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National Aeronautics and
Space Administration

Budget Estimates

FISCAL YEAR 1987

Volume I

Agency Summary

Research and **Development**

Space Flight, Control and Data Communications

CONTENTS

NATIONAL AERONAUTICS AND SPACE ADMINISTRATION

FISCAL YEAR 1987 ESTIMATES

VOLUME I

TABLE OF CONTENTS

AGENCY SUMMARY

	Page No.
General statement	AS 1
Budget summary	AS 4
Program highlights	AS 5
Summary reconciliation of appropriations to budget plan	AS 13
Distribution of budget plan by installation	AS 14
Summary of permanent positions by installation	AS 15
Organization chart	AS 16

RESEARCH AND DEVELOPMENT

General statement	RD SUM 1
Appropriation language (proposed)	RD SUM 4
Reimbursable program summary	RD SUM 5
Budget plan by subfunction	RD SUM 6
Distribution of budget plan by installation and fiscal year	RD SUM 7
Justification by program:	
Space station	RD 1-1
Capability development	RD 2-1

SPACE SCIENCE AND APPLICATIONS PROGRAMS	Page No.
Budget summary	RD 55a-1
Physics and astronomy	RD 3-1
Life sciences	RD 4-1
Planetary exploration	RD 5-1
Solid earth observations	RD 6-1
Environmental observations	RD 7-1
Materials processing in space	RD 8-1
Communications	RD 9-1
Information systems	RD 10-1
COMMERCIAL PROGRAMS	RD CP-1
Technology utilization	RD 11-1
Commercial use of space	RD 12-1
AERONAUTICS AND SPACE TECHNOLOGY PROGKAMS	
Budget summary	AST 1
Aeronautical research and technology	RD 13-1
Transatmospheric research and technology	RD 14-1
Space research and technology	RD 15-1
TRACKING AND DATA ADVANCED SYSTEMS	RD 16-1

SPACE FLIGHT, CONTROL AND DATA COMMUNICATIONS

General statement	SF SUM 1
Appropriation language (proposed)	SF SUM 3
Reimbursable program summary	SF SUM 4
Budget plan by subfunction	SF SUM 5
Distribution of budget plan by installation and fiscal year	SF SUM 6
Justification by program:	
SPACE TRANSPORTATION PROGRAMS	
Budget summary	SF ST-1
Shuttle production and operational capability	SF 1-1
Space transportation operations	SF 2-1
SPACE AND GROUND NETWORKS, COMMUNICATIONS AND DATA SYSTEMS	SF 3-1

THIS DOCUMENT DOES NOT REFLECT: (1) THE FY 1986 REDUCTIONS THAT ARE LIKELY TO RESULT UNDER THE BALANCED BUDGET AND EMERGENCY DEFICIT CONTROL ACT OF 1985; OR (2) THE EFFECTS RESULTING FROM THE LOSS OF THE CHALLENGER AND CREW ON JANUARY 28, 1986. PROPOSED CHANGES IN PROGRAM PLANS AND BUDGET ESTIMATES WILL BE TRANSMITTED LATER.

AGENCY
SUMMARY

NATIONAL AERONAUTICS AND SPACE ADMINISTRATION
PROGRAM HIGHLIGHTS
SPACE FLIGHT, CONTROL AND DATA COMMUNICATIONS

SHUTTLE PRODUCTION AND OPERATIONAL CAPABILITY/SPACE TRANSPORTATION OPERATIONS

o Continue with the operational establishment of a versatile and cost-effective space transportation system to provide for:

- Operating a national fleet of four Space Shuttle orbiters
- Completing the development of an operationally cost effective main engine with adequate safety margins
- Ground support equipment, launch site equipment and manpower to support launch and landing operations
- External tanks and solid rocket boosters and the manufacturing tooling/equipment supporting their production
- Establishing logistics support capability to provision spares, repair and overhaul flight hardware
- Provision of capability for training astronauts, launch and flight operation personnel

o Seventeen operational flight missions in FY 1987 building to a flight rate of 24 per year by FY 1989

o Continued improvement of Shuttle performance capability

o Support to first Vandenberg Air Force Base flight

o Implementation of improvements to make space transportation more economical and cost effective to all users

MAJOR FLIGHT ACTIVITY

	Fiscal Years						
	1985	1986	1987	1988	1989	1990	1991
Space Shuttle: Operational flights	8	14	17	18	24	24	24

BUDGET PLAN (millions of dollars)	FY 1985	FY 1986	FY 1987
Shuttle Production and Operational Capability	1,484.5	971.5	745.4
Space Transportation Operations	1,314.0	1,725.0	1,524.7
	2,798.5	2,696.6	2,270.1

NATIONAL AERONAUTICS *AND* SPACE ADMINISTRATION
PROGRAM HIGHLIGHTS
RESEARCH *AND* DEVELOPMENT

SPACE RESEARCH AND TECHNOLOGY

o Provide a technology base essential to future United States leadership in space by:

- Improving performance and effectiveness
- Reducing cost and risk
- Increasing reliability
- Developing technological options

o Achieve these objectives, by means of ground and space-based research and technology activities, through advances in the technology areas of:

- Aerothermodynamics
- Materials and structures
- Space energy conversion
- Propulsion
- Space data and communications
- Information sciences
- Controls and guidance
- Human factors
- Flight systems
- Systems analysis
- Automation and robotics

MAJOR FLIGHT ACTIVITY

	Fiscal Years						
	1985	1986	1987	1988	1989	1990	1991
Space technology Shuttle/Spacelab payloads	Δ———	———	———	———	———	———	———
Long duration exposure facility (Launch/Retrieval)		Δ	Δ———	———	Δ		

BUDGET PLAN (millions of dollars)	FY 1985	FY 1986	FY 1987
Space Research and Technology	150.0	168.0	180.2

NATIONAL AERONAUTICS AND SPACE ADMINISTRATION
PROGRAM HIGHLIGHTS
RESEARCH AND DEVELOPMENT

TRANSATMOSPHERIC RESEARCH AND TECHNOLOGY

- Develop the critical technologies data base to enable the United States to make a future decision on the flight research phase of a transatmospheric vehicle by conducting research and technology development in:
  - Efficient, high thrust, airbreathing propulsion systems
  - Reusable and durable thermal structures minimum weight, high performance, propulsion/airframe integration

'BUDGET PLAN (millions of dollars)

	FY 1985	FY 1986	FY 1387
Transatmospheric Research and Technology	---	---	45.0

NATIONAL AERONAUTICS AND SPACE ADMINISTRATION
PROGRAM HIGHLIGHTS
RESEARCH AND DEVELOPMENT

AERONAUTICAL RESEARCH AND TECHNOLOGY

- o Conduct the fundamental research and technology in the aeronautical disciplines and systems research applicable to general classes of advanced civil and military aircraft to:
  - Improve performance
  - Reduce costs
  - Increase safety
  - Reduce energy requirements
  - Decrease environmental effects
- o Develop and sustain a strong research and technology base in:
  - Fluid and thermal physics
  - Applied aerodynamics
  - Materials and structures
  - Controls and guidance
  - Human factors
  - Information sciences
  - Propulsion and power
  - Flight systems
  - Systems analysis
- o Conduct focused systems technology to evaluate the technical feasibility of advances or concepts:
  - Numerical aerodynamic simulation for complex aerospace computational problems
  - Technology for next generation rotorcraft including X-Wing and advanced tilt-rotor technology
  - Turbine engine hot section technology for higher performance and longer lasting engines
  - Hiyh-performance flight research
  - Advanced rotorcraft technology and flight research
  - General aviation/commuter engine technology for better performance and efficiencies
  - Advanced turboprop systems for faster, more fuel-efficient transport and commuter aircraft
  - Ceramics for turbine engines for high operating temperatures
  - Oblique wing technology for aerodynamic efficiency over transonic speeds
- o Maintain expertise and operate significant national facilities to support research and technology:
  - Research and test facilities
  - Simulation facilities
  - Wind tunnels

BUDGET PLAN (millions of dollars)	FY 1985	FY 1986	FY 1907
Aeronautical Research and Technology	342.4	354.0	376.0

NATIONAL AERONAUTICS AND SPACE ADMINISTRATION

FISCAL YEAR 1387 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 activities are designed to enhance United States leadership in aeronautics and in space research, exploration and utilization. More specifically, the objectives of NASA's activities are to:

-- Make the Space Transportation System fully operational and cost effective;

-- Move forward toward the establishment of a permanently manned Space Station;

-- Conduct an effective and productive program of aeronautical research and technology which will contribute materially to the enduring preeminence of the United States in aviation;

-- Conduct an effective and productive Space and Earth Sciences program which expands human knowledge of the Earth, its environment, the solar system and the universe;

-- Conduct effective and productive space applications and technology programs which contribute materially to our nation's current and future leadership in space; and

-- Enhance opportunities for U.S. private sector involvement in civil space and space-related activities

The NASA FY 1387 budget recommendation of $7,694 million provides for a deliberately paced program of flight projects and ground-based activities to make progress toward these objectives.

Space program elements in FY 1987 involve:

o Definition and technology effort and initial development efforts on a permanently manned Space Station, the next major step in exploration and utilization of space and a key element in continued U.S. leadership in space. The ability to function routinely in space onboard the Space Station will provide countless opportunities for experimenting in the known sciences as well as in those still to be discovered. The Space Station will be a multi-purpose, international facility for scientific and technical research and for unique commercial applications, broadening the horizons of all those who participate. Definition and preliminary design contracts as well as advanced technology development will continue in FY 1986 in preparation for initiation of development efforts in FY 1987.

- Expanded use of the Space Shuttle and other elements of the Space Transportation System capitalizing on its demonstrated capabilities to place satellites in orbit, to retrieve and repair satellites, and to conduct experiments and make observations using the Shuttle and the Spacelab. The FY 1987 program will provide for the procurement of the hardware, mission integration and training, ground processing and flight operations of the Space Shuttle. Seventeen Shuttle flights during 1987 will carry payloads for NASA, Department of Defense and domestic commercial and international users of space. Additional Spacelab flights will capitalize on the success of the initial missions as this unique capability is exploited for space research and applications missions. The first uses of the planetary version of the Centaur Upper Stage will occur in 1986 for the Galileo and Ulysses missions adding this high energy upper stage to the STS system. The initial launch from the Vandenberg launch site in 1986 using the first set of lightweight filament wound cases for the Solid Rocket Booster will also greatly expand the versatility of the STS system. In 1367, work will continue on the the Space Shuttle main engine to improve the operating margins, reliability and maintainability of the present configuration and development efforts will be continued on a reusable orbital maneuvering vehicle to extend operational on-orbit capabilities beyond the range of the orbiter.

