preclude recurrence of problems which have occurred on prior flights such as formation of wax due to the mixing of lube oil and fuel. The new GPC will add memory and increase operating speed in order to avoid the operational limitations of the current hardware and will result in a more maintainable system. In addition, funds are included to continue necessary safety mdifications such as a new carbon brake system and to conduct studies on a crew escape system.

The orbiter funding also covers systems integration of all redevelopment analyses and hardware changes, as well as procuring orbiter support items and capability changes to the on-board flight software. Continuing developnent of the capabilities of the on-board primry and backup flight software is necessary due to expanding safety requirgnents and system capabilities.

BASIS OF FY 1988 FUNDING REQUIREMENT

REPLACEMENT ORBITER

	1986 Actual	1987 hnded Budget	1987 Current Estimte	1988 Budget Estimate
		(Thousands of Dollars)		
Orbiter Replacement	---	250,000	2,100,000	---

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In order to provide safe access to space and t in United t t preeminence in p NASA has been directed to procure a replacement orbiter (O ·105 with fullf p in Y 987 This placemen t will provide a significant increase in existing l onal launch capability to fly off tl backlog of national ur nternational U.S. space i tr and missions resulting fr the accident.

Currently, a set of structural spares is nearing completion and will be utilized in the production of OV-105. A proposal is being prepared by Rockwell International for the production of this orbiter with a planned full start in August 1987 and planned delivery in 1991. Funding includes a full set of new main engines and the necessary ancillary govermnt furnished equipment such as the remote mnipulator arm, space suits, galley, etc. Procurement of this equipment is planned for an August 1987 start leading to delivery of the orbiter in FY 1991.

BASIS OF FY 1988 FUNDING REQUIREMENT

I AND MISSION SUPPORT

	1986 Actual	1987 l Budget	1987 er. Estimte	1988 Budget Estimte
		(Thousands of Dollars)		
Launch site equipment..	75,700	44,500	61,800	57,700
Mission support capability............	48,600	72,600	42,900	120,900
Mission operations capability.........	55,700	43,900	43,500	70,700
Total...........................	180,000	161,000	148,200	249,300

'ES AND

: activity supports the lopment of :h and mission supp ilities r incipally at the Johnson Space Center (JSC) and Kennedy Space :enter (KSC) The 'irs line of ties at : developed during the DDT&E ar to up launch ng d checkout of one St vehicle through launch. A second line" of facilities is i in t launch site : | budget to o processing and :c of up c three : in flow and to sustain the : t launches at S

Second line facilities already operational include the second launch pad, the second high bay of the orbiter processing facility, the second mobile launch platform, and two additional high bay areas in the vehicle assembly building. The third mobile launch platform has been delayed from an originally scheduled carpletion of September 1986 until early 1989 due to the program standdown. An orbiter mintenance and refurbishment facility is under construction to provide a minimal mintenance and storage capability. In FY 1987, this budget also contains funding required to conduct the necessary mdifications to the KSC ground support equipnent to return to flight status, such as inproving the external tank hydrogen vent system on the launch pad, installation of debris traps in the main propulsion system propellant lines and new support equipnent for the redesigned solid rocket boosters.

Funding has been included for additional landing aids and runway end barriers for the current, and one additional, contingency/abort landing site. Capability inprovements have been added for weather prediction and information handling to improve system monitoring, notably for anomaly tracking. A shift in priority in the ground system replacement/refurbishment program, consistent with the Rogers Commission recommendations, has delayed improvements to the Mission Control Center and accelerated improvements in the simulation training facility including new host computers and associated interface controllers. Critical improvements in simulation fidelity will be accommodated with the expanded capacity of the new hardware. Reliability -- required for the longer integrated simulations — and associated maintenance cost will also be substantially improved with these replacements. A "kit" will be manufactured that will allow the modification of a Boeing 747 into a (second) Shuttle Carrier Aircraft (SCA), thus reducing the potential downtime impact of this major single point of failure. Projects that have been ongoing but which have been rephased or otherwise restructured include the overhaul/uprating of the SCA engines, the life extension of the T-38 aircraft, and procurement of sufficient extravehicular mobility units (EMU's) and other crew-related equipment.

CHANGES FROM FY 1987 AMENDED BUDGET

The Launch and Mission Support total has decreased $12.8 million. The launch site equipment increase of $17.3 million is due to the requirement to conduct the mandatory "return-to-flight-status" modifications to the facilities and equipment at KSC and the upgrading of selected high priority ground processing equipnt. The increases were partially offset by delaying other equipment procurement and modifications consistent with slips in the launch schedule and lower flight rate. The decrease of $29.7 million in the mission support capability estimate for FY 1987 is due to the decrease in crew equipment and post flight testing as well as the reallocation of funding to orbiter and propulsion projects to support the Challenger accident recovery activities. Mission operations capability decreased by $.4 million with the increases for contingency landing sites and the Shuttle Carrier Aircraft (SCA) mod kit being offset by rephasing of the Shuttle Carrier Aircraft (SCA) engine and T-38 engine overhauls.

BASIS OF FY 1988 ESTIMATE

In FY 1988, the launch site equipment activity includes finalizing the return-to-flight status modifications in the KSC ground support equipment associated with the vehicle and launch processing facilities. Activities are also underway to improve the capability to support the flight rate requirements at KSC. These include a digital intercommunications system with associated fiber optics cabling, equipment for installation into the orbiter maintenance and refurbishment facility, replacement equipment for the launch processing system, extension of the launch equipment test facility (LETF), and installation of equipment at the contingency landing sites. The mobile launcher platform previously scheduled for readiness in September 1986, has been delayed until FY 1989 consistent with the adjusted flight rate requirements. Identification, replacement and upgrading of obsolete ground processing equipment is also continued.

Mission support capability requirements continue to establish an inventory of crew equipment, principally extravehicular mobility units (EMU), to support the flight rate. STS operations effectiveness work and other support functions continue to support the STS achievement of program-wide requirements including flight safety, mission success, and rate capability.

Mission operations capability funding in FY 1988 provides for completion of replacement of the host computers and selected critical items for the Shuttle training simulators. FY 1988 is the initial year in the efforts to procure a fourth Shuttle Training Aircraft (STA), to re-engine the Shuttle Carrier Aircraft (SCA) and to replace ADP and other hardware in the Software Production facility. Continuing projects include the procurement of the Shuttle Carrier Aircraft (SCA) mod kit and improvements to weather prediction, information handling, and mission control systems.

BASIS F FY 1988 FUNDING [redacted]

PROPULSION SYSTEMS

	1986 Actual	1987 Budget	1987 Current Estimate	1988 Budget Estimate
		(Thousands of Dollars)		
Main engine	394,400	293,200	299,800	366,800
Solid rocket booster	328,500	17,600	115,500	140,700
External tank	63,200	27,600	46,800	42,200
Systems support	2,800	---	1,800	2,400
Total	788,900	338,400	463,900	552,100

OBJECTIVES AND STATUS

vide for the d tion of the Space Sh i engines (SSME), the implementation of the capability to support operational equirements and anomaly r lut r the l cket booster) and external tank (ET). The SSME program includes the p of t min engines quir d the orbiter fleet, procurement of spares, ground i ons, development d t activities to inprove i mrgins, rel i an a l The SRB program a r g development and if effort for the solid rocket motors to impro safety margin and corr the defici that led to the Chal accident. The SRB p also includes a t valuation of the booster hardware, of va reusabili and cost reductions, and procurement of manufactur ol and p to the jected flight rate. In the ET program, the j t are t y activities and the to safe fl Systems support l pr for the testing of the SSME in the main propulsion te ar configuration.

The total SSME ground test 1,300 tests totaling approximtely 270,000 seconds of test time. This experience includes 250 t exceeding 55,000 seconds of operation, at the full power el .

During the course of FPL testing over the past several years, it became apparent that design mrgins were inadequate for routine FPL flight operation and that the current SSME configuration required an unacceptable amount of mintenance at that power level. Consequently, the SSME program has been structured into three major elements under Shuttle Production and Operational Capability: **(1)** flight engine; **(2)** developnt engine; and (3) advanced developnt.

The flight engine activity includes the production of new engines, retrofit of inproved hardware into the fleet, and anomaly resolution activity. One additional engine is being procured to replace engines lost during ground testing during the past year.

The developnent engine activity provides for the developnt, certification, and flight certification extension of inproved hardware including a redesigned hot gas manifold and near-term high pressure turbopump improvements such as inproved blades and bearings. The conversion of the **NSTL B-1** test stand to single engine test capability has been added to the program to meet expanded ground test requirements.

The advanced developnent element includes the alternate turbopump program and the technology test bed. **An** alternate source for high pressure turbopurps was selected in August, **1986.** These alternate pumps **will** be designed for greater reliability, safety margin, and lower operational costs. The technology test bed **will** provide an independent means to evaluate the technical advances arising from the developnent program, the alternate pump effort, and the OAST technology program.