- Space Science and Applications programs which are directed toward increasing our knowledge and understanding of life processes, the Earth and its space environment, the planets, the Sun, the stars, and the universe, as well as conducting a carefully coordinated and logically phased set of research and development activities that demonstrate and transfer the applications of space-related technology which can be effectively used for down-to-Earth practical benefits. The FY 1987 program provides for operations and data analysis activities in support of Galileo, Ulysses and Hubble Space Telescope missions which will be launched in 1986 and for research and analysis activities in physics and astronomy, planetary, life sciences, and space applications. NASA will use the ASTRO mission telescopes, to be carried aboard the Shuttle in early 1986, as a major element of its participation in the international program for the observation of Halley's Comet. Efforts will also continue on approved flight programs which include: the Gamma Ray Observatory, which will study the total range of gamma ray energies, the most energetic electromagnetic radiation known; the Upper Atmosphere Research Satellite mission, which will make integrated measurements of energy inputs, temperature, chemical constituents and winds; the Magellan mission (formerly Venus Radar Mapper) which will address the fundamental questions regarding the origin and evolution of the planet Venus by obtaining global radar imagery of the plsnet; the Mars Observer mission, which will provide geoscience and climatology mapping of Mars and extend and complement the data acquired by the Mariner and Viking missions; the continued develoment of the Scatterometer, which will be flown on the Navy's N-Ross mission; and continued development of the Explorer missions and the Spacelab and Tethered Satellite System payloads. Development will be initiated on the Ocean Topography Experiment, a joint cooperative effort with the French to develop and launch a new oceaning-observing satellite and to use the data obtained to develop an improved understanding of the ocean circulation and its influence on our global environment. These major development efforts are integrated with and based on a broad scale program of research and analysis to define future potential missions and to develop and demonstrate ground-based application of the data acquired by remote sensing techniques.

- Space research and technology activities to advance the technology base which provides new concepts, materials, components, devices, software and subsystems for use in United States civil and military space activities. This research emphasizes the longer range aspects of generic research and technology development in transportation, spacecraft and platform systems which are crucial to future United States leadership in space.

The Aeronautical research and technology program contributes materially to the enduring preeminence of U.S. civil and military aviation by: (1) conducting disciplinary and systems research at the leading edge of technology in those areas critical to the continued superiority of U.S. aircraft; (2) maintaining the research centers in positions of excellence in facilities and technical staff; (3) assuring timely transfer of research results to the U.S. aeronautical industry; (4) assuring appropriate involvement of universities and industry; and (5) providing aeronautical development support to other government agencies and U.S. industry. Conducted well in advance of and independent of specific applications, the Aeronautical research and technology program includes both fundamental research in the aeronautical disciplines and systems research applicable to general classes of advanced military and civil aircraft. The program involves participation by aeronautical manufacturers to ensure that the technology is compatible with practical design considerations and can be successfully transferred into application in new and better aircraft, systems and components.

Transatmospheric research and technology efforts to accelerate the development of a critical technologies data base that may enable a potential new class of vehicles in the future capable of flight to orbit and/or hypersonic cruise. Possible opportunities in this regime include launch vehicles, hypersonic transports, and military applications.

Resources Summary

The budget authority recommended for FY 1987 totals $7,694.4 million with estimated outlays of $7,641.3 million and civil service staffing level of 21,800 full-time equivalent workyears.

F Y 1987

NATIONAL AERONAUTICS *AND* SPACE ADMINISTRATION

BUDGET SUMMARY
(Thousands of Dollars)

	Budget Plan 1985	1986	1987
RESEARCH AND DEVELOPMENT	2,468,100	2,756,800	3,003,100
Space Station	155,500	205,000	410,000
Space Transportation Capability Development	391,400	437,000	465,500
Space Science and Applications	1,404,500	1,546,500	1,464,000
Technology Utilization	9,500	11,100	13,300
Commercial Use of Space	(7,600)[a/]	17,000	32,000
Aeronautical Research and Technology	342,400	354,000	376,000
Transatmospheric Research and Technology	---	---	45,000
Space Research and Technology	150,000	168,000	180,200
Tracking and Data Advanced Systems	14,800	16,200	17,100
SPACE FLIGHT CONTROL AND DATA COMMUNICATIONS	3,594,200	3,397,900	3,069,000
Shuttle Production and Operational Capability	1,484,500	971,600	745,400
Space Transportation Operations	1,314,000	1,725,000	1,524,700
Space & Ground Networks, Comm. and Data Systems	795,700	701,300	798,900
CONSTRUCTION OF FACILITIES	157,600	139,300	181,300
RESEARCH AND PROGRAM MANAGEMENT	1,331,780	1,362,000	1,441,000
TOTAL	7,551,680	7,656,000	7,694,400
OUTLAYS	7,317,741	7,587,203	7,641,347

a/ In FY 1985, funded as part of the Office of Space Station ($.4 million), Office of Space Flight ($.5 million), Office of Space Science and Applications ($3.5 million), Office of Aeronautics and Space Technology ($1.2 million), and Office of Space Tracking and Data Systems ($2.0 million).

NATIONAL AERONAUTICS AND SPACE ADMINISTRATION
PROGRAM HIGHLIGHTS
RESEARCH AND DEVELOPMENT

SPACE STATION

- o Establish a permanently manned space station:
  - The next logical step in U.S. leadership in space
  - Built upon the operational capabilities of the Space Shuttle
  - Conducive to user community
  - Orbital activities begin in the next decade
- o Conclude a thoroughly detailed front-end definition including:
  - Engineering design by industrial contractors
  - Subsystem advanced development and tests in dedicated test beds
  - Early flight experiments on the Shuttle to prove system feasibility
  - Continued trade studies for system optimization
- o Initiate development of a multi-purpose facility involving both manned and unmanned elements to facilitate:
  - Essential scientific and technical research
  - Unique commercial activities
  - More efficient operational tasks in space such as:
    - Satellite servicing
    - Assembly and servicing of platforms
    - Placement of spacecraft into higher orbits
  - Extensive national and international user community participation through:
    - Simplified user interfaces
    - Capability for on-orbit crew maintenance
    - Operational autonomy to achieve effective long-term performance
  - Staging for potential future national programs such as:
    - Manned missions to the Moon or planets
    - Unmanned scientific probes and sample returns

MAJOR FLIGHT ACTIVITY	Fiscal Years						
	1985	1986	1987	1988	1989	1990	1991
Flight Experiments on Space Shuttle..		Δ					

BUDGET PLAN (millions of dollars)	FY 1985	FY 1986	FY 1387
Utilization	9.3	11.1	15.C
Advanced Development	50.1	70.8	83.0
Program Management/Integration	57.5	613.0	57.0
Operational Readiness	2.9	5.3	17.0
Systems Definition	35.7	57.8	88.U
Systems Development	---		150.U
Total	155.5	205.0	41U.G

NATIONAL AERONAUTICS AND SPACE ADMINISTRATION
PROGRAM HIGHLIGHTS
RESEARCH AND DEVELOPMENT

SPACE TRANSPORTATION CAPABILITY DEVELOPMENT

- o Proceed with development of the capabilities to enhance the space transportation system through pursuit of:
  - Manned orbital experiments using Shuttle and Spacelab
  - First use of Centaur upper stage to place payloads into deep space and in geosynchronous orbits
  - Identification of future space programs and new technology to reduce program risks
  - Orbital placement, servicing and retrieval of automated satellites
  - Orbital maneuvering vehicle to extend operational on-orbit capabilities range
- o Development of United States-Italian Tethered Satellite System
- o Maintain engineering, scientific and technical support capability
- o Development of operational equipment to support payload pre- and post-launch processing and on-orbit operations

MAJOR FLIGHT ACTIVITY

	Fiscal Years 1985	1986	1987	1988	1989	1990	1991
Spacelab (Operational flights)...................	△						
Tethered Satellite System..					A		
Orbital Maneuvering Vehicles................................							△

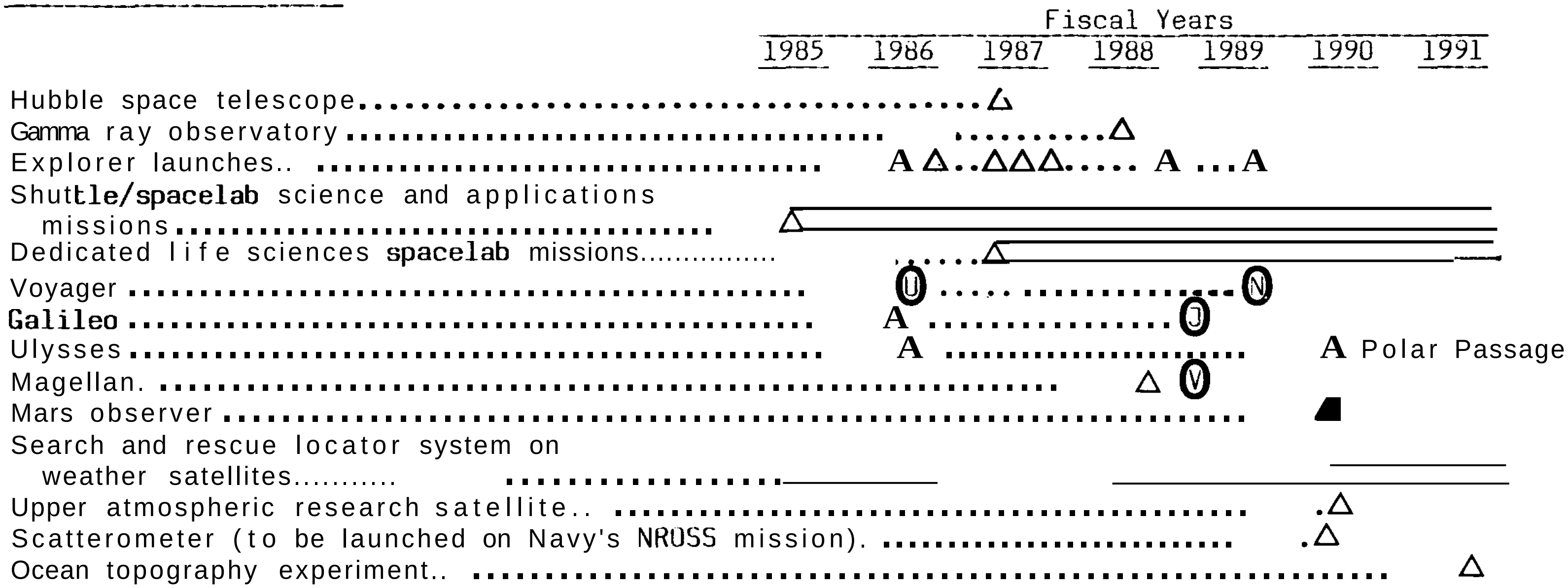
BUDGET PLAN (millions of dollars)	FY 1985	FY 1986	FY 1987
Space Transportation Capability Development	391.4	437.0	465.5

NATIONAL AERONAUTICS AND SPACE ADMINISTRATION
PROGRAM HIGHLIGHTS
RESEARCH AND DEVELOPMENT

SPACE SCIENCE AND APPLICATIONS

- o Increase our understanding of the Earth and its environment, the solar system, and the universe through a balanced program of space exploration missions and ground-based investigations;
- o Utilize the space environment for research in the biomedical, biological, and bioinstrumentation fields;
- o Exploit the knowledge gained from current and completed program efforts by thorough analysis and interpretation of the scientific data obtained; and
- o Develop and demonstrate practical uses of space and space-derived technology

MAJOR FLIGHT ACTIVITY



BUDGET PLAN (millions of dollars)	FY 1985	FY 1986	FY 1987
Physics and Astronomy	677.2	607.1	539.4
Life Sciences	62.3	69.9	74.7
Planetary Exploration	290.9	352.8	323.3
Space Applications	374.1	518.7	524.6
Total Space Science and Applications	1404.5	1548.5	1464.0

NATIONAL AERONAUTICS AND SPACE ADMINISTRATION
PROGRAM HIGHLIGHTS
SPACE FLIGHT, CONTROL AND DATA COMMUNICATIONS

SPACE AND GROUND NETWORKS, COMMUNICATION AND DATA SYSTEMS

o Tracking and Data Acquisition using Space and Ground Network interconnected with highly reliable communications to provide support to:

- Shuttle operational flights
- Automated Earth orbiting missions - supports applications and scientific spacecraft including the Nimbus, Landsat, International Ultraviolet Explorer, International Sun-Earth Explorer, Solar Maximum Mission, Dynamics Explorer, Solar Mesosphere Explorer, Earth Radiation Budget Satellite, and Activa Magnetospheric Particle Tracer Explorer.
- Planetary missions - support: will continue for Pioneers-10 and -11, Pioneer Venus, and Voyagers-1 and -2, as well as limited support for the earlier Pioneer missions
- Upcoming missions which will include Hubble Space Telescope, Galileo and Ulysses
- Sounding rockets
- Aeronautical flight research program

o The Tracking and Data Relay Satellite System (TDRSS) will replace most ground stations in providing tracking, command and telemetry services to all low-Earth orbital missions. The first spacecraft was launched in April 1983, the second is scheduled to *be* launched in January 1986 and the third launch is planned for the last half of 1986.