The solid rocket booster **(SRB)** funding requirements support the redesign and requalification efforts necessary as a result **of** the Challenger accident. Based upon the investigation results of the failure and the actions recommended by the Rogers Carmission, a complete reassessment of the certification program on all hardware and a redesign **of** the solid rocket mtor joint configurations are underway. In-depth reviews of the systems failure mde and effects analysis **(FMEA),** operational procedures and the design of critical hardware on the critical items list (CIL) is being conducted and changes **will** be implmented as necessary. Extensive testing **will** be conducted of all design alternatives under conditions that accurately simulate the launch enviromnt to insure that the final design meets the program safety and performance requirements. A second SRM static firing test stand is being provided to assure the capability to initiate the flight program in FY **1988.** All necessary hardware replacement on refurbishments **will** be procured to support resurption of flight activities and the planned build-up in flight rate. Funding is also included for alternative source procurement studies for the SRM. The filament wound case program is being deferred as a result of the extensive changes being considered in the basic SRB program and the Air Force's decision to defer activation **of** the Vandenberg launch site. **FWC** funding is provided through carpletion of the structural test program.

In systems support, capability is being maintained for the full power level test of three clustered engines in the NSTL main propulsion test stand in early **1989.** This test **will** provide for a verification of the main propulsion system operations at full power level using the main propulsion system test hardware munted in the aft end of the simulated orbiter.

CHANGES FROM FY 1987 AMENDED BUDGET

The $125.5 million increase in funding for Propulsion Systems is primarily to support recovery activities in the solid rocket booster (SRB) project. Funding for the SRB project has been increased as a result of the redesign effort by $97.9 million to cover support for the solid rocket motor (SRM) redesign effort, redesign of tooling and ground support equipment for the new mtor design, additional effort to support the analysis and recertification of the SRB, ground support equipment for the second test stand, and development of non-asbestos insulation material. Funding is also included to canplete development of the Filament Wound Case through structural testing. All future development and production efforts on this project will be delayed pending final resolution of the SRM joint design and Vandenberg launch requirements. The Main Engine test and development activities have increased a net of *$6.6* million reflecting additional development and testing of turbine blades and engine components necessary to resume flights. Funding has also increased for the engine technology test bed to improve instrumentation. This increase has been largely offset by deferrals in the certification of the improved hot gas manifold and the Block II controller projects. Long lead funding has been added to support the mnufacturing of additional engines that could support either the development program or the replacement orbiter. Funding in the External Tank project is increased $19.2 million to support design verification and studies including the failure modes and effects analysis, tooling requirements deferred fran 1986, and a delay in the Main Propulsion Test.

BASIS OF FY 1988 ESTIMATE

Funding for the FY 1988 budget is based upon resumption of the flight program in February, 1988 and the design, test, and certification of the propulsion hardware for flight. A canplete reassessment of the program is included. It consists of a thorough review of the FMEA/CIL's and recertification of all flight hardware to assure compliance with flight requirements. The *SSME* program will continue production of flight hardware and the development programs including necessary improvements to the current configuration and the alternate turbopump programs. The SRB program will canplete the redesign of the solid rocket motors and be re-certified prior to the first flight. The external tank program will canplete the FMEA/CIL reviews and continue the efforts to develop processing improvements to reduce the cost of manufacturing tanks, the continued installation of rate tooling to support the future flight rates and overhaul of the barges used to transport finished tanks frcm Michoud to the launch sites.

CHANGES AND SYSTEMS UPGRADING

	1986 Actual	1987 hnded Budget	1987 Current Estimte	1988 Budget Estimte
		(Thousands of Dollars)		
Changes and system upgrading........	---	274,000	20,000	25,000

OBJECTIVES AND STATUS

Management, technical flight experience, and cost reviews of the Shuttle program have stressed the need for providing an allowance for changes and modifications which inevitably are required in a large, complex, and technically demanding space system.

The Changes and Systems Upgrading budget represents the estimated requirement for potential changes and system modifications and unanticipated developments which are not included in the program element budget estimtes. Such funds are necessary to provide for programmatic and technical changes, such as mdifications to the flight hardware to inprove system reliability, safety and performance; changes and upgrading of ground system to reduce turnaround time between missions, and replacement/modification of hardware elements to achieve increased operating economies.

As the changes and upgrading requirements are identified and approved, the remaining FY 1987 funds will be allocated to the appropriate budget activity.

CHANGES FROM FY 1987 AMENDED BUDGET

The 4. million educt reflects the allocat of funding to the Shut for recovery act as individual tasks were Thes funds h be applied to , Solid Rocket Booster and other Propulsion elements and and Mission S j for these recovery including activities r by the Rogers Commission.

BASIS OF FY 1988 ESTIMATE

The funding requested for FY 1988 will provide for those changes which are considered to have the highest priority. The objectives are to inprove reliability, increase operating safety mrgins and efficiency, and reduce costs. Changes and upgrading areas of interest include mdifications to flight and ground system; design and developnent of hardware/software system which met requirements for improved safety, reliability, performance and cost-effectiveness; and changes which will reduce operational costs by extending operational life, by facilitating improved mission-to-mission turnaround time, and by improving mission performance margins.

OPERATIONS

BASIS OF FY 1988 FUNDING [redacted]

SPACE TRANSPORTATION OPERATIONS

	1986 Actual	1987 Amended Budget	1987 Current Estimte	1988 Budget Estimate	Page Number
	(Thousands of 'Dollars)				
Flight operations....................	434.200	399.000	557.700	561.100	SF 2-4
Flight hardware......................	890,900	646.200	936.000	923.100	SF 2-6
Launch and landing operations.........	315.100	300.500	353.300	401.600	SF 2-8
Total............................	1.640.200	1.345.700	1.847.000	1.885.800	

Distribution of Program hunts by Installation

	1986 Actual	1987 Amended Budget	1987 Current Estimte	1988 Budget Estimate
Johnson Space Center..................	528.000	495.100	474.400	523.900
Kennedy Space Center..................	348.900	310.300	470.800	486.000
Marshall Space Flight Center...........	738.000	510.800	596.800	776.500
National Space Technology Laboratories	1.000	1.000	1.000	2.000
Goddard Space Flight Center...........	1.600	1.700	1.700	1.800
Langley Research Center...............	100	100	100	100
Ames Research Center..................	5.500	4.900	4.700	6.000
Headquarters.........................	17.100	21.800	297.500	89.500
Total............................	1.640.200	1.345.700	1.847.000	1.885.800

OBJECTIVES AND STATUS

Funding for Shuttle Operations is combined with the reimbursements for Shuttle launch services received from other U.S. Govermnt, commercial, and international users to support the launch and flight operations requirements of the Space Shuttle. Previous Shuttle missions demonstrated many of the Shuttle's capabilities including deployments of spacecraft and their upper stages, satellite repairs, satellite retrieval, operations using the remote manipulator, integral scientific experimentation using Spacelab system, extravehicular activity operations, a night landing, and a widening of the Shuttle's performance envelope.

The Flight Operations activity is divided into three mjor elements: mission support, integration, and support. Mission support includes training, flight operations activities and a wide variety of planning activities ranging from operational concepts and techniques to detailed system operational procedures and checklists. Integration includes launch support services and sustaining engineering for orbiter system, cargo analytical integration, and system integration. The support element includes base operational support at JSC and system support activity at JSC, Headquarters, and the Goddard Space Flight Center.

The Flight Hardware program element provides for: the procurement of external tanks (ET), solid rocket motors, booster hardware, and propellants; spare components for the Space Shuttle Main Engine (SSME); orbiter spares; ET disconnects, logistics support for the ET, SRB, and SSME flight hardware elements; and maintenance and operations of flight crew equipment. Included in the funding request for tanks and boosters are the long lead time raw materials, subassemblies, and subsystems necessary to sustain the production of elements in a mnner consistent with the flight rate.

Launch and Landing Operations provides for the pre-launch preparation, launch, and landing operations of the Shuttle and its cargo. Also, liquid propellants used in launch operations are provided for in this budget.

There are currently no planned reimbursable funds for Shuttle Operations in either FY 1987 or FY 1988. The FY 1987 Amended Budget had projected a net reimbursement availability in FY 1987 of $352.0 million reflecting the net of planned receipts from DOD and planned re-payments to foreign and commercial customers. Congressional action on the amended budget appropriated the funding that had been planned for DOD reimbursements. It is anticipated that reimbursable funding will resume in the future as the shuttle flight rate builds up.

The Expendable Launch Vehicle (ELV) program provides for the procurement of expendable launch vehicles and launch support services. The Department of Defense and the National Oceanic and Atmospheric Administration are continuing to utilize the Delta, Scout, Atlas and Atlas Centaur expendable launch vehicles on a fully reinbursable basis. The only planned NASA launch is for the COBE spacecraft which will utilize a Delta launch vehicle made available by using reimbursements for residual. vehicle hardware made available to other users. There are currently no direct funding requirements for the Expendable Launch Vehicle program.

BASIS OF FY 1988 FUNDING REQUIREMENT

FLIGHT OPERATIONS

	1986 Actual	1987 Amended Budget	1987 Current Estimate	1988 Budget Estimate
		(Thousands of Dollars)		
Mission support..	223,800	113,200	158,200	167,000
Integration	112,800	139,800	195,400	196,200
support.	97,600	146,000	204,100	197,900
Total	434,200	399,000	557,700	561,100

OBJECTIVES AND STATUS

Flight operations is divided into three major areas of activity: mission support, integration, and support. Mission support includes a wide variety of planning activities ranging fran the development of operational concepts and techniques to detailed systems operational procedures and checklists. Tasks include flight planning, preparation of systems and software handbooks, flight rules, detailed crew activity plans and procedures, development and implementation of the mission control center (MCC) and network system requirements for each flight, and operations input to the planning for the selection and operation of Shuttle payloads. Specific flight planning activity encompasses the flight design, flight analysis, and software activities. Flight design products include conceptual flight profiles and operational flight profiles which are issued for each flight as well as support to the crew training simulations and flight techniques. In addition, the flight-dependent data located in the erasable memory (mission-to-mission changes) is developed in the flight design process for incorporation into the orbiter software, Shuttle mission simulator, and MCC systems. Integration includes Orbiter sustaining engineering, payload intergration into the Shuttle, system integration of the flight hardware elements, orbiter launch support services to the launch site and flight development and verification software. The software activities include the developnt, formulation, and verification support of the guidance, targeting, and navigation systems software requirements in the orbiter. Support includes base operations support to Shuttle operations at JSC and systems level support at JSC, Headquarters, and Goddard. Currently, the resources for Flight Operations are focused upon fixing a backlog of system discrepancies and incorporating a large number of changes to ground systems hardware, software, and procedures including those resulting fran the ongoing process of analysis and decision-making in the wake of the Challenger accident. Those changes, as well as the long lead time in certain areas of flight preparation (e.g. payload analytical integration) require that work be underway now for the early Shuttle flights. Flight preparation, training of ground and flight crews (including system-wide integrated simulations), and other functions are being carried out. These efforts are being held to the minim level required to prepare for the planned resurption of Shuttle flights.

CHANGES FROM FY 1987 AMENDED BUDGET

The Flight Operations direct budget increase of $158.7 million reflects a **$104.4** million allocation of increased funding reflecting congressional action providing direct appropriation to replace lost reimbursable income and a **$54.3** million increase in program requirement. The amended budget already reflected reductions for the reduced number of flights following the Challenger accident. New requirements have resulted in increases in support to system design reviews, and safety/reliability oversight. Orbiter sustaining design engineering activity has expanded to include support of the orbiter **FEMA/CIL** analysis and the resulting procedure and hardware modifications in addition to the activities that ensure maintainability, reliability, and anomaly resolution during operations. In addition, launch support services activity has increased in the areas of configuration management, design liaison, and project engineering support to the shuttle processing contractor (SPC).

BASIS OF FY 1988 ESTIMATE

The Flight Operations portion of the Shuttle Operations budget continues to support that activity predominately associated with the effort at JSC to plan for and conduct the on-orbit portion of STS missions from launch to landing. The functions are essentially the same as in the past: mintain and operate all the ground facilities necessary for flight preparation and execution, and to instruct the flight and ground controller crews; mintenance and operation of proficiency, training and orbiter ferry aircraft and to perform analyses and operation of the mission planning necessary to conduct and control each mission. It also includes the sustaining engineering required to integrate all flight and ground elements and to assure system safety and integrity; the analytical integration of the payloads into the orbiter and the planning to assure compatibility and verification of interfaces; and support of crew operations and training programs. Orbiter engineering manpower continues the required support of procedure and hardware mdifications resulting fran the **FMEA/CIL** reviews in addition to the sustaining engineering activities that ensure maintainability, reliability, and anomaly resolution during operations.

BASIS OF FY 1988 FUND REQUIREMENT

FLIGHT HARDWARE

	1986 Actual	1987 Amended Budget	1987 Current Estimate	1988 Budget Estimate
	(Thousands of Dollars)			
Orbiter....	270,800	214,500	366,100	278,300
Solid rocket booster.................	335,000	224,500	251,600	317,800
External tank........................	285,100	207,200	318,300	327,000
Total..........	890,900	646,200	936,000	923,100

OBJECTIVES AND STATUS

The Flight Hardware program element provides for the procurement of external tank (ET), the mnufacturing and refurbishnt of solid rocket booster (SRB) hardware and motors, spare components for the main engine (SSME); orbiter spares including ET disconnects, sustaining engineering and logistics support for ET/SRB/main engine flight hardware elements; and maintenance and operation of flight crew equipnent. Included in the funding request for tanks and boosters are the long lead time raw materials, subassemblies, and subsystems necessary to sustain the production of these elements in a mnner consistent with the increasing flight rate. Production phasing of these elements is based on the current flight traffic model and is structured to mintain a smooth and efficient buildup of the production capability. In the ET, production continues at a minim level of activity to retain mnufacturing capability. The orbiter line element includes orbiter spares for replenishment of line and shop replaceable units, the manpower for supporting the logistics operation, and the repair capability for flight hardware. SSME includes component and engine overhauls, flight support, and procurement of replacement spare parts. Also included are provision for the fixed level of annual support for the liquid hydrogen plant and replaceable spares field support, and mintenance of crew-related equipnent. Sane examples of orbiter spare equipment are fuel cells, tiles for thermal protection, tape recorders, leading edge support structures, wheels, brakes and pyrotechnics. The crew-related equipment activities include support to the pre-flight training and flight usage of the extravehicular mneuvering unit, emergency portable oxygen systems, radiation instrumentation, survival radios, closed-circuit television cameras, medical support, and food and other galley-related items. The majority of the crew equipment tasks transitioned into the consolidated Flight Equipment Processing Contract (FEPC) during FY 1986 from 16 earlier contracts.

CHANGES FROM FY 1987 AMENDED BUDGET

Flight hardware increased a net of **$289.8** million reflecting a **$348.0** million increase due to Congressional action to replace lost reimbursable income and **$58.2** million reduction in requiremen s primarily due to operations savings in the **SRB** project as manpower is diverted to the recovery activities. These savings have been partially offset by increased funding in Orbiter and **Main** Eng ne to replenish spare parts inventories to insure adequate support to the flight program once flights resume. The FY **1987** amount includes provision for refund to commercial entities of previous payments for flights which have been terminated or delayed as a result of the accident and Ministration policy decisions.

BASIS OF FY 1988 ESTIMATE

Requirements for orbiter flight spares, crew equipnent spares, and logistics are based on estimates that consider projected flight rates, mintenance schedules, operational hours, turnaround times, and lead times to procure or repair flight hardware. The budget provides replenishment line and shop replaceable units, as well as the manpower to support the overhaul and repair activity for the orbiter, extravehicular mneuvering unit and other crew equipnent. The flight equipnent processing contract (FEPC) which **was** initiated during FY **1986** is continuing its buildup to full capability to support the projected flight rates. Main engine hardware provides for manufacturing and delivery of overhauled engines, engine component spares and flight support. Flight hardware requirgnents activity for the SRB and ET include the procurement of the materials and labor required for refurbishnt and fabrication of units which will be flown during FY **1988**, as well as the support of the production of units which will be flown thereafter.

BASIS OF FY 1988 FUNDING REQUIREMENT

LAUNCH AND LANDING OPERATIONS

	1986 Actual	1987 Amended Budget	1987 Current Estimate	1988 Budget Estimate
		(Thousands of Dollars)		
Launch operations....................	282,400	268,000	315,100	352,400
Payload and launch support...........	32,700	32,500	38,200	49,200
Total..............................	315,100	300,500	353,300	401,600

OBJECTIVES AND STATUS

Launch & Landing operations provides for the manpower and materials to process and prepare the Shuttle flight hardware elements for launch as they flow through the ground processing facilities at KSC. Standard service processing and preparation of payloads as they are integrated into the orbiter are also funded by this category as is procurement of liquid propellants for launch and base support. Support to landing operations at KSC and contingency sites, as required, is also provided.

Operation of the launch and landing facilities and equipment at KSC is the primary function of the Shuttle Processing Contractor (SPC). This includes stacking and mating of the flight hardware elements into a launch vehicle configuration, verification of the launch configuration, and operation of the launch processing system prior to lift-off. Support manpower is also provided by the SPC for booster retrieval operations, configuration control, logistics, transportation and inventory management.

Base support to the Shuttle program is provided by the Base Operations Contract (BOC) which will complete its fourth full year of operation in January 1987. The BOC is responsible for operations support functions such as printing and graphics, calibration of instrumentation, and evaluation, test and modification to launch support equipnt.

Other launch support services included in this budget are maintenance and repair of the central data subsystem, which supports both Shuttle processing as an on-line element of the launch processing system, range support provided by the DOD, Shuttle related data management functions such as work control and test procedures, and purchase of equipnt, supplies and services not related to the Shuttle Processing Contractor.

The Payload and Ground Operations Control (PGOC) is the third and final consolidation contract for KSC operations and will be the major contract for the payload processing activities. McDonnell

Douglas was selected as the PGOC as the result of a competitive procurement and it is anticipated that the contractor will begin transition in January 1987. PGOC will also be the primary contractor for Spacelab and Space Station payload processing at KSC, funded under their respective budgets.