MAJOR FLIGHT ACTIVITY

	Fiscal Years						
	1985	1986	1987	1988	1989	1990	1991
Tracking and Data Relay Satellite.. (Backup satellites available)		Δ* A					

BUDGET PLAN (millions of dollars)	FY 1985	FY 1986	FY 1387
Space & Ground Network, Comm., and Data Systems	795.7	701.3	798.9

*Mission failed January 28, 1986

NATIONAL AERONAUTICS AND SPACE ADMINISTRATION

FISCAL YEAR 1987 ESTIMATES

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

	Total	Research and Development	Space Flight, Control and Data Comm.	Construction of Facilities	Research and Program Management
Fiscal Year 1985					
Appropriation PL 98-371............	7,495,900	2,417,100	3,601,800	150,000	1,317,000
Reappropriation, PL 98-371.........	5,500	5,509	---	---	---
Transfer Between Accounts..........	---	---	-7,600	+7,600	---
Supplemental Appropriation, PL 99-88........................	66,800	45,500	---	---	21,300
Rescission.........................	-6,009	---	---	---	-6,000
Lapse	-520	---	---	---	-520
Total Budget Plan................	7,551,680	2,468,100	3,594,200	157,600	1,331,780
Fiscal Year 1986					
Appropriation, P.L. 99-160.........	7,656,000	2,756,800	3,397,900	139,300	1,362,000
Fiscal Year 1987					
Appropriation Request/Budget Plan..	7,694,400	3,003,100	3,069,000	181,300	1,441,000

NATIONAL AERONAUTICS AND SPACE ADMINISTRATION

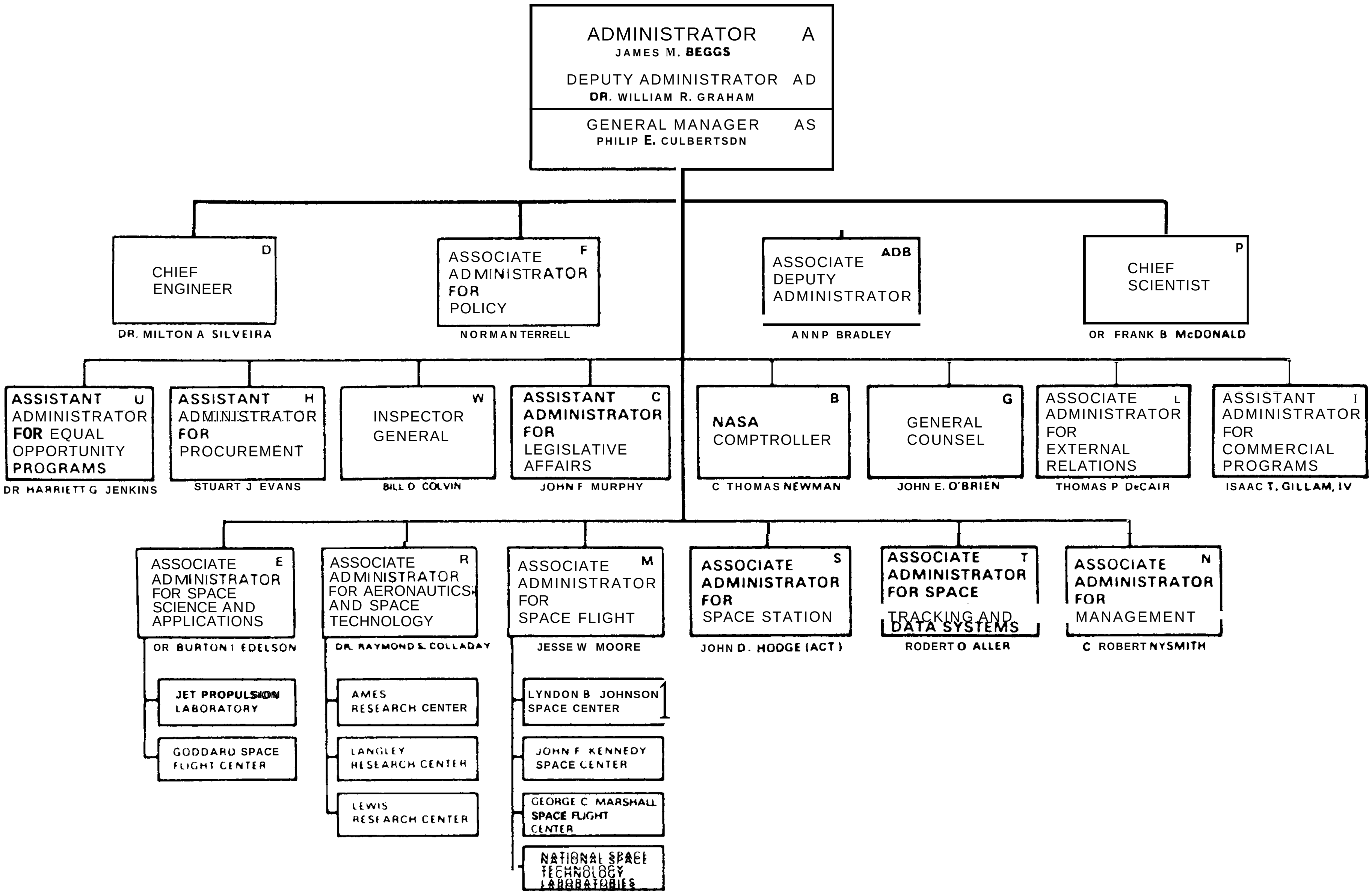
FISCAL YEAR 1987 ESTIMATES

SUMMARY OF BUDGET PLANS BY INSTALLATION BY APPROPRIATION
(Millions of Dollars)

	Total			Space Flight Control and Data Communications			Research and Development			Construction of Facilities			Research and Program Management		
	1985	1986	1987	1985	1986	1987	1985	1986	1987	1985	1986	1987	1985	1986	1987
Johnson Space Center	1,617,341	1,410,066	1,132,233	1,159,650	918,900	560,500	239,680	280,079	339,623	3,200	1,100	14,000	214,811	209,987	218,110
Kennedy Space Center	650,192	692,815	760,492	383,100	407,200	485,800	45,704	69,915	63,196	36,900	21,000	3,400	184,488	194,700	208,096
Marshall Space Flight Center	1,922,928	1,951,033	1,811,551	1,223,487	1,258,200	1,087,700	499,772	486,238	517,904	1,600	6,500	2,100	198,069	200,095	203,847
National Space Technology Laboratories..	31,117	33,168	32,218	6,300	8,300	8,600	10,848	11,461	12,165	3,300	2,500	—	10,669	10,907	11,453
Goddard Space Flight Center.	1,029,214	1,025,124	1,060,479	431,146	366,600	378,400	399,011	450,794	459,741	2,200	3,800	8,000	196,857	203,930	214,338
Jet Propulsion Laboratory...	511,895	580,691	626,545	111,002	122,500	129,700	388,693	449,291	484,445	12,200	8,900	12,400	—	—	—
Ames Research Center	363,522	388,253	443,336	12,345	15,800	14,800	217,287	239,555	267,723	13,600	8,200	26,900	120,290	124,698	133,913
Langley Research Center.....	337,016	332,910	388,592	100	100	100	175,994	177,881	221,759	13,800	4,900	11,700	147,122	150,029	155,033
Lewis Research center	452,178	469,024	358,177	3,400	3,000	500	311,595	323,047	201,557	—	—	5,800	137,383	142,977	150,320
Inspector General...........	5,225	5,511	5,494	—	—	—	—	—	—	—	—	—	5,225	5,511	5,494
Headquarters..	605,252	739,005	1,026,783	263,670	297,300	402,900	179,716	268,539	434,987	45,000	54,000	61,000	116,866	119,166	127,896
Agencywide Activities	—	—	12,500	—	—	—	—	—	—	—	—	—	—	—	12,500
Undistributed Construction of Facilities:															
Various Locations	13,800	17,400	22,000	—	—	—	—	—	—	13,800	17,400	22,000	—	—	—
Facility Planning and Design..............	12,000	11,000	14,000	—	—	—	—	—	—	12,000	11,000	14,000	—	—	—
Total Budget Plan........	7,551,680	7,656,000	7,694,400	3,594,200	3,397,900	3,069,000	2,468,100	2,756,800	3,003,100	157,600	139,300	181,300	1,331,780	1,362,000	1,441,000

NATIONAL AERONAUTICS AND SPACE ADMINISTRATION
SUMMARY OF PERMANENT CIVIL SERVICE WORKYEARS BY INSTALLATION
FISCAL YEAR 1987 ESTIMATES

	FY 1985	FY 1986	FY 1987
Johnson Space Center	3.247	3.252	3.253
Kennedy Space Center	2.G64	2.035	2.030
Marshall Space Flight Center	3.263	3.229	3.234
National Space Technology Laboratories	114	119	119
Goddard Space Flight Center	3.559	3.576	3.576
Ames Research Center	2.044	2.029	2.029
Langley Research Center	2.824	2.812	2.812
Lewis Research Center	2.647	2.655	2.655
Headquarters	1.267	1.242	1.242
Inspector General	94	97	97
Subtotal. Full-Time Permanent	21.123	21.046	21.047
Other Than Full-Time Permanent	870	754	753
Total. Ceiling Controlled Civil Service	21.993	21,800	21,800


ADMINISTRATOR A
JAMES M. BEGGS
DEPUTY ADMINISTRATOR AD
DR. WILLIAM R. GRAHAM
GENERAL MANAGER AS
PHILIP E. CULBERTSDN
CHIEF ENGINEER D
DR. MILTON A SILVEIRA
ASSOCIATE ADMINISTRATOR FOR POLICY F
NORMAN TERRELL
ASSOCIATE DEPUTY ADMINISTRATOR ADB
ANN P BRADLEY
CHIEF SCIENTIST P
OR FRANK B McDONALD
ASSISTANT ADMINISTRATOR FOR EQUAL OPPORTUNITY PROGRAMS U
DR HARRIETT G JENKINS
ASSISTANT ADMINISTRATOR FOR PROCUREMENT H
STUART J EVANS
INSPECTOR GENERAL W
BILL D COLVIN
ASSISTANT ADMINISTRATOR FOR LEGISLATIVE AFFAIRS C
JOHN F MURPHY
NASA COMPTROLLER B
C THOMAS NEWMAN
GENERAL COUNSEL G
JOHN E. O'BRIEN
ASSOCIATE ADMINISTRATOR FOR EXTERNAL RELATIONS L
THOMAS P DeCAIR
ASSISTANT ADMINISTRATOR FOR COMMERCIAL PROGRAMS I
ISAAC T. GILLAM, IV
ASSOCIATE ADMINISTRATOR FOR SPACE SCIENCE AND APPLICATIONS E
OR BURTON I EDELSON
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JOHN F KENNEDY SPACE CENTER
GEORGE C MARSHALL SPACE FLIGHT CENTER
NATIONAL SPACE TECHNOLOGY LABORATORIES

RESEARCH AND DEVELOPMENT

SUMMARY
INFORMATION

NATIONAL AERONATUTICS AND SPACE ADMINISTRATION

RESEARCH AND DEVELOPMENT

FISCAL YEAR 1987 ESTIMATES

GENERAL STATEMENT

The objectives of the National Aeronautics and Space Administration program of research and development are to extend our knowledge of the Earth, its space environment, and the universe; to expand the technology for practical applications of space technology; to develop and improve manned and unmanned 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: A program 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 stimulating advanced technologies.