CHANGES FROM FY 1987 BUDGET ESTIMATE

Direct funding requirements for Launch and Landing Operations reflect an increase of $52.8 million due to a $78.6 million increase fran Congressional action to replace lost reinbursable income and a $25.8 million reduction in the KSC operations workforce. The decrease resulted fran reduction in Shuttle processing, cargo processing and base operations manpower as well as the flight savings in propellants realized from the cessation of launch activity at KSC. Following the STS Challenger accident, steps were taken to reduce manpower and equipment acquisition directly related to launch and cargo operations activities. Skills to protect the basic launch and cargo operational capability were, however, maintained such that appropriate testing and training activities could continue in order to insure that the necessary design modifications resulting fran the safety design reviews can be implemented to flight hardware and the revised launch schedule could be supported when required.

BASIS OF FY 1988 BUDGET

Launch operations funding in FY 1988 provides for manpower and support services necessary for processing launches from KSC. This includes manpower to process the build-up of the SRB's, mate the boosters and tanks: process the orbiter: mate the orbiter to the integrated SRB's and tank: process and checkout integrated flight elements through launch: retrieve the SRB's for refurbishment: and support landing of the orbiter either at KSC or at a contingency landing site when required. Funding also supports the manpower required for sustaining engineering, spares provisioning, logistics, launch processing system operation and mintenance, and maintenance/modifications of all other Shuttle-related ground support equipment and facilities.

Payload and launch support funding provides propellants for launch operations and base support, and contractor support for the assembly of individual payloads into a total cargo. This element includes providing launch site support managers to payload customers, verifying cargo-to-orbiter interface, and providing operations maintenance and logistic support to cargo support equipment such as cargo integration test equipment and multi-mission payload support equipment and to the payload support areas including the Vertical Processing Facility, operations and checkout building, and cargo hazardous servicing facilities. Support required for maintaining the Dryden Flight Research Facility as a contingency landing site is also included.

TRACKING AND DATA ACQUISITION

SPACE FLIGHT, CONTROL AND DATA COMMUNICATIONS

FISCAL YEAR 1988 ESTIMATES

BUDGET SUMMARY

OFFICE OF SPACE TRACKING AND DATA SYSTEMS SPACE AND GROUND NETWORKS, COMMUNICATIONS AND DATA SYSTEMS

SUMMARY OF RESOURCES REQUIREMENTS

	1986 Actual	1987 Amended Budget	1987 Current Estimte	1988 Budget Estimate	Page Number
		(Thousands of Dollars)			
Space network..........................	273,700	407,300	407,300	481,500	SF 3-4
Ground networks.......................	210,400	250,100	250,100	257,100	SF 3-10
Communications and data systems........	176,300	205,500	205,500	210,300	SF 3-18
....	660,400	862,900	862,900	948,900	
Distribution of Program Amounts by Installation					
Marshall Space Flight Center..........,	29,655	35,800	35,800	34,700	
Goddard Space Flight Center....,.......	329,436	433,500	433,500	514,000	
Jet Propulsion Laboratory...............	115,588	126,600	126,600	131,800	
Ames Research Center..................	9,900	11,800	11,800	10,200	
Headquarters..........................	175,813	255,200	255,200	258,200	
Johnson Space Center..................	8	---	---	---	
WAL................................	660,400	862,900	862,900	948,900	

SPACE FLIGHT, CONTROL AND DATA COMMUNICATIONS

FISCAL YEAR 1988 ESTIMATES

OFFICE OF SPACE TRACKING AND DATA SYSTEMS SPACE AND GROUND NETWORKS, COMMUNICATIONS AND DATA SYSTEMS

PROGRAM OBJECTIVES AND JUSTIFICATION

The purpose of this program is to provide vital tracking, telemetry, command, data acquisition, communications and data processing support to meet the requirements of all NASA flight projects. In addition to NASA flight projects, support is provided on a reimbursable basis for projects of the Department of Defense (DOD), other Government agencies, commercial firms, and other countries and international organizations engaged in space research.

Support is provided for Earth orbital, planetary and solar system exploration missions, research aircraft, sounding rockets and balloons. Included in Earth orbital support are the Space Shuttle Spacelabs, and scientific and applications missions. The various types of support provided include: (a) tracking to determine the position and trajectory of vehicles in space; (b) acquisition of scientific and space applications data fran on-board experiments and sensors; (c) acquisition of engineering data on the performance of spacecraft and launch vehicle systems; (d) reception of television transmissions fran space vehicles; (e) transmission of commands from ground stations to the spacecraft; (f) communications with astronauts; (g) transfer of information between the various ground facilities and control centers; and (h) processing of data acquired fran the launch vehicles and spacecraft. Such support is essential for achieving the scientific objectives of all flight missions and for executing the critical decisions which must be made to assure the success of these missions.

Tracking and acquisition of data for the spaceflight projects is presently accomplished through the use of a worldwide network of NASA ground stations, and by the first of a system of three tracking and data relay satellites in geosynchronous orbit working with a single highly specialized ground station. Ground facilities are interconnected by terrestrial and cmnications satellite circuits which tie together the spacecraft and control centers for control of the missions.

To meet the support requirements levied by the wide variety and large number of flight projects, NASA has three basic support capabilities to meet the needs of all classes of NASA flight missions. These are the Spaceflight Tracking and Data Network (STDN), which supports Earth orbital missions; the Deep Space Network (DSN), which primarily supports planetary and interplanetary flight missions; and the Space Network including the Tracking and Data Relay Satellite System (TDRSS), which will provide all low Earth orbital mission support when it becomes fully operational.

The STDN will provide Earth orbital support until the TDRSS becomes operational. At that time the STDN phasedown will continue with the closure of several ground stations. The DSN, under the management of the Jet Propulsion Laboratory (JPL), provides support to geosynchronous, highly elliptical, and planetary and solar system exploration missions, as well as support to those spacecraft, now in low-Earth orbit, which are not compatible with TDRSS.

Highly specialized computation facilities provide real-time information for mission control and process into meaningful form the large amounts of scientific, applications, and engineering data which are collected from flight projects. In addition, instrumentation facilities are provided for support of sounding rocket launchings and flight testing of aeronautical research aircraft.

The Space Flight, Control and Data Communications appropriation includes the Space Network, Ground Networks, and Communications and Data Systems elements of the program, and provides funds for: (a) the cost of TDRSS service; (b) operations and maintenance of the tracking, data acquisition, mission control, data processing and communications facilities; and (c) the engineering services and procurement of equipment to sustain and modify the various systems to support continuing, new, and changing flight project requirements.

SIS OF FY 1988 UNDING REQUIREMENTS

SPACE NETWORK

	1986 Actual	1987 Amended Budget	1987 Current Estimate	1988 Budget Estimate
		(Thousands of Dollars)		
Tracking and data relay satellite system (TDRSS)........................	205,600	301,500	301,500	325,000
Space network operations..............	40,500	43,700	43,700	44,400
Systems engineering and support........	21,300	28,100	28,100	27,000
TDRS Replacement spacecraft............	4,900	33,000	33,000	76,000
Second TDRSS ground terminal..........	1,400	1,000	1,000	9,100
TOTAL..............................	273,700	407,300	407,300	481,500

OBJECTIVES AND STATUS

The Space Network consists of the Tracking and Data Relay Satellite System (TDRSS) and a number of NASA ground elements to provide the necessary tracking, telemetry, command, and communications services to low Earth orbital spacecraft. The TDRSS itself, when fully operational, will consist of a three satellite constellation including an on-orbit spare in geostationary orbit and ground facilities located at White Sands, New Mexico. From the White Sands location, satellite and ground communication links interconnect the NASA elements of the network and any remotely located user facilities.

The FY 1988 request includes funding for: repayment of the loans extended by the Federal Financing Bank for TDRSS development; maintenance and operation of the White Sands complex and other NASA elements of the network; 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 procurement of an additional TDRS spacecraft to replace the one lost in the Challenger accident; and the implementation of a second ground terminal at White Sands.

	1986 Actual	1987 Amended Budget	1987 Current Estimate	1988 Budget Estimate
		(Thousands of Dollars)		
Tracking and data relay satellite system	205,600	301,500	301,500	325,000

OBJECTIVES AND STATUS

The Tracking and Data Relay Satellite System (TDRSS) objective is to provide communications service between the user spacecraft and ground facilities. The relay satellites provide space-to-space communications to and from the user satellites and relay these communications to the ground via the White Sands facilities which are interconnected with the other elements of the network. From their position in geostationary orbit, the TDRS's can provide nearly a six-fold increase in the orbital coverage provided by ground tracking stations and can accommodate extremely high user data rates ranging up to 300 megabits per second.

The TDRS-1 was launched in April 1983, and since that time it has supported Shuttle missions, including Spacelabs, and free flyer missions such as the Solar Maximum Mission (SMM), Earth Radiation Budget Satellite (ERBS), Landsat, and Solar Mesopheric Explorer (SME). The TDRS-2 was destroyed in the Challenger accident in January 1986. The four remaining spacecraft are undergoing modifications to be compatible with Shuttle safety requirements and are in various stages of construction, assembly and retesting. Launch of the next TDRS is scheduled for the first quarter of 1988 on the first Shuttle mission when flights resume. The third TDRS is scheduled for launch in the last half of 1988. Once these two spacecraft have been successfully launched and the system achieves operational status, TDRS-1 will become the on-orbit spare.