SPACE TRANSPORTATION CAPABILITY DEVELOPMENT: A program to provide for the development and use of capabilities related to the Space Shuttle. The principal areas of activity in Space Transportation Capability Development are efforts related to the development and flight certification of the jointly developed U.S./Italy Tethered Satellite System, development 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 environment, 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; materials processing research and experimentation; and remote sensing to acquire information which will assist in the solution of Earth resources and environmental 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 development 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 development.

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 development of systems and techniques leading to improved tracking and data program capabilities.

NATIONAL AERONAUTICS AND SPACE ADMINISTRATION

RESEARCH AND DEVELOPMENT
FY 1987 BUDGET ESTIMATES

	1985 Actual	1986 Budget Estimate	1986 Current Estimate	1987 Budget Estimate
		(Thousands of Dollars)		
SPACE STATION	155.500	230.000	205,000	410,000
SPACE TRANSPORTATION CAPABILITY DEVELOPMENT	391,400	459,300	437,000	465.500
SPACE SCIENCE AND APPLICATIONS	1,404,500	1,613,200	1,548,500	1,464,000
Physics and astronomy	677,200	630,400	607,100	539,400
Life sciences	62,300	72,000	69,900	74,700
Planetary exploration	290,900	359,000	352,800	323,300
Solid earth observations	57,600	74,900	74,900	74,100
Environmental observations	212,700	317,500	289,800	367,900
Materials processing	27,000	34,000	35,000	43,900
Communications	60,600	106,200	100,300	19,500
Information systems	16,200	19,200	18,700	21,200
COMMERCIAL PROGRAMS	9,500	41,100	28,100	45,300
Technology Utilization	9,500	11,100	11,100	13,300
Commercial Use of Space	(7,600) a/	30,000	17,000	32,000
AERONAUTICS AND SPACE TECHNOLOGY	492,400	522,000	522,000	601,200
Aeronautical research and technology	342,400	354,000	354,000	376,000
Transatmospheric research and technology	---	---	---	45,000
Space research and technology	150,000	168,000	168,000	180,200
TRACKING AND DATA ADVANCED SYSTEMS	14,800	16,200	16 200	17,100
TOTAL	2,468,100	2,881,800	2 756,800	3,003,100

a/ In FY 1985, funded as part of the Office of Space Station ($.4 million), Office of Space Flight ($.5 million), Office of Space Science and Applications ($3.5 million), Office of Aeronautics and Space Technology ($1.2 million), and Office of Space Tracking and Data Systems ($2.0 million)

NATIONAL AERONAUTICS AND SPACE ADMINISTRATION

PROPOSED APPROPRIATION LAGUAGE

RESEARCH ASD DEVELOPMENT*

* See Pan II lor 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; [$2,756,800,000] *$3,003.100.000*, to remain available until September 30, [1987] *1988*. *(Department of Housing and Urban Development-Independent Agencies Appropriations Act. 1986; additional authorizing legislation to be proposed.)*

NATIONAL AERONAUTICS AND SPACE ADMINISTRATION

Research and Development

Reimbursable Summary
(In thousands of dollars)

Research and Development	Budget Plan FY 1985	FY 1986	FY 1987
Space Transportation Capability	297,486	238,543	264,000
Space Science and Applications	326,125	345,627	345,000
Technology Utilization	3,475	2,274	3,000
Space Research and Technology	15,044	10,058	9,400
Aeronautical Research and Technology	56,882	54,224	55,500
Energy Technology	85,988	82,474	60,300
Total	785,000	733,200	737,200

NATIONAL AERONAUTICS AND SPACE ADMINISTRATION

RESEARCH AND DEVELOPMENT

FISCAL YEAR 1987 ESTIMATES

SUMMARY OF BUDGET PLAN BY SUBFUNCTION
(In thousands of dollars)

Code		FY 1985	FY 1986	FY 1987
253	Space Flight....................................	546,900	642,000	875,500
254	Space Science, Applications and Technology........	1,564,000	1,744,600	1,712,000
255	Supporting Space Activities......................	14,800	16,200	17,100
(250)	Subtotal, General Science, Space and Technology	2,125,700	2,402,800	2,604,600
402	Air Transportation..............................	342,400	354,000	398,500
	Total..	2,468,100	2,756,800	3,003,100

NATIONAL AERONAUTICS AND SPACE ADMINISTRATION

FISCAL YEAR 1987 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	1985	155,500	63,566	2,852	36,009	300	16,379	5,277	3,240	4,880	16,734	6,263
	1986	205,000	100,202	3,216	37,242	624	16,611	4,464	1,943	5,627	20,769	14,302
	1987	410,000	146,800	10,200	37,000	600	15,000	5,900	1,700	4,600	20,500	167,700
Space Transportation Capability Development	1985	391,400	118,000	34,600	92,700	7,800	1,000	400	—	800	124,100	12,000
	1986	437,000	119,600	56,100	113,100	7,300	1,000	1,000	—	400	75,500	63,000
	1987	465,500	121,400	43,500	185,600	7,800	1,600	1,000	—	500	30,000	74,100
Space Science and Applications	1985	1,404,500	43,910	7,521	355,768	2,563	369,318	347,482	65,214	15,234	54,722	142,768
	1986	1,548,500	47,802	9,509	312,728	3,037	419,738	407,697	70,757	22,646	94,135	160,451
	1987	1,464,000	57,623	7,481	268,074	3,155	428,782	436,300	73,973	22,686	11,800	154,126
Physics and Astronomy	1985	677,200	7,328	4,997	338,824	—	193,087	60,913	22,565	2,914	—	46,632
	1986	607,100	9,874	6,854	293,217	—	169,054	47,413	29,920	1,625	—	49,143
	1987	539,400	15,190	4,786	246,466	—	10.N	53,110	29,666	1,250	—	48,211
Life Sciences	1985	62,300	22,329	2,524	—	50	310	316	25,709	523	—	10,539
	1986	69,900	22,058	2,655	—	47	383	1,397	27,859	495	—	15,016
	1987	74,700	26,860	2,695	—	55	410	1,575	30,345	510	—	12,250
Planetary Exploration	1985	290,900	10,482	—	16	—	3,751	225,878	8,593	25	—	42,155
	1986	352,800	10,770	—	11	—	5,601	284,262	9,478	26	—	42,652
	1987	323,300	10,873	—	8	—	11,884	249,734	10,462	26	—	40,313
Solid Earth Observations	1985	57,600	960	—	250	2,213	32,360	14,952	2,578	—	—	4,307
	1986	74,900	1,000	—	300	2,700	37,500	26,200	800	—	—	6,400
	1987	74,100	800	—	600	2,800	36,300	26,100	800	—	—	6,500
Environmental Observations	1985	212,700	170	—	8,200	60	126,416	31,266	5,559	10,516	—	30,513
	1986	289,800	200	—	11,200	100	190,300	31,800	2,700	19,200	—	34,300
	1987	367,900	200	—	8,500	100	219,500	82,900	2,700	18,600	—	35,400
Materials Processing in Space	1985	27,000	2,661	—	8,353	—	—	4,544	—	1,256	5,767	4,419
	1986	35,000	3,900	—	8,100	—	—	6,600	—	1,300	6,600	8,600
	1987	43,900	3,700	—	12,300	—	—	9,700	—	2,300	6,700	9,200
Communications	1985	60,600	—	—	—	—	3,792	4,579	—	—	48,955	3,274
	1986	100,300	—	—	—	—	4,220	5,416	—	—	87,535	3,129
	1987	19,500	—	—	—	—	5,087	8,272	—	—	5,100	1,041
Information Systems	1985	16,200	—	—	125	240	9,602	5,034	270	—	—	929
	1986	18,700	—	—	—	190	12,680	4,609	—	—	—	1,221
	1987	21,200	—	—	—	200	14,880	4,909	—	—	—	1,211
Commercial Programs	1985	9,500	202	335	184	185	1,132	135	106	697	412	6,112
	1986	28,100	775	690	4,268	500	1,745	730	555	1,708	2,243	14,886
	1987	45,300	1,900	1,915	6,730	610	2,059	1,045	1,300	4,173	3,007	22,561
Technology Utilization	1985	9,500	202	335	184	185	1,132	135	106	697	412	6,112
	1986	11,100	175	490	268	300	1,295	680	155	408	443	6,886
	1987	13,300	300	415	530	210	1,259	345	400	573	1,007	8,261
Commercial Use of Space	1985	—	—	—	—	—	—	—	—	—	—	—
	1986	17,000	600	200	4,000	200	450	50	400	1,300	1,800	8,000
	1987	32,000	1,600	1,500	6,200	400	800	700	900	3,600	2,000	14,300
Aeronautics and Space Technology	1985	492,400	14,002	396	15,111	—	6,782	25,171	148,703	154,383	115,427	12,425
	1986	522,000	11,700	400	18,900	—	7,000	23,900	166,300	147,500	130,400	15,900
	1987	601,200	11,900	100	200,500	—	7,300	28,100	190,750	189,800	136,250	16,500
Aeronautical Research and Technology	1985	342,400	1,055	—	949	—	290	188	132,933	116,430	84,903	5,652
	1986	354,000	1,100	—	1,100	—	300	200	150,100	101,400	93,100	6,700
	1987	376,000	1,100	—	1,100	—	300	200	165,600	118,400	82,600	6,700
Space Research and Technology	1985	150,000	12,947	396	14,162	—	6,492	24,983	15,770	37,953	30,524	6,773
	1986	168,000	10,600	400	17,800	—	6,700	23,700	16,200	46,100	37,300	9,200
	1987	180,200	10,600	100	19,400	—	7,000	27,900	18,900	48,400	37,900	9,800
Transatmospheric Research and Technology	1985	—	—	—	—	—	—	—	—	—	—	—
	1987	—	—	—	—	—	—	—	—	—	—	—
	1988	45,000	—	—	—	—	—	—	6,250	23,000	15,750	—
Tracking and Data Acquisition	1985	14,800	—	—	—	—	4,400	10,228	24	—	—	148
	1986	16,200	—	—	—	—	4,700	11,500	—	—	—	—
	1987	17,100	—	—	—	—	5,000	12,100	—	—	—	—
TOTAL BUDGET PLAN	1985	2,468,100	239,680	45,704	499,772	10,848	399,011	388,693	217,287	175,994	311,395	179,716
	1986	2,756,800	280,079	69,915	486,238	11,461	450,794	449,291	239,555	177,881	323,047	268,539
	1987	3,003,100	339,623	63,196	517,904	12,165	459,741	484,445	267,723	221,759	201,557	434,987