BASIS OF FY 1988 ESTIMATE

Under the terms of the TDRSS service contract, loans were extended by the Federal Financing Bank (FFB) to Space Communications Company (SCC), the owner-operator of the TDRSS, for program development. Under the terms of the loan agreement and assignment, NASA repays these loans directly to the FFB. In addition, NASA will make payments to SCC for the operation and maintenance of the White Sands complex and for completion of satellite construction and other support provided during the year. Funding is also included for studies to define the next generation of relay satellites and the required technology.

Of the amount requested in FY 1988, approximately $227 million is for the FFB loan repayments. The remainder of the request is for continuing spacecraft construction, modification, test, storage, and assembly, launch related costs and operation and maintenance of the White Sands Ground Terminal.

	1986 Actual	1987 Amended Budget	1987 Current Estimate	1988 Budget Estimate
		(Thousands of Dollars)		
Space network operations..............	40,500	43,700	43,700	44,400

OBJECTIVES AND STATUS

The objective of Space Network Operations is to provide for the operation and maintenance of the associated NASA ground systems and facilities which, when combined with TDRSS, provide a full array of reliable tracking, telemetry, command, and communications services to user spacecraft in low Earth orbit. Each of these NASA network elements performs specific functions for the Space Network.

The NASA Ground Terminal (NGT) monitors TDRSS performance, provides fault isolation monitoring for the network, and serves as the communications interface between White Sands and all other facilities. The Network Control Center (NCC) schedules TDRSS services for all user spacecraft, and the Flight Dynamics Facility (FDF) provides orbit determination, trajectory analysis, and position location for flight missions supported by the Space Network and for selected missions supported by the ground networks. The Bilateration Ranging Transponder System (BRTS) provides precision location and orbit determination information for the TDRSS. The Simulations Operations Center (SOC) and the Compatibility Test Vans (CTV) provide necessary pre-launch testing, simulations, and interface verification for both user spacecraft and the various network elements to assure the operational readiness of the network to support a given mission.

The individual network elements are designed to function as an integrated operational system. The overall system has provided service to a variety of missions, including Shuttle and Spacelab, since TDRS-1 became operational. Effort is continuing to achieve an operational configuration that will be capable of supporting an expanded workload in the late 1980's.

BASIS OF FY 1988 ESTIMATE

The funding request provides for services to operate the network 24 hours a day, seven days per week, and for related hardware and software maintenance. Funding is also provided for a variety of support activities such as operational analysis, mission planning, simulations, user compatibility testing, and documentation.

	1986 Actual	1987 Amended Budget	1987 Current Estimate	1988 Budget Estimate
		(Thousands of Dollars)		
Systems engineering and support....... .	21,300	28,100	28,100	27,000

OBJECTIVES AND STATUS

The objecti of Systems g a is to provide tl ine r s and hardware q to sustain and modify tl NASA nt of the Network. E ng vices are supplied g tl operat and intenance con act and a number of small engineer service which provide highly specialized support.

ont to assure system readiness for the resumption of Shutt flights including the coming TDRS launches and for fu n t operation once the TDRSS is ational. There s ongoing ivi to sustain system eliabi for current users and t are underway to t the support r of upcoming missions such as the Hubble Space Telescope In the t (equipment n ions d lacemen are being made and twar ue to TDRSS and operational reliability.

BASIS OF THE FY 1988 ESTIMATE

Funds are requested to provide systems engineering, performance and operations analysis, minor facility modifications, network readiness testing and interface verification, sustaining engineering support, test equipnent, and vendor mintenance for specialized equipnent and subsystems within the Space Network. Design and analytical studies will be conducted on a wide variety of items, ranging fran subsystemmodifications to meet new mission requirements or to correct operational deficiencies to the analysis of radio frequency environment for potential impact to network systems. Funds are also requested for continued software development for the NCC and ongoing hardware implementation, replacement, and modification.

	1986 Actual	1987 Amended Budget	1987 Current Estimte	1988 Budget Estimte
		(Thousands of Dollars)		
TDRS Replacement Spacecraft...........	4,900	33,000	33,000	76,000

OBJECTIVES AND STATUS

A contract has been awarded to TRW, the sub-contractor for the TDRSS space segment, to provide a replacement spacecraft and long-lead parts for an optional additional spacecraft. During the program definition phase preliminary design studies will identify parts and components no longer available and recommend design changes to increase spacecraft safety and reliability. The design objective is to provide a functionally identical satellite with minimal change from the current spacecraft and which is fully compatible with the existing system.

BASIS OF FY 1988 ESTIMATE

The requested funding ll ide for continuing th development phase of the i s scheduled for ini in mid-1987. This will i the i of t materials, and subsystem as we as led system design.

	1986 Actual	1987 Amended Budget	1987 Current Estimate	1988 Budget Estimate
		(Thousands of Dollars)		
Second TDRSS Ground Terminal (STGT)....	1,400	1,000	1,000	9,100

OBJECTIVES AND STATUS

The objective of this program is t provide a backup to the existing l ermin t Sands, New , to insure i of s and to minimize the potential oss of critical space assets includi data. The exi ermina i a s int of failure for the entire Space Network, and a catastrophic f i i l could resul i a nearly complete loss of NASA communications and data gatheri apabi for earth In i the sent ri has l y service outages due to equipment failure t could have been avoided with a backup terminal.

to the of the equipment, rep of major and components in the ting terminal will eventua be required, ting an ternate means of network operations while the replacement y is underway. The addition of a second ground t rminal will pr the necessary alternative means for nu operational support while t existing terminal i down dur the replacement.

Because the design of the current terminal is limited to full operation of two TDRS spacecraft, a second terminal will also provide the additional flexiblity to operate more spacecraft if, as anticipated, mission requirements exceed the two satellite operations capability in the mid-1990's.

BASIS OF FY 1988 ESTIMATE

A competitive award for two preliminary design contracts will be made in late FY 1987. The FY 1988 request includes funds for completing these design efforts and for development of system specifications for the implementation phase. A competitive award to a single contractor for implementation is planned for late FY 1988. Initial funding for the implementation phase is also included in the request.

BASIS OF FY 1988 FUNDING REQUIREMENTS

GROUND NETWORKS

	1986 Actual	1987 Amended Budget	1987 Current Estimate	1988 Budget Estimate
		(Thousands of Dollars)		
Spaceflight tracking and data network systems implementation........	3,000	3,900	3,900	3,300
Spaceflight tracking and data network operations....................	53,960	81,400	81,400	85,500
Deep space network systems implementation.......................	42,765	44,000	44,000	49,000
Deep space network operations..........	85,301	93,300	93,300	94,100
Aeronautics, balloons, and sounding rocket support systems implementation	10,434	11,200	11,200	8,500
Aeronautics, balloons, and sounding rocket support operations............	14,940	16,300	16,300	16,700
Total..............................	210,400	250,100	250,100	257,100

OBJECTIVES AND STATUS

The Ground Networks prov [illegible] support to th [illegible] ies of missions: earth orbital [illegible] planetary and [illegible]l system [illegible] ati [illegible] and aeronautics [illegible] and [illegible] g rockets. E[illegible] bital support is provided primarily by the [illegible] ig Tracking and Data Network [illegible] STDN) a network of eight [illegible] ly dispersed ground stations. The Deep Space Network, with [illegible] located at [illegible] sites approximately 120 degrees apart in longi [illegible] prov [illegible] support to the [illegible] and solar system exploration missions as well as earth orbital missions not supportable by [illegible] eronauti[illegible], balloons and sounding [illegible] is [illegible] orted by specially instrumented ranges as well as mobile systems.

Funding for the Ground Networks provides for operation and maintenance of the worldwide tracking facilities, engineering support, and the procurement of hardware and software to sustain and modify network capabilities. The workload in FY 1988 will include support to the Space Shuttle and support to ongoing missions such as Dynamic Explorer (DE), International Ultraviolet Explorer (IUE), and Solar Maximum Missfon (SMM). Preparations will be underway for the upcoming 1989 Voyager-Neptune encounter and future planetary missions including Galileo, Ulysses, Magellan, and Mars Observer. Aircraft test programs will also be supported.

	1986 Actual	1987 Amended Budget	1987 Current Estimate	1988 Budget Estimate
		(Thousands of Dollars)		
Spaceflight tracking and data network systems implementation........	3,000	3,900	3,900	3,300

OBJECTIVES AND STATUS

The Spaceflight Tracking and Data Network (STDN) systems implementation program encompasses the procurement of hardware and attendant engineering services to sustain, modify, and replace existing network capabilities to ensure reliable tracking, command and data acquisition support to NASA's spaceflight missions.

BASIS OF FY 1988 ESTIMATE

The FY 1988 request includes funds for replacement of obsolete and difficult-to-maintain equipment at the eight tracking stations and other network facilities. The funds requested also provide for the procurement of major subsystem spares, the replacement of older test equipment, and minor equipment modifications resulting from changes in support requirements.

Funds are also required to upgrade equipment systems and subsystems at those facilities to be retained after TDRSS is operational. These facilities include the Merritt Island, Florida and Bermuda STDN stations which provide prelaunch, launch, and shuttle landing support, as well as limited orbital support. Also included is the orbital tracking facility at the Wallops Flight Facility which provides orbital tracking support.

	1986 Actual	1987 Amended Budget	1987 Current Estimate	1988 Budget Estimate
		(Thousands of Dollars)		
Spaceflight tracking and data network operations....................	53,960	81,400	81,400	85,500

OBJECTIVES AND STATUS

The primary function of the Spaceflight Tracking and Data Network (STDN) system is to support NASA's earth orbiting spaceflight missions, including the Space Shuttle. This network also provides launch support to NASA planetary missions, and on a reimbursable basis, spaceflight missions of other United States government agencies (NOAA and DOD) and other nations.

The STDN presently consists of eight geographically dispersed ground stations. They are located at: Merritt Island, Florida; Kauai, Hawaii; Guam; Ascension Island; Dakar, Senegal; Bermuda; Santiago, Chile and Yarragadee, Australia. Each of these stations, with the exception of Yarragadee, have the capability to electronically track spacecraft, send commands for spacecraft and experiment control purposes, and receive and display engineering and scientific data from the spacecraft. In the case of manned flights, they also maintain voice communications for crew operations and safety and other project-related purposes. The Yarragadee, Australia station provides only air-to-ground voice communication with the Space Shuttle astronauts.

The STDN will undergo a highly significant change from its current state when the Space Network achieves operational status. At that time five STDN stations will cease operations and either close or be transferred to other organizations. These stations are Ascension Island, Guam, Hawaii, Santiago, and Yarragadee. Dakar will close when the Space Network is capable of supporting the ascent phase of STS missions. The two remaining stations at Merritt Island and Bermuda will provide prelaunch, launch, and Shuttle landing support as well as limited orbital support.

BASIS OF FY 1988 ESTIMATE

The FY 1988 funding request provides for a full year of operation of the eight STDN stations. In addition to the costs of operating the eight STDN stations, the request includes funding for logistics support, network planning, scheduling, control center operations, engineering, documentation, and software programming support. Logistics support funded under this program is provided to a variety of users such as the Deep Space Network, NASA Communications Network, Wallops Flight Facility, and spacecraft control centers at GSFC.

	1986 Actual	1987 Amended Budget	1987 Current Estimate	1988 Budget Estimate
		(Thousands of Dollars)		
Deep space network (DSN) systems implementation................	42,765	44,000	44,000	49,000

OBJECTIVES AND STATUS

The role of the Deep Space Network (DSN) is to provide the communication link between each of NASA's planetary and interplanetary spacecraft and the Earth. The DSN is responsible for receiving science and engineering data and providing the navigation, command and control capabilities from the ground to a wide variety of spacecraft ranging in distance from earth orbit to over 6.0 billion kilometers from earth. The DSN also has support responsibility for several spacecraft in earth orbit that are not supportable by the TDRSS.

The systems and facilities required to support spacecraft at the limits of the solar system are highly specialized and include the use of large aperture antennas electronically configured in an array to receive the extremely weak radio signals. The antennas use ultrasensitive, cryogenically-cooled receivers and powerful transmitters. Extremely stable hydrogen maser time standards are required for precise navigation of distant spacecraft. Advanced data handling systems are required at both the DSN complexes and the Network Operations Control Center.

With the first deep space mission using the X-band frequency spectrum planned for launch in 1989, the ground network is being equ-pped to transmit commands in this frequency range. Initially, the 34-meter antennas at Goldstone, Spain and Australia will have this capability. Not only will Galileo utilize this new frequency for spacecraft telecommunications, but it will also use a new precision tracking capability to perform experiments designed to detect perturbations in the gravity field caused by collapsing quasars. Since other deep space missions will also utilize X-band, it is planned to implement this capability on most of the remaining antennas in the DSN by 1992.

The four major objectives for the DSN in the late 1980's are as follows: (1) to provide communications channels to scientific spacecraft at ever-increasing distances and to provide the capability to receive images at these great distances; (2) to increase the frequency range and data rate capability of the ground network to accommodate new spacecraft requirements; (3) to provide support for a new set of spacecraft which will include non TDRSS compatible highly elliptical earth orbiters and synchronous earth orbital missions; and (4) to provide the improved navigation capabilities required for precise spacecraft targeting and probe delivery.

These objectives continue to represent a significant challenge to the DSN. The most distant planetary encounter will be with Neptune by Voyager 2 in late 1989. This encounter will occur some 4.5 billion kilometers from earth. At that time, Voyager 2 is expected to transmit the first high resolution images ever received from a spacecraft at such a distance. To meet the challenge, an expansion of the 64-meter antennas to 70 meters is currently underway. This expansion along with multiple antenna arraying (signal combining) of radiotelescopes in New Mexico and Australia, will provide the Yncreased signal capturing capability for our first look at Neptune.

Future deep space missions which will be supported by the DSN include Galileo, Ulysses, Magellan and Mars Observer.

BASIS OF FY 1988 BUDGET TIMATE

Funding in the FY 1988 request v for tinu ng of the , ling advant of the latest i to meet increasingly complex p requirements. new l needed to meet the more stringent navigation and t-ground telecommunications requirements.

Fu d are included in the 1988 budget to implement the new capabilities required for the Magellan and Mars Observer These il i lude telemetry sy modifications to handle the high data rates and extensive change to t ver stem requir by t signal dynamics.

The X-band ransmiss ap il y being em at the new tions to the ant feed and the addition of a transmitter to the antennas which are ently in a sten only" ation. ve improvemen to the tracking sys are required in 988 to provide the navigation accuracy necessary for the ali probe r This mission event equires that the posi of the f be precisely known in order that the when eleased, i l the correct ballistic into th Jovian atmosphere

Work will continue in 1988 in preparation for the Voyager 2 spacecraft encounter with Neptune in late 1989. This activity consists of implementation of a X-band receive capability for the Very Large Array radiotelescope at Socorro, New Mexico (which will be arrayed with the Goldstone, California antennas) and the 64-meter radiotelescope antenna at Parkes, Australia (which will be arrayed with the DSN antennas at Canberra, Australia).

This program also includes funds for sustaining type activity in the DSN such as reliability modifications, operational improvements, and replacement of obsolete equipment at the signal processing centers, the three DSN complexes and at the Network Control Center at Pasadena, California.

	1986 Actual	1987 Amended Budget	1987 Current Estimte	1988 Budget Estimate
		(Thousands of Dollars)		
Deep space network operations..........	85,301	93,300	93,300	94,100

OBJECTIVES AND STATUS

The three Deep Space Network (DSN) complex locations — Goldstone, California; Canberra, Australia; and Madrid, Spain--are approximately 120 degrees apart in longitude to permit continuous viewing of planetary and solar system spacecraft. After completion of the project in 1988 to expand the diameter of the 64-meter antenna dishes to 70 meters, each complex will have four antennas: one 70-meter, two 34-meter and one 26-meter. A centralized control center for the network is located at the Jet Propulsion Laboratory (JPL) in Pasadena, California.

The Voyager-2 spacecraft encounter with Uranus in January 1986 provided the first detailed information on that distant planet. Voyager-1 is now over 4 billion kilometers from earth on a trajectory that will take it out of the solar system. The Pioneer-10 spacecraft is beyond the orbit of Neptune, and is the first man-made object to leave the solar system. It now takes just under ten hours for a radio signal, traveling at the speed of light, to make the round trip between earth and Pioneer-10. The Pioneer-11 spacecraft, some 3.4 billion kilometers from earth, continues to be tracked. The Pioneer-6 through 8 spacecraft are provided support during solar conjunctions and gravity wave experiments.

The DSN facilities are also used on a non-interference basis for ground based measurements in support of experiments in planetary radar mapping and in the field of radio astronomy. The ultrasensitive network antennas are being used in an attempt to learn more about pulsar high energy sources, quasars, and other interstellar and intergalactic phenomena.

BASIS OF FY 1988 ESTIMATE

The DSN operations funding provides for the maintenance and operation of network facilities and the support and engineering effort required for continuing operation of the network. The expected DSN workload in 1988 consists of support for the two Voyager spacecraft, the six ongoing Pioneer spacecraft (Pioneer 6, 7, 8, 10, 11 and Pioneer Venus), Active Magnetosphere Particle Tracer Explorer, International Sun Earth Explorer-1 and -2, Nimbus-7, Dynamics Explorer, and International Comet Explorer. Provision has also been made in the DSN to provide emergency backup support for Space Shuttle, TDRSS and Hubble Space Telescope.

	1986 Actual	1987 Amended Budget	1987 Current Estimate	1988 Budget Estimate
		(Thousands of Dollars)		
Aeronautics, balloons and sounding rocket support systems implementation	10,434	11,200	11,200	8,500

OBJECTIVE AND STATUS

The facilities of the Aeronautics, Balloon and Sounding Rocket (AB&SR) Program encompass the ground support capabilities required to capture the scientific and engineering data from aircraft, balloons, sounding rockets and some low earth orbiting vehicles engaged in scientific research. The primary fixed facilities are located at the Wallops Flight Facility (WFF), the Ames Research Center (ARC) and the Dryden Flight Research Facility (DFRF).