SPACE
STATION

RESEARCH AND DEVELOPMENT

FISCAL YEAR 1987 ESTIHATES

BUDGET SUMMARY

OFFICE OF SPACE STATION | SPACE STATION PROGRAM

SUMMARY OF RESOURCES REQUIREMENTS

	1985 Actual	1986 Budget Estimate	1986 Current Estimate	1987 Budget Estimate	Page Number
		(Thousands of Dollars)			
Definition	155.500	230.000	205.000	260.000	RD 1-4
Utilization	(9,300)	(15.000)	(11.100)	(15.000)	RD 1-4
Advanced Development	(50.100)	(82,000)	(70.800)	(83.000)	RD 1-4
Program Management/Integration	(35.700)	(52.000)	(57.800)	(88.000)	RD 1-5
Operational Readiness	(2,900)	(7,000)	(5,300)	(17.000)	RD 1-5
System Definition	(57.500)	(74.000)	(60.000)	(57.000)	RD 1-5
Development	---	---	---	150.000	RD 1-5
Total	155.500	230,000	205,000	410.000	

Distribution of Program Amount by Installation:

	1985 Actual	1986 Budget Estimate	1986 Current Estimate	1987 Budget Estimate
Johnson Space Center	63.566	111.900	100.202	146.800
Kennedy Space Center	2.852	5.300	3.216	10.200
Marshall Space Flight Center	36.009	45.400	37.242	37.000
National Space Technology Laboratories	300	400	624	600
Goddard Space Flight Center	16.379	17.800	16.611	15.000
Jet Propulsion Laboratory	5.277	7.600	4.464	5.900
Ames Research Center	3.240	4.500	1.943	1.700
Langley Research Center	4.8813	4.100	5.627	4.600
Lewis Research Center	16.734	26.800	20.769	20,500
Headquarters	6.263	6.200	14.302	167,700*
Total	155.500	230.000	205.000	410.000

*Development funds of $150.000 are shown at Headquarters pending decisions on the individual elements and related field center assignments.

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 stimulating advanced technologies. Development of the permanently manned Space Station, as directed by President Reagan, will follow a vigorous but deliberately-paced program plan which will permit us to maintain the preeminence in space our Nation has attained through various manned and unmanned programs.

The Space Station will be a multi-purpose, international facility providing a permanent 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 in the Space Station program was encouraged by President Reagan in his 1984 State of the Union address. Canada, member states of the European Space Agency (ESA), and Japan have responded enthusiastically. Memoranda of Understandings (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 are undertaking parallel definition and preliminary design studies to identify Space Station elements that each of them may consider for development.

The Space Station will be designed to permit the system to evolve, as warranted, over time and 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 is conducting trade studies to evaluate various subsystems changes to the Space Station options. Changes to the reference configuration are being made to arrive at the optimum baseline configuration considering user requirements, systems efficiency, development and operations cost, and growth potential. Changes to the initial "power tower" reference configuration that have been baselined so far are: (1) dual keel; (2) "figure 8" module pattern; (3) *43.7* feet module length; (4) 14.7 psi cabin pressure; *(5)* assembly altitude of 220 nautical miles and a minimal operating altitute of 250 nautical miles; and, *(6)* 10 to the minus 5 g's microgravity level.

During the definition program, NASA is undertaking a Congressionally-mandated study to examine the feasibility of initially building and deploying a man-tended Space Station followed with a three to five year phase-in of a permanently manned capability. This study will be submitted to the Congress prior to the Administrator's selection of a baseline permanently manned Space Station configuration. All of the NASA centers and Space Station definition contractors are involved in this study which is progressing on schedule.

The Station and its platforms will be placed and maintained in low-Earth orbit by the Space Transportation System, thereby building upon the previous national investment in space. The initial launch of the Space Station elements will occur in the early to mid-1990's.

The definition and preliminary design phase will continue through FY 1987 and will provide the technical and programmatic plan for the Space Station program, including the completion of the detailea definition and preliminary design, the analysis and integration of national and international user community requirements, and the advanced development of technology options. A continuing emphasis on user requirements will be maintained throughout the definition phase as the preliminary engineering design evolves through subsystem advanced development and testing in dedicated test beds. Flight experiments on the Shuttle will be performed to prove system feasibility, and trade studies to optimize systems and operations will be conducted. This detailed system definition will provide assurance of achieving program objectives.

The development phase, beginning early in FY 1987, will include establishing system design requirements and performing detailed analysis for the initiation of the design and layout of the modules and subsystems, the design of ground support equipment and government furnished equipment, and the design and plans for tooling and manufacturing processes.

CHANGES FROM FY 1986 BUDGET ESTIMATE

The FY 1986 budget estimate of $236 million was reduced in the Congressional review process by $25 million to $205 million. In addition, Congressional direction required that $5 million be added within the available funding for advanced technology work in support of delivery of a flight telerobotic system for a mobile remote manipulator and a smart front-end on the Orbital Maneuvering Vehicle to be used for remote operations and servicing.

To accommodate the effective $30 million budget decrease in the original budget plan, reductions and reallocations were made within the six definition phase functional areas.

Reductions in Utilization were taken in all five discipline areas. These reductions were achieved by eliminating parallel efforts between work package contractors and centers and by consolidating specific discipline definition efforts into common generic tasks that addressed the concerns of science and applications, commercial, and technology accommodations. The reductions in Advanced Development touched all technology areas. The effect of these reductions is the elimination of some technology options earlier than originally planned. For example, in the power technology area, all tasks relating to advanced solar arrays have been terminated including the flight experiment designed to study the interactions of space plasma with high voltage solar arrays. Similarly, in the propulsion/fluid management areas, the flight experiments to establish cryogenic fluid transfer (liquid helium) techniques have been eliminated. Examples of reduced tasks are a two-phase thermal control flight experiment and the data managment test bed engineering and operations tasks. The Program Management/Integration area was increased due to higher usage rates of facilities and equipment in various laboratories, such as the crew systems lab, the structures lab, and the antenna test range, as well as increased efforts in documentation and configuration management support. Reductions in Operational Readiness were achieved by reducing or eliminating parallel efforts between centers and by deferring some tasks into FY 1987. Parallel maintainability plan tasks were eliminated and facilities/ground systems tasks deferred into FY 1987. In the System Definition work, the reduction resulted in delays of portions of the definition and preliminary design contract deliverable products and studies into FY 1987.

BASIS OF FY 1987 ESTIMATE

This estimate provides for the initiation of development efforts as well as completion of the definition work, including the technology assessments, and the eight contracted studies begun in April 1985.

Utilization -- To ensure responsiveness to the national and international user community, customer advocacy groups established early in the program will continue to work with users to further define their requirements in the areas of science and applications, commercialization, and technology development. Other user requirements to be defined are: on-board accommodations; support for assembly, staging and servicing spacecraft; and maintainence or modification of equipment. The definition of consistent and user friendly interfaces is a key activity in FY 1987. Interface work will include the definition of access procedures for arranging for services, provisioning/replenishment requirements, and the methods for retrieval and protection of products, and/or data of both a scientific and technical nature. Definition of the user operational requirements will also be a focus of the Utilization program.

Advanced Development -- This activity provides for the continuing development of advanced technology options that are reliable and cost effective and will ensure that the initial Space Station configuration incorporates provisions for growth. Examples of key technologies on which work will continue in FY 1987 include: solar dynamic power generation and energy storage; regenerative life support system; food/hygiene technology; man/machine interfaces and work integration; two-phase thermal bus and two-phased fluid systems, material tests, and dynamic tests of representative structural elements. This effort is being conducted to validate the operation of selected technology options in the environment to which they will be exposed when incorporated in the Space Station.

Automation and robotics technology is applied throughout the advanced development effort. The limited crew size in the initial station dictates a development scenario that will result in maximum autonomy from the ground and a high level of automation and robotic activities. In FY 1986, Congress directed NASA to undertake an automation and robotic effort that will be continued in FY 1987.

Program Management/Integration -- This effort provides for the management and integration of all elements of the Space Station program including the input from international participants. The major components of this activity are the systems engineering and integration (SE&I) effort, the Technical and Management Information System (TMIS), and program support activities.

The SE&I effort includes the systems engineering and analysis of technical requirements and alternatives; the definition and integration of all elements that comprise the program; and the development of the master data base and the engineering master schedules. TMIS will be an integrated system of hardware, software, and procedures to collect, organize, and distribute engineering and management data among NASA centers, contractors and international partners. The program support activities provide management, technical, and institutional support from the individual centers necessary to sustain the development activities of the Space Station.

Operational Readiness -- The definition effort for operations includes the development of plans, requirements, and preliminary designs for the major operational support systems of integrated logistics management, space systems operations, launch/return operations, and user operations. International involvement and operational roles and missions will be assessed. The objective of all these activities is to insure the total operational readiness of the Space Station system, including platforms and ground support elements, in order to conduct a variety of scientific, technological and commercial missions.

System Definition -- Eight system definition contracts were initiated within four separate work packages in April 1985 for the initial definition and preliminary design of the Space Station and its evolution. Completion is scheduled for early FY 1987. In addition to permanently manned features, the contractors are also studying a man-tended approach which phases into a permanently manned capability. The contractors are also supporting the NASA SE&I activity by defining the configurations, interfaces, and functional requirements of individual system elements.

Development -- The development phase includes the contractor effort work packages, supporting development activities such as the NASA SE&I, the software support environment, and the evolvement of operational planning. Some of these supporting development activities will commence early in FY 1987. The SE&I effort will be performed primarily by civil service personnel at the Johnson Space Center with additional SE&I

support provided by other NASA centers. SE&I activities will include system requirements and analyses; interface design and control; and safety, reliability and quality assurance requirements. The engineering master schedule and other key systems level schedules 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. The software support environment activity will provide the infrastructure for the development of common applications software required for flight and ground systems. Other supporting development activities to be performed by the Government with contractor support include the initiation of procurement of government-furnished equipment and the design of the ground support equipment. The ground support equipment will be required during the processing flow of the Space Station system for system level integration, test and check-out, as well as for processing and integration of payloads.

Work package contracts for the development phase are planned to begin incrementally, starting in mid-FY 1987. This contracted effort, as currently contemplated, will be divided into four major categories, which may be adjusted as a result of the definition studies and/or international participation. Present planning calls for one category to include the common modules, the environmental control and life support systems, the outfitting of laboratory and logistics modules, the auxiliary propulsion systems and related applications software. A second category will consist of the distributed systems (including communication and tracking, data management systems, thermal system, mechanisms and the connect/interconnect module); trusses and other structural items; the guidance, navigation and control system; the resources integration and Shuttle interface analysis; and, related applications software. The third category includes the platforms, the facilities and techniques for the servicing of free flyers and other space hardware, as well as the outfitting of laboratories and related applications software. The final category consists of the power generation, power storage, and power management and distribution.

The design and development of the modules, structures, distributed subsystems and platforms will be phased to optimize fabrication, assembly and checkout flow times to support an initial launch of Space Station elements in the early to mid-1990's.