The Wallops Flight Facility, under the management of GSFC, operates an extensive range at Wallops Island, Virginia, which supports aeronautics research as well as sounding rocket and small weather balloon launches. In 1986, a capability was established at WFF to provide tracking and data acquisition support to certain low earth orbiting satellites to supplement the capabilities of the Spaceflight Tracking and Data Network (STDN). WFF also manages the operation of off-site ranges located at the White Sands Missile Range, New Mexico; Poker Flats Research Range, Fairbanks, Alaska; and the National Scientific Balloon Facility, Palestine, Texas. Mobile campaigns for balloon and sounding rocket launches are conducted at various sites throughout the world.

The ranges at Moffett Field, Crows Landing and the Dryden Flight Research Facility (DFRF), under the management of ARC, are configured to support aeronautics research. The DFRF also has the additional capability to support shuttle landings.

The AB&SR system implementation program is directed primarily at the systematic replacement of obsolete systems and the upgrade of these facilities to assure reliable support to NASA's research programs. FY 1987 is the last year of a phased equipment replacement and refurbishment program which will insure reliable real-time data collection and handling support in the future.

BASIS OF FY 1988 ESTIMATE

The aeronautical research efforts and scientific experiments using sounding rockets and balloons are programs of a continuing nature which generally require a constant level of support. Support for these programs requires fixed and mobile instrumentation systems; namely, radar, telemetry, optical, communications, command, data handling and processing systems. To maintain these facilities, replacement parts must be acquired, test and calibration equipment routinely replaced, and equipment refurbished or modified to assure reliable support.

	1986 Actual	1987 Amended Budget	1987 Current Estimte	1988 Budget Estimate
		(Thousands of Dollars)		
Aeronautics, balloons and sounding rocket support operations............	14,940	16,300	16,300	16,700

E

The p element of he AB&SR F includes the operations and maintenance f instrumentati s st both fixed and l under h management of the s Research Center l the Goddard Space Fl t Center. These facilities t NASA aeronautics, t l and a limited number of th orbit r pr ams Funding des f i and consumable li required to operate and maintain he adar telemetry, data acquisition, data processing, data display n special purpose p equipment es to the conduct of these research programs.

The aeronautical test ranges at the Dryden Flight Research Facility and the Moffett Field Flight Complex (MFFC) under the auspices of the Ames Research Center maintain an active schedule of aeronautics research support. During FY 1986, about 1300 missions were conducted at DFRF and MFFC. Programs supported by the ranges encompassed a wide variety of activities including revolutionary aircraft configurations, advanced technologies, high performance aircraft, highly integrated control systems and powered lift technologies.

The GSFC managed activities supported aeronautics progrm as well as sounding rocket, balloon and low earth orbiting satellite programs. During 1986, approximately 290 aeronautics missions were supported at the Wallops Flight Facility covering such progrm as Advanced Transport aerating Systems, AV-8B full scale development tests, runway friction testing, microwave landing system operations testing, storm hazards research and general aviation light aircraft stall/spin research. The sounding rocket program conducted approximately 140 launches in FY 1986 which included 37 of the larger rockets with mjor scientific payloads. The remainder were the smaller meteorlogical and special purpose rockets supporting a variety of research progrm. The balloon program had 122 launches during FY 1986. Low earth orbiting satellites supported included IUE, IMP-8 and Nimbus.

M I S FOR FY 1988 ESTIMATE

The funding estimate for FY 1988 is based on a relatively constant level of mission support activity. aerations, maintenance, logistical support and technical services for the ground-based fixed and mobile instrumentation systems will be continued in support of the ongoing sounding rocket, balloon, orbiting satellite and aeronautical research progrm.

BASIS OF FY 1988 FUNDING REQUIREMENTS

COMMUNICATIONS AND DATA SYSTEMS

	1986 Actual	1987 Amended Budget	1987 Current Estimate	1988 Budget Estimate
		(Thousands of Dollars)		
Communications systems implementation..	5,500	7,400	7,400	6,400
Communications operations.............	82,049	91,700	91,700	97,200
Mission facilities....................	13,820	12,200	12,200	7,400
Mission operations....................	18,900	23,700	23,700	28,000
Data processing systems implementation	21,100	28,400	28,400	22,300
Data processing operations............	34,931	42,100	42,100	49,000
Total................................	176,300	205,500	205,500	210,300

OBJECTIVES AND STATUS

Funds requested for the Communications and Data Systems program provide for the implementation and operation of facilities and systems which are required for data transmission, mission control and data processing support.

Communication circuits and services provide for the transmission of data among the remote tracking and data acquisition facilities, launch areas, and the mission control centers. Real-time information is crucial to determining the condition of the spacecraft and payloads for the generation of commands for spacecraft and payload control. Data received from the various spacecraft must be processed into a usable form before transfer to control centers and experimenters. Missions supported include Shuttle, Spacelab, NASA scientific and application projects and international cooperative efforts.

Major activities underway include the implementation of: 1) a mission control and data capture system for the Hubble Space Telescope and 2) mission control and data processing capabilities for support of upcoming missions such as Spacelabs, Gamma Ray Observatory (GRO) and Upper Atmosphere Research Satellite (UARS). In addition, studies have been initiated to evaluate Space Station support requirements.

	1986 Actual	1987 Amended Budget	1987 Current Estimate	1988 Budget Estimate
		(Thousands of Dollars)		
Communications systems implementation....................	5,500	7,400	7,400	6,400

OBJECTIVES AND STATUS

The objective of the Communications Systems Implementation Program is to provide the necessary capability in NASA's Global Communications Network (NASCOM) to meet new program support requirements, to increase the efficiency of the network, and to keep NASCOM at a high level of reliability for the transmission of data. NASCOM interconnects the tracking and data acquisition facilities which support all flight projects; it also links such facilities as launch areas, test sites, and mission control centers.

The major effort being initiated in NASCOM is the planning, engineering and equipment acquisition required to tie together the existing TDRS ground terminal at White Sands with the second TDRS ground terminal. This requires an integrated communications capability for the control and transfer of data between the two facilities.

BASIS OF 1988 EST

The FY 1988 funding requirements will provide the sustaining equipment and modifications to support the NASCOM network and continue replacement of the voice and data message switching system at GSFC. Effort will continue on the implementation of a new voice intercom system for all the Project Operations Control Centers at GSFC. Additional funding will be provided to continue modifications to the fiber optic system at GSFC to handle high speed data, digital voice, and increased security requirements.

	1986 Actual	1987 Amended Budget	1987 Current Estimate	1988 Budget Estimate
		(Thousands of Dollars)		
Communications operations.............	82,049	91,700	91,700	97,200

OBJECTIVES AND STATUS

NASA's Global Communications Network (NASCOM) interconnects, by means of leased voice, data, and wideband circuits, the tracking and data acquisition facilities which support all flight projects. *Also,* NASCOM links such facilities as launch areas, test sites, and mission control centers. Goddard Space Flight Center (GSFC) operates the NASCOM and serves as its major switching control point. In the interest of economy, reliability, and full utilization of trunk circuitry, subswitching centers have been established at key domestic and overseas locations. The NASA flight projects require the transfer of data between the mission control centers and the sites because of the need for real time control of spacecraft and on-board experiments. In addition, there are requirements to provide experiment data expeditously to users for analysis.

NASA's Program Support Communications Network (PSCN) interconnects by means of leased voice, data, and wideband circuits the NASA Centers, Headquarters, and major contractor locations for the transfer of programmatic and administrative information. Marshall Space Flight Center (MSFC) operates the PSCN and serves as its major switching control point.

BASIS OF FY 1988 ESTIMATE

The FY 1988 funding requirements for Communications Operations will provide the circuits and service required to operate and maintain the NASA Global Communications Network. International communications satellites and cables will continue to provide digital wideband services to all the overseas tracking stations. Domestic satellite systems and terrestrial networks will continue to service the continental United States stations. With the reactivation of the Shuttle network and the trend toward fiber optic systems there will be a dramatic increase in the use of digital technology in NASCOM with a corresponding decrease in the use of analog technology.

In addition, funds are included for PSCN which provide for the circuits and facilities for programmatic and day-to-day operations such as facsimile, teleconferencing, data transmission, and computer-to-computer data sharing for NASA Centers and Headquarters. In FY 1988 funds are required to operate and maintain the PSC network hardware and wideband satellite and terrestrial circuits at all NASA locations and selected contractor sites. The network will support all NASA programs and projects such as the Shuttle, Hubble Space Telescope, and Space Station management information system. In addition, the network will support office automation and institutional information systems.

	1986 Actual	1987 Amended Budget	1987 Current Estimate	1988 Budget Estimate
		(Thousands of Dollars)		
Missionsff	13,820	12,200	12,200	7,400

OBJECTIVES AND STATUS

The Mission liti Implementation Prog e the til ti n for the command and control f NASA' ann cientific and applications satellite programs. Command and contr of the spacecraft and on-board e l are c out via the Payload : Control Centers l d related Mission Support Systems.

The POCC's are responsible for the receipt, processing, and display of spacecraft engineering data and the transmission of commands. Four POCC's currently monitor and control numerous spacecraft. In addition, a new dedicated control center is under development to control the Hubble Space Telescope scheduled for launch in late calendar year 1988. Related mission support systems include a Johnson Space Center/Goddard Space Flight Center Shuttle POCC Interface Facility (SPIF) and a Mission Planning System to plan and schedule spacecraft support.

BASIS OF FY 1988 ESTIMATE

The FY 1988 funding requirements will provide for Hubble Space Telescope prelaunch systems testing and software to control the accurate pointing of the telescope and the on-orbit power consumption of the spacecraft subsystem and scientific instruments.

In addition, FY 1988 funds are included for modifications to the existing Multisatellite Operations Control Center (MSOCC) for control of the Gama Ray Observatory (GRO), Cosmic Background Explorer (COBE), Upper Atmosphere Research Satellite (UARS), and various Shuttle attached payloads. In FY 1988 control center modifications to permit spacecraft payload operations from user facilities will be underway. This new concept which is planned for use with Space Station will provide operational efficiencies for experimenters.

	1986 Actual	1987 Amended Budget	1987 Current Estimate	1988 Budget Estimate
		(Thousands of Dollars)		
Mission operations....................	18,900	23,700	23,700	28,000

OB AND STATUS

The Mission Operations Program in FY 1988 will provide for the operation of the five Payload Operations Control Centers (POCC's) and the related software and support services necessary for the monitoring and control of eight in-orbit spacecraft and prelaunch preparations for four spacecraft.

The POCC's, which are the control facilities for spacecraft/payload operations, have the capability for receiving, processing, and displaying spacecraft engineering and telemetry data and for sending commands to the spacecraft. Commands transmitted to the spacecraft include both emergency commands resulting from decisions made by the spacecraft analysts and preplanned command sequences generated in advance to carry out the mission objectives. Each POCC is operated 24 hours per day, 7 days per week in mission support. For Shuttle launches with attached payloads, for which GSFC has responsibility, there is a specialized GSFC Shuttle Payload Interface Facility (SPIF) which processes and provides for the display of Shuttle-unique data that is necessary for payload control.

BASIS OF FY 1988 ESTIMATE

The FY 1988 budget request includes funds to operate the POCC's and supporting facilities for control of on-orbit missions and control center software development for supporting upcoming missions. In FY 1988, the new Hubble Space Telescope POCC will be in the final stages of spacecraft and ground systems testing. A major activity that will be conducted in this facility is the operational checkout and calibration of the total ground system, the spacecraft and its scientific instruments. Also in FY 1988, software development activities will continue to increase for the GRO and UARS missions. Software to enable the POCC to control the COBE will continue along with SPIF software development.

Also included in the FY 1988 budget request are funds for software and related support services which include maintenance of a software library, computer-generation of command sequences, equipment maintenance, engineering, logistics and documentation 'services.

	1986 Actual	1987 Amended Budget	1987 Current Estimate	1988 Budget Estimate
		(Thousands of Dollars)		
Data processing systems implementation	21,100	28,400	28,400	22,300

OBJECTIVES AND STATUS

The Data Processing Systems Implementation Program provides for the procurement of equipment and related services for the large data processing and computation systems at the Goddard Space Flight Center (GSFC) which support both the operational and payload requirements of space missions. To meet operational requirements, these systems determine spacecraft attitude and orbit and generate on-board commands to the spacecraft subsystems. In support of spacecraft payloads, the systems process the data from science and applications experiments for subsequent transfer to the experimenters for analysis.

Major computation capabilities include the Flight Dynamics Facility which performs the real time attitude, orbit computation and flight maneuver control functions and the Command Management System which provides memory management for on-board computers. In addition, there are four major systems for processing data: 1) the Telemetry On-Line Processing System (TEMPS) which routinely supports a number of Earth-orbiting spacecraft; 2) the Image Processing Facility (IPF) which generates products for Nimbus 7; 3) the Spacelab Data Processing Facility (SLDPF) which supported the Spacelab 1, 2, 3, and D1 missions and the Shuttle Imaging Radar-B experiment; and 4) the Hubble Space Telescope Data Capture Facility (HSTDCF) which will capture, process, and forward to the Science Institute Facility the packetized telemetry data from the Hubble Space Telescope spacecraft.

Significant activities in this program continue at GSFC to keep the large systems viable and responsive to project support requirements. Implementation continues on new systems to process data from the Gama Ray Observatory (GRO) and the Upper Atmosphere Research Satellite (UARS) missions.

Also included is the development of a test bed facility to be used for prototyping, testing, and evaluating maturing technologies resulting from the Advanced Systems Program. Promising technologies for application to future support will be investigated in the areas of remote payload operation and control, expert systems, high speed data processing, high level languages, and very large scale integration (VLSI).

BASIS OF FY 1988 ESTIMATE

The FY 1988 budget request will provide continued funding for phased replacement of the existing computation systems at GSFC which provide real-time support to NASA spacecraft. Funding is also included for completing replacement of display equipment and for large application software programs for the Trajectory Computation Orbit Products System (TCOPS). In addition, the request provides for the improvement/upgrade of the Flight Dynamics Facility (FDF) and for systems studies in autonomous navigation.

Funds are required in FY **1988** to continue the implementation of an institutional packet telemetry processing system with the GRO as its first user. This facility will capture, error check, and ship real-time, quick-look and production data to various users. The "packet" telemetry concept allows the scientific data of an experiment to be handled with minimum involvement by the ground system, thus reducing ground data processing time as well as ensuring faster delivery of data to the experimenters.

The FY **1988** budget request includes funds to continue the upgrade of the existing TELOPS system in order to develop a generic time division multiplexed (TDM) system for processing data of which the UARS will be the first user. The handling of UARS data will serve as a baseline for providing such support to other users allowing for tradeoffs between development costs and support risks for future missions. Funds are also requested for upgrading the data processing capabilities at GSFC to facilitate the exchange of data within the data processing complex and with other mission support facilities. This upgrading will also expedite the shipment of science data to users.

There is a continuing requirement to procure and maintain an adequate supply of unique spare parts to replace failure-prone and high-maintenance electronic modules, to provide test equipment, and to undertake minor modifications and hardware fabrication associated with new equipment installation and reconfiguration. Funds are included in the request for continuing the evaluation of Space Station support requirements and the capabilities needed to meet the requirements.

	1986 Actual	**1987** Amended Budget	**1987** Current Estimate	**1988** Budget Estimate
		(Thousands of Dollars)		
Data processing operations.............	**34,931**	**42,100**	**42,100**	**49,000**

' AND STATUS

Information received in the form of tracking and telemetry data from the various spacecraft must be processed into a usable form before transfer to control centers and experimenters. This transformation and computation process is performed as part of the data processing function and applies to a wide variety of programs, ranging from the small explorer satellites to complex imaging type satellites such as Nimbus.

In addition to the actual processing of data, upcoming projects require extensive prelaunch orbit analysis including spacecraft position and attitude predictions. Analyses are also required to develop operational sequences and procedures to be used during the actual operation of these complex spacecraft.

Telemetry data is the primary product of spacecraft, and it is through reduction and analysis of this data by the experimenters that the planned objectives are achieved. Data is processed to separate the information obtained from various scientific experiments aboard the spacecraft, consolidate information for each experimenter, determine spacecraft attitude, and correlate these measurements with spacecraft position data. Four facilities, the Image Processing Facility (IPF), the Telemetry On-Line Processing System (TELOPS), the Spacelab Data Processing Facility (SLDPF), and the Hubble Space Telescope Data Capture Facility (HSTDCF) have been established at the Goddard Space Flight Center to pre-process different types of raw experimental data.

The IPF, initially established to handle image data from the Landsat-1, has supported Landsat-2 and Landsat-3 and presently is processing data from the Nimbus mission. The Nimbus spacecraft is being supported with an all-digital system using high density recorders and computer compatible tapes. This system is being used to process data, required for climatic and meteorological studies, into film and digital tape products. The digital data can be manipulated in the scientist's computer with specific algorithms to enhance the interpretation of the data and related phenomena.

The TELOPS handles satellite non-image data which is received in a digital form from the tracking stations via NASCOM. It is capable of electronically storing large volumes of telemetry data, thus eliminating most of the tape and tape handling operations. Facility management, maintenance and operations, and software development support for the image and non-image data processing facilities are also provided. The operation of the SLDPF is included along with software development and maintenance required for attitude determination, flight maneuvers, and mission simulations.

BASIS OF FY 1988 ESTIMATE

The FY 1988 budget request provides for operation of the various computation and data processing facilities including the SLDPF which requires maintenance of unique hardware and software for Spacelab and Dedicated Discipline Laboratory (DDL) missions.

Application software development, prototyping, and system testing activities are continuing. Requirements definition and analysis have been initiated in support of upcoming space science and applications missions such as Cosmic Background Explorer, Gamma Ray Observatory, Shuttle attached payloads, and the Upper Atmosphere Research Satellite. For on-orbit spacecraft, software development and maintenance is required on a continuing basis in order to perform flight control maneuver operations and for the data processing activities.