SPACE TRANSPORTATION CAPABILITY DEVELOPMENT

RESEARCH AND DEVELOPMENT

FISCAL YEAR 1987 ESTIMATES

BUDGET SUMMARY

OFFICE OF SPACE FLIGHT

SPACE TRANSPORTATION CAPABILITY DEVELOPMENT PROGRAM

SUMMARY OF RESOURCES REQUIREMENTS

	1985 Actual	1966 Budget Estimate	1966 Current Estimate	1987 Budget Estimate	Page Number
	(Thousands of Dollars)				
Spacelab	55.700	96.700	92.900	89.700	RD 2-6
Upper stages	137.400	122.000	122.000	85.100	RD 2-9
Engineering and technical base	105.700	109.700	109.700	119.900	RD 2-12
Payload operations and support equipment	56.300	63.900	63.900	72.600	RD 2-15
Advanced programs	20.500	21.000	21.000	16.600	RD 2-17
Tethered satellite system	15.800	21.000	17.500	11.600	RD 2-19
Orbital maneuvering vehicle	---	25.000	10.000	70.000	RD 2-20
Total	391.400	459.300	437.000	465.500	

Distribution of Program Amounts By Installation	1985 Actual	1966 Budget Estimate	1966 Current Estimate	1987 Budget Estimate
Johnson Space Center	118.000	115.100	119.600	121.400
Kennedy Space Center	34.600	56.900	56.100	43.500
Marshall Space Flight Center	92.700	128.400	113.100	185.600
National Space Technology Laboratories	7.800	7.100	7.300	7.800
Goddard Space Flight Center	1.000	---	1.100	1.600
Jet Propulsion Laboratory	400	1.000	1.000	1.000
Langley Research Center	800	200	400	500
Lewis Research Center	124.100	115.300	75.500	30.000
Headquarters	12.000	35.300	63.000	74.100
Total	391.400	459.300	437.000	465.500

PROGRAM OBJECTIVES AND JUSTIFICATION

The principle areas of activity in Space Transportation Capability Development are efforts related to the Spacelab, the Upper Stages that place satellites in high altitude orbits, the Engineering and Technical Base support at NASA centers, Payload Operations and Support Equipment, Advanced Programs study and evaluation efforts, the development and first flight of the United States/Italian Tethered Satellite System, and the development 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 development program which has been carried out jointly by NASA and the European Space Agency (ESA) continues with the procurement of hardware for the Dedicated Discipline Laboratory, the Hitchhiker System, the Spacelab Pallet System, the Space Technology Experiment Platform and the intitial lay-in of spares. Operational missions for FY 1987 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, a solid rocket motor integrity program to establish an engineering data base for solid stage components, and for the NASA share of the joint Air Force development effort being conducted with the Department of Defense (DOD) on the Centaur upper stage for use in the Shuttle.

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.

Payload Operations and Support Equipment provides for developing and placing 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 programmatic data for their definition and evaluation. Activity is focused on six major areas: advanced missions, satellite services, spacecraft systems, advanced transportation systems, crew systems, and generic space system capabilities. Advanced development activities are conducted to provide a basis for obtaining significant performance and reliability improvements and reducing future program risks and development costs through the effective use of new technology.

The Tethered Satellite System (TSS), a joint Italian/United States development effort, will provide a new capability for conducting space experiments in regions remote from the Shuttle orbiter. The objectives of the initial TSS mission planned for 1988 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, to be initiated in 1986, will provide a capability for payload delivery, retrieval, and servicing beyond that currently available in the STS.

OBJECTIVES AND STATUS

The first operational Spacelab flight (SL-3) and the second development flight (SL-2) were successfully flown during FY 1985. With the delivery of the instrument pointing system in the fourth quarter of FY 1385, the delivery of the major portion of the follow on procurement Spacelab hardware was completed. Additional hardware for the Dedicated Discipline Laboratory (DDL) flights, the Spacelab Pallet System (SPS), the Space Technology Experiment Platform (STEP),and the Hitchhiker system is being procured.

The major missions of the Spacelab system during FY 1986 will demonstrate its varied capabilities. The first reimbursable flight, Deutschland-1 (D-1), was flown during the first quarter of FY 1586. Astro-1, an astronomical observation of Halley's comet, and an Earth Obssrvatory Wission (EOM-1/2), a mission flying several experiments previously flown on SL-1 will be flown during FY 1986. Also, the initial flights of the Goddard and Marshall Hitchhikers will be in FY 1986.

In Upper Stages, a joint development program with the DOD was initiated in FY 1983 for the use of the Centaur as an STS upper stage. The common vehicle, designated Centaur-;, accommodates a 40 foot long, approximately 10,000 pound payload in the orbiter payload bay, and is capable of placing it into geosynchronous orbit. A longer version of the Centaur-G, known as G Prime, is being developed by VASA for launch of the Galileo and Ulysses spacecraft in mid-1986. The G Prime is approximately 10 feet longer than the G Vehicle and is capable of placing a 14,560 pound payload into geosynchronous orbit from the orbiter. Two Centaur-G Prime vehicles are currently under procurement for the Galileo and

Ulysses missions. Procurement has been initiated for one Centaur-G vehicle to support the Magellan mission (formerly known as the Venus Radar Mapper mission) in 1988.

The commercially developed Payload Assist Modules (PAM) provide low cost transportation, principally for commercial spacecraft, from the Shuttle's low Earth orbit. The Delta class PAM-D is capable of injecting up to 2,751, pound payloads into geosynchronous transfer orbit. The PAM-DII will be 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 616 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. Fourty PAM-D's have been successfully launched on the Delta, Atlas, and Space Shuttle. There have been 20 consecutive successful PAM-D missions as of January 1986.

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. TDRS-2, which is the next NASA use of an IUS, is scheduled for launch in early 1986.

The Transfer Orbital Stage (TOS) is a three-axis stabilized perigee stage that is being commercially developed by the Orbital Sciences Corporation for use in the Shuttle. It will have the capability of placing 6,000 to 13,000 pounds into geosynchronous transfer orbit and thus bridges the gap between PAM-DII and Centaur. The scheduled launch availability is early 1987.

The Apogee Maneuvering Stage (AMS) is a three-axis stabilized liquid propellant apogee stage which is also being commercially developed 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. Projected availability is late 1987.

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 procurred including initial spares for cargo integration test equipment, fiber optic cabling and equipment for communication links between the payload procesing facilities and standard sets of wire harnesses for interconnection of mixed cargoes in the payload bay.

The Advanced Programs effort is focused on six major areas--advanced misions, satellite services, spacecraft system, advanced transportation systems, crew systems, and generic space system capabilities. Advanced planning and analysis efforts will increasingly be focused on long range manned mission options in and beyond Earth orbit. Satellite servicing systems will continue definition and advanced development 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. 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 development was initiated in FY 1984 following the completion of an advanced development phase initiated in FY 19113. Systems definition studies were completed 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 1987. The Italians started satellite and core equipment development in FY 1984, and a cooperative first flight is presently scheduled for 1988.

The Orbital Maneuvering Vehicle (OMV) completed early study and feasibility efforts in FY 1985 and is progressing toward contractor selection for full-scale hardware development by the middle of 1986. The OMV will be a reusable, remotely operated propulsive 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 1987 FUNDING REQUIREMENT

SPACELAB

	1985 Actual	1986 Budget Estimate	1986 Current Estimate	1987 Budget Estimate
		(Thousands of Dollars)		
Development....	19,200	16,000	19,300	14,700
Operations.	36,500	80,700	73,600	75,000
Total	55,700	96,700	92,900	89,700

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 allows for 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.

The remaining hardware is in Spacelab's development budget, including such major elements as the crew transfer tunnel, verification flight instrumentation, certain ground support equipment, 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 from ESA under terms of the ESA/NASA Memorandum of Understanding and the Intergovernment Agreement. With the delivery of the follow on procurement (FOP) IPS in the fourth quarter FY 1985, the delivery of the major portion of the FOP Spacelab unit was completed. Additional Spacelab hardware, primarily for Spacelab Dedicated Discipline Laboratory (DDL) flights and the initial lay-in of spare hardware, is being procured from Europe. The establishment of a depot maintenance program for United States-provided and European-supplied hardware will continue during FY 1986. 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 also continuing.

Spacelab's operation 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, an observation of Halley's comet, and an Earth Observatory Mission (EOM-1/2), a mission flying several experiments previously flown on SL-1, will also be flown during FY 1986. The initial flights of the Goddard Hitchhiker (HG-1) and the Marshall Hitchhiker (HM-1) will be in 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 ESH will continue throughout FY 1986. Operation of the depot maintenance program for U.S.-provided and European-supplied hardware and the procurement of replenishment spares will continue in FY 1986.

CHANGES FRM 1986 BUDGET ESTIMATE

The $3.3 million increase in development is primarily due to the procurement of additional ground support equipment and flight spares, including instrument pointing system spares. In addition, there are modifications planned to existing hardware and a transfer of the dedicated cable harness from Payload Operations. The operations decrease of $7.1 million is due to changes in the manpower levels required to support the rephased Shuttle/Spacelab manifest.

BASIS OF FY 1987 ESTIMATE

Funding in FY 1987 is required for the continued procurement of initial lay-in of both United States and European source spares. The establishment of a depot maintenance system for U.S. and European-supplied hardware will also continue during FY 1987. Additionally, development of the STEP and procurement of hardware to support the DDL will continue.

Funding is also required for the FY 1987 Spacelab operational flights, including the International Microgravity Lab (IML-1), four Hitchhiker flights, Astro-2 and 3, Space and Life Sciences Laboratory SLS-1, Material Science Laboratory mission (3, 4, 5, 6 and 7), and other small payloads, all to be flown in FY 1987. FY 1987 funding is required to support flights to be flown in subsequent years, including the planned FY 1986 launch of an Earth Observation Mission (EOM-3), Sunlab-I/Dark Sky, SLS-2 and the Material Science Laboratory missions (8, 9, 10, and 11). Two additional reimbursable missions will be flown: the Japanese Spacelab mission (Spacelab-J) in FY 1988; and a West Germany mission (Spacelab-D2) in FY 1989. 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.

BASIS OF FY 1987 FUNDING REQUIREMENT

UPPER STAGES

	1985 Actual	1986 Budget Estimate	1986 Current Estimate	1987 Budget Estimate
		(Thousands of Dollars)		
Development	38,000	5,700	3,900	4,900
Procurement and operations.	99,400	116,300	118,100	80,200
Total..............................	137,400	122,000	122,000	85,100

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), the Centaur/STS, 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, such as the Transfer Orbit Stage (TOS) and the Apogee Maneuvering Stage (AMS), 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 from STS-51C in January 1985. Four IUS vehicles have been procured by NASA for launch of the initial four Tracking and Data Relay Satellite System spacecraft; the first three were funded through the TDHSS contract while the fourth is funded under this budget element.

NASA and DOD have entered into a joint development program for a wide-body derivative of the Centaur stage as used in the Atlas-Centaur program. The common vehicle, designated Centaur-G, will accommodate a 40-foot long, approximately 10,000 pound payload in the orbiter payload bay, and be capable of placing it into geosynchronous orbit. It will be available in 1987. A longer and more powerful version of the Centaur-G, known as G Prime, is being developed by NASA for launch of the Galileo and Ulysses spacecrafts in mid-1986.

Two Centaur-G Prime vehicles are currently being procured for the Galileo and Ulysses missions. Procurement was initiated in FY 1985 for one G vehicle to support the Magellan (formerly Venus Radar Mapper) mission. The Air Force and NASA share common design ana development costs for the Centaur-G up to a $150 million cap for DOD participation, as agreed to in the Memorandum of Agreement. The Air Force and NASA separately budget for hardware production and operations costs associated with each agency's missions. Both NASA and DOD plan additional procurement of vehicles at a later date to meet future requirements. The planned activities for Centaur in 1987 include the work required on the RL-10 engine to provide added capability for NASA and DOD missions.

The objective of the PAM program is to provide low cost transportation, principally of commercial spacecraft from 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 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. Fourty PAM-D's have been successfully launched on the Delta, Atlas, and Shuttle as of January 1986. Twenty of these have occurred since the two PAM-D's failed on STS-11. 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.

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, and thus bridge the gap between PAM-DII and Centaur. The scheduled launch availability is early 1987. A TOS-class vehicle is baselined for the Mars Observer mission in 1990. The Apogee Maneuvering Stage (AMS) is a three-axis stabilized liquid propellant apogee stage that is being developed commercially also 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. Projected availability is late 1987.

The solid rocket motor integrity program was initiated during FY 1984, following the PAM failures on STS-11, 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. Physical and mechanical properties of selected components are currently being examined and means of instrumenting manufacturing processes and their impact on material properties are being developed. Motor testing will be conducted to verify analyses and create an engineering data base.

CHANGES FROM FY 1986 BUDGET ESTIMATE

The development decrease of $1.8 million is due to a restructuring of the RL-10 program. Production has increased $1.8 million reflecting Centaur cost increases of **$4.3** million offset by minor PAM and IUS decreases.

BASIS OF FY 1987 ESTIMATE

The FY 1987 development funds are required to complete the RL-10 engine improvement program in order to provide increased capability for NASA and DOD missions. Also, technical monitoring of the **TOS** upper stage will be continued. Production and operations funds in FY 1987 are required to continue production of one Centaur-G vehicle to support the Magellan (formerly Venus Radar Mapper) mission scheduled for launch in 1988 and upper stages for the Mars Observer, TDRS-5 and TDRS-6. Vehicle selections are currently in the source evaluation process for upper stage vehicles for TORS-5, TDRS-6, and the Mars Observer. Monitoring of the PAM-D, PAM-DII and TOS programs will continue. Funds are also required to support continuation of the solid rocket motor integrity program. Funding starts in FY 1587 on two upper stages, one PAM-D class and one AMS class, for the ESA and Japanese Solar Terrestial Physics spacecrafts.

BASIS OF FY 1986 FUNDING REQUIREMENT

ENGINEERING AND TECHNICAL BASE

	1985 Actual	1986 Budget Estimate	1986 Current Estimate	1987 Budget Estimate
		(Thousands of Dollars)		
Research and test support	47,500	50,300	44,500	52,600
Data systems and flight support	16,200	17,100	19,000	14,100
Operations support	38,900	39,300	42,500	48,700
Launch systems support	3,100	3,100	3,700	4,500
Total	105,700	109,700	109,700	119,900

OBJECTIVES AND STATUS

The Engineering and Technical Base (ETB) provides the core capability required to sustain an engineering and development base for various NASA programs 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 from center to center due to programmatic and institutional differences. At JSC, the core level requirement is that one shift of operations be maintained in the engineering and development laboratories, the White Sands Test Facility, and reliability and quality assurance areas. The core level for the central computer complex 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, computational and communications services, and at NSTL for facilities operations, including security.

CHANGES FROM FY 1986 BUDGET ESTIMATE

The total funding for ETB has not changed in FY 1986. Reductions have been possible in research and test support by deferring equipment acquisitions and by reallocations between in-house laboratories. Data systems and flight support has increased to provide for additional communications and computational support. Operations support has increased to enhance base engineering and logistics activities support. Launch systems support includes additional development of beneficial applications of new technology to solve operational problems.

BASIS OF FY 1987 ESTIMATE

The requested funding for the ETB in FY 1987 provides for a continuation of the FY 1986 level of support for institutional research and development facilities and services at the centers. The increase in FY 1987 budget authority requirements over FY 1986 reflects increased rates at the contractor workforce.

In research and test support, effort will be continued on the provision for increased capabilities at MSFC for engineering and science projects enabled by acquisition of a Class VI computer system. This capability is required for the solution of more complex main engine three-dimensional dynamics modeling problems and for complex structural analyses. Present supporting activities at MSFC will be continued during FY 1986. At JSC, the requested funding will provide for a five-day, one-shift operation for the safety, reliability and quality assurance activities and for the engineering and development laboratories, such as the Electronic Systems Test Laboratory and the Thermal Test Area.

Data systems and flight support provide a minimal core level of support based on a five-day, two-shift operation of the central computer complex at JSC.

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 1987 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 items 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 1987 funds will provide the 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 development of beneficial application of new technology to the solution of operational problems and development of improved operational capabilities for launch site hardware, ground processing and support systems.

BASIS OF FY 1987 FUNDING REQUIREMENT

PAYLOAD OPERATIONS AND SUPPORT EQUIPMENT

	1985 Actual	1986 Budget Estimate	1986 Current Estimate	1987 Budget Estimate
	(Thousands of Dollars)			
Payload operations....................	41,600	53,400	54,600	66,900
Payload support equipment.............	14,700	10,500	9,300	5,700
Total..............................	56,300	63,900	63,900	72,600

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 development and acquisition of multi-mission reusable ground support equipment required for a wide range of payloads. This includes test equipment required to checkout payload-to-orbiter interfaces at KSC, test equipment for checkout of NASA payloads at Vandenburg Air Force Base (VAFB), mixed cargo hardware such as standard cable harnesses, and displays and controls related to payload bay operations.

CHANGES FROM FY 1986 BUDGET ESTIMATE

Payload operations funding requirements increased by $1.2 million to support the development of a standard remateable umbilical for on-orbit spacecraft servicing. Payload support equipment estimates have decreased by $1.2 million reflecting a transfer of dedicated Spacelab wiring harnesses to the Spacelab program.

BASIS OF FY 1987 ESTIMATE

Payload operations funding is required to furnish continued payload services for currently scheduled NASA launches. Major NASA and joint endeavor payloads receiving support during this year include Spartans, Space Life Science Laboratory (SLS-2), Electrophoreses Operations in Space (EOS), Long Duration Exposure Facility Retrieval (LDEF), Spacelab Solar Telescope (Sunlab), Materials Science Laboratories (MSL), Astros, Shuttle Radar Laboratory (SRL), Tracking and Data Relay Satellite (TDRS), International Micogravity Laboratory (IML), Combined Release and Radiation Effects Satellit (CRRESS), Roentgen satellite (ROSAT), Shuttle Solar Backscater Ultra-Violet Instruments (SSBUV) and Large, High Capacity Heat Pipe Radiator (TEMP-3B). Sustaining engineering and operations support for the manned maneuvering unit will continue in support of NASA flight requirements. Further, 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.

FY 1987 funding for payload support equipment will be used for the development, test, and installation of mixed cargo hardware and test equipment, long lead procurement of equipment for NASA payloads at VAFB, procurement and installation of fiber optics, and continued procurement of cargo integration hardware required to meet the mission manifest.

BASIS OF FY 1987 "" DING REQUIRMENT

ADVANCED PROGRAMS

	1985 Actual	1986 Budget Estimate	1986 Current Estimate	1987 Budget Estimate
		(Thousands of Dollars)		
Advanced programs	20,500	21,000	21,000	16,600

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 STS 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 1986, 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, maintenance 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 from the Shuttle. Advanced transportation studies are focused on study of potential future reusable orbit transfer vehicles (OTV), space-based operations of OTV's, competitive 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 a heavy lift launch capability and associated advanced development.

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 early Space Station. Integrated program options involving low Earth orbit, geostationary orbit, lunar and planetary missions will be investigated, with the multi-year purpose to develop goals, planning information, and infrastructure requirements for expanding manned presence in space beyond the period of the Space Station development and initiation.

BASIS OF FY 1987 ESTIMATE

In FY 1987, major emphasis will be placed on system concept definition and key advanced developments in crew systems, geostationary Earth orbital unmanned platforms, reusable OTV's, new capability mission kits for orbital maneuvering 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 elements needed for space operations over the next twenty years.

The satellite servicing program element will continue to explore effective manned 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 development efforts. Detailed engineering systems analysis will be continued to determine the efficiency of future tethered platform applications. Completion of preliminary definition of orbit transfer vehicle systems will be accomplished in the advanced transportation element, including a detailed systems engineering understanding of space basing and what key advanced developments must be initiated. Second generation shuttle concept studies and advanced developments will also be conducted. In the crew systems area, new life support system concepts and advanced developments will be conducted 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 1987 FUNDING REUUIRMENT

TETHERED SATELLITE SYSTEM

	1985 Actual	1986 Budget Estimate	1986 Current Estimate	1987 Budget Estimate
		(Thousands of Dollars)		
Tethered satellite system............	15,800	21,000	17,500	11,600

OBJECTIVES AND STATUS

The development of a Tethered Satellite System (TSS) will provide a new facility for conducting space experiments at distances up to 100 kilometers from 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 thermosphere, new observations of crustal geomagnetic phenomena, 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, orbiter integration, and hardware development of the deployment mechanism which was initiated in FY 1984. The Italians initiated the satellite hardware development in 1984. They are responsible for the satellite development and instrument and experiment integration.

CHANGES IN FY 1986 BUDGET ESTIMATE

Funding requirements have decreased by $3.5 million to reflect a slower development schedule of the NASA deployer consistent with the pace of other elements of the program.

BASIS OF FY 1987 ESTIMATE

FY 1987 funding of 811.6 million will continue the hardware design and development leading to an engineering verification flight scheduled for 1988. The planning estimate for the total development cost for the United States activities remains at $60 million.

BASIS OF FY 1987 FUNDING REQUIREMENT

ORBITAL MANEUVERING VEHICLE

	1985 Actual	1986 Budget Estimate	1986 Current Estimate	1987 Budget Estimate
		(Thousands of Dollars)		
Orbital maneuvering vehicle...........	---	25,000	10,000	70,000

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 man-in-the-loop control, the spacebaseble reusable OMV, operating as far as 800-1400 nautical miles from 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 platforms and the retrieval of space debris which could represent an orbital hazard to all future space missions.

CHANGES IN FY 1986 BUDGET ESTIMATE

The $15.0 million decrease for OMV reflects the implementation of Congressional actions on the FY 1986 budget request. This change will result in a delay of the first flight from 1990 to 1991.

BASIS FOR FY 1987 ESTIMATE

The funds provided in FY 1986 will be used to initiate OMV hardware development through competitively awarded contracts in the summer of 1986. FY 1987 funds will be used to continue this development effort leading to first flight in 1991.

SPACE SCIENCE
AND
APPLICATIONS

NATIONAL AERONAUTICS AND SPACE ADMINISTRATION

FISCAL YEAR 1987 ESTIMATES

RESEARCH AND DEVELOPMENT BUDGET PLAN FOR SPACE SCIENCE AND APPLICATIONS PROGRAMS

Programs	1985 Actual	1986 Budget Estimate	1986 Current Estimate	1987 Budget Estimate
		(Thousands of Dollars)		
Physics and astronomy...................	677,200	630,400	607,100	539,400
Life sciences,	62,300	72,000	69,900	74,700
Planetary exploration.................	290,900	359,000	352,800	323,300
Solid earth observations..............	57,600	74,900	74,900	74,100
Environmental observations............	212,700	317,500	289,800	367,900
Materials processing in space.........	27,000	34,000	35,000	43,900
Communications........................	60,600	106,200	100,300	19,500
Information systems...................	16,200	19,200	18,700	21,200
Total...............................	1,404,500	1,613,200	1,548,500	1,464,000

PHYSICS AND
ASTRONOMY

RESEARCH AND DEVELOPMENT

FISCAL YEAR 1987 ESTIMATES

BUDGET SUMMARY

OFFICE OF SPACE SCIENCE AND APPLICATIONS

PHYSICS AND ASTRONOMY PROGRAM

SUMMARY OF RESOURCES REQUIREMENTS

	1985 Actual	1986 Budget Estimate	1986 Current Estimate	1987 Budget Estimate	Page Number
	(Thousands of Dollars)				
Hubble space telescope development....	195,000	127,800	127,800	27,900	RD 3-4
Gamma ray observatory development.....	117,200	87,300	67,300	51,500	RD 3-6
Shuttle/Spacelab payload development and mission management..............	105,400	135,500	108,300	115,100	RD 3-8
Explorer development..................	51,900	55,200	50,700	56,700	HD 3-11
Mission operation and data analysis.. .	109,100	119,900	118,000	172,700	RD 3-14
Research and analysis.................	39,900	42,300	51,500	51,100	RD 3-16
Suborbital program....................	58,700	62,400	63,500	64,400	RD 3-13
Total..............................	677,200	630,400	607,100	539,400	

Distribution of Program Amount by Installation

	1985 Actual	1986 Budget Estimate	1986 Current Estimate	1987 Budget Estimate
Johnson Space Center..................	7,328	9,500	9,874	15,190
Kennedy Space Center..................	4,997	7,250	6,a54	4,786
Marshall Space Flight Center..........	338,824	283,298	293,217	246,466
Goddard Space Flight Center...........	193,087	216,996	169,054	140,721
Jet Propulsion Laboratory.............	60,913	34,525	47,413	53,110
Ames Research Center..................	22,505	27,500	29,920	29,666
Langley Research Center...............	2,914	3,233	1,625	1,250
Headquarters..........................	46,632	48,098	49,143	48,211
Total..............................	677,200	630,400	607,100	539,400

PROGRAM OBJECTIVES AND JUSTIFICATION

The major objective of the Physics and Astronomy program is to increase our knowledge of the origin, evolution, structure, and composition of the universe, including the Sun, the stars, and other celestial bodies. Space-based research is being conducted to investigate the structure and dynamics of the Sun and its long and short-term variations; cosmic ray, x-ray, ultraviolet, optical, infrared, and radio emissions from stars, interstellar gas and dust, pulsars, neutron stars, quasars, blackholes, and other celestial sources; and the laws governing the interactions and processes occurring in the universe. Many of the phenomena being investigated are not detectable from ground-based observatories because of the obscuring or distorting effects of the Earth's atmosphere.

To achieve the objectives of the Physics and Astronomy program, NASA employs theoretical and laboratory research; aircraft, balloon and sounding rocket flights; Shuttle/Spacelab flights; and free-flying spacecraft. 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 for application to and the advancement of scientific knowledge, education and technology.

The Physics and Astronomy missions undertaken to date have been extraordinarily successful, and a number of missions continue to produce a rich harvest of scientific data; the International Ultraviolet Explorer (IUE) and the Solar Maximum Mission (SMM) are still operating. New scientific results are continually emerging from the analysis of the High Energy Astrophysics Observatories (HEAO) and Infrared Astronomical Satellite (IRAS) data sets.

Explorer satellites are relatively low cost but are extremely effective in missions which have been developed and launched since the beginning of our country's space program. Present examples are the Active Magnetospheric Paricle Tracer Explorer (AMPTE), launched in 1984, which is studying the solar wind at the subsolar point and identifying particle entry windows, energization processes and transport processes into the magnetosphere. The Infrared Astronomical Satellite (IRAS), developed in collaboration with the Netherlands and the United Kingdom, and launched in January 1983, made exciting discoveries and significant contributions to astronomical research as it observed the cool and obscured objects of the universe. While the spacecraft has completed operations, the analysis of the IRAS data will continue for several years.

Two major Explorer missions are now under development: the Cosmic Background Explorer (COBE) and the Extreme Ultraviolet Explorer (EUVE). In addition, a U.S. X-ray high resolution imager is being developed for launch in 1988 on the Roentgen Satellite (ROSAT), which is being developed by the Federal Republic of Germany. A Cosmic Ray Isotope Experiment is also being developed for flight in 1988 on a Department of Defense satellite.

The Hubble Space Telescope program will provide an international spaceborne astronomical observatory capable of measuring objects appreciably fainter and more distant than those accessible from the ground. This increased capability will allow us to address such basic questions as the origin, evolution, and disposition of stars, galaxies, and clusters, thus allowing us to significantly increase our understanding of the universe.

In 1988 the Gamma Ray Observatory mission will be launched by the Space Shuttle. This mission will measure gamma radiation and explore the fundamental physical processes powering it. Through the instruments flown on this mission unique information on astronomical objects such as quasars, black holes, and neutron stars may be examined.

The Shuttle/Spacelab program will continue, with flight of the ASTRO-1 mission and the first Earth Observation Mission (EOM) scheduled to occur in 1986. The ASTRO-1 mission will investigate the interstellar medium through x-ray observations, while the EOM will start a long-term series of studies related to the Earth's atmosphere and the solar constant. Activity will also be conducted on several future missions, including Astro-2, subsequent EOM's, Materials Science Labs, and the first dedicated Life Sciences mission. In addition, sounding-rocket-type instrumentation will be developed to be flown on the Space Transportation System to allow longer flight time of these relatively low-cost instruments.

Suborbital observations will continue to be conducted in FY 1987 from balloons, sounding rockets, Spartans, and high-flying aircraft that carry instruments above most of the atmosphere. An aircraft is being acquired and modified in FY 1986 and FY 1987 to replace the CV-990 research aircraft, "Galileo II", which was destroyed in an accident in July.

BASIS OF FY *1987* FUNDING REQUIREMENT

HUBBLE SPACE TELESCOPE DEVELOPMENT

	1985 Actual	1986 Budget Estimate	1986 Current Estimate	1987 Budget Estimate
		(Thousands of Dollars)		
Spacecraft.......	174,100	113,900	113,900	24,900
Experiments.......	20,900	13,900	13,900	3,000
Total	195,000	127,800	127,800	27,900
Mission operations and data analysis.	(74,700)	(88,000)	(87,700)	(137,600)
Space transportation system operations	(28,000)	(41,500)	(40,100)	(---)

,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. Operating in space above the atmospheric veil surrounding the Earth, the Hubble Space Telescope will increase, by more than a hundredfold, 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 observations possible 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 far into the distant past of our universe. 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 observation 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 in-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 1985, significant progress was made towards completion of the Hubble Space Telescope (HST) development program. Almost all major elements of the spacecraft, including the Optical Telescope Assembly, the three flight Fine Guidance Sensors, the Science Instrument Control and Data Handling Unit, and the five Scientific Instruments have been delivered and assembled into the observatory at Lockheed. The Assembly and Verification (A&V) program of the integrated spacecraft began at Lockheed in FY 1985. HST functional, modal and electromagnetic compatibility testing have all been successfully completed. These tests verified the overall mechanical, electrical and structural integrated system design integrity and quality of workmanship. Especially gratifying were the pointing stability results from modal testing, which showed performance well within specifications.

In FY 1986, program focus will continue on the A&V activities at Lockheed. Major remaining A&V testing include acoustic, thermal vacuum and pre-ship functional. HST will then be shipped from Lockheed (California) to Kennedy Space Center for launch during the first quarter of FY 1967.

CHANGES FROM FY 1986 BUDGET ESTIMATE

While there are no changes in requirements from the FY 1986 budget, the launch date of the Hubble Space Telescope has been changed from August 1986 to October 1986. Resources have been added to FY 1987 to support the change in the launch date and for potential problems.

BASIS OF FY 1987 ESTIMATE

The FY 1987 funding is required for HST launch and orbital checkouts, related costs and associated contractor award fee payments.

BASIS OF FY 1987 FUNDING REQUIRMENT

GAMMA RAY OBSERVATORY DEVELOPMENT

	1985 Actual	1986 Budget Estimate	1986 Current Estimate	1987 Budget Estimate
	(Thousands of Dollars)			
Spacecraft............................	91,400	59,700	59,700	35,500
Experiments and ground operations.....	25,800	27,600	27,600	16,000
Total................................	117,200	87,300	87,300	51,500
Space transportation system operations	(5,400)	(12,000)	(14,800)	(22,600)

OBJECTIVES AND STATUS

The objective of the Gamma Ray Observatory mission is to measure gamma radiation from the universe, and to explore the fundamental physical processes powering it. Certain celestial phenomena are accessible only at gamma ray energies. The observational objectives of the Gamma Ray Observatory are to search for direct evidence of the synthesis of the chemical elements; to observe high energy astrophysical processes occurring in supernovae, neutron stars and black holes; to locate gamma ray burst sources; to measure the diffuse gamma ray radiation for cosmological evidence of its origin; and to search for unique gamma ray emitting objects.

Cosmic gamma rays represent one of the last frontiers of the electromagnetic spectrum to be explored. The low flux levels of gamma rays, and the high background they produce through their interaction with the Earth's atmosphere, coupled with the demand for better spectral, spatial, and temporal resolution of source features, combine to require that very large gamma ray instruments be flown in space for a prolonged period of time. Gamma rays provide unique information on the most intriguing astronomical objects yet discovered, including quasars, neutron stars, and black holes.

The Gamma Ray Observatory is scheduled for launch by the Space Shuttle in 1988. The spacecraft is designed to accommodate four scientific instruments and to allow for refueling by the Space Shuttle. Because of the necessity for long exposures, the spacecraft will be pointed in a fixed direction in space for periods of a few hours up to two weeks at a time.

In FY 1985, critical design review for the spacecraft system was completed. In addition, fabrication of instrument hardware continued. In FY 1986, assembly of the scientific instruments will be completed and the spacecraft fabrication and test will be underway.

BASIS OF FY 1987 ESTIMATE

The FY 1987 funding is required for science instrument integration and test with the spacecraft as well as system verification and test necessary for the planned 1988 launch.

BASIS OF FY 1987 FUNDING REQUIREMENT

SPACELAB PAYLOAD DEVELOPMENT AND MISSION MANAGEMENT

	1985 Actual	1986 Budget Estimate	1986 Current Estimate	1987 Budget Estimate
		(Thousands of Dollars)		
Payload development & mission management	105,400	135,500	108,300	115,100
(Solar Optical Telescope Development)	(9,789)	(30,000)	(5,000)	(---)

OBJECTIVES AND STATUS

The objectives of Spacelab payload development and mission management are to develop instruments in order to conduct experiments and acquire new knowledge in the disciplines of physics and astronomy, to develop experiment interface hardware for materials processing, to develop sounding rocket class payloads for flight on the Space Shuttle, and to manage the mission planning, integration, and execution of all NASA Spacelab and attached payloads. This project also supports the development of all physics and astronomy experiments; system management and engineering development of flight equipment and software; payload specialist training and support; physical integration of the payloads with the Spacelab system; operation of the payloads in flight; dissemination of data to experimenters; and analysis of physics and astronomy flight data. In addition, this project funds the mission management efforts for all NASA Spacelab and other attached payloads.

Instruments are currently under development for several Shuttle/Spacelab missions with primary emphasis on physics and astronomy. These instruments are divided in two classes: multi-user instruments and principal investigator instruments. The multi-user instruments are those instruments that have a broad capability, can accommodate a number of principal investigator-furnished instruments, and have a larger user community. The principal investigator instruments are those proposed for a specific scientific investigation by a single investigator who may not have co-investigators.

Three ultraviolet telescopes are currently in development leading to a launch in March 1986 (ASTRO-1). This mission is designed to conduct investigations in ultraviolet imaging, spectrophotometry, and polarimetry at very high resolution. The ASTRO-1 mission will also carry two wide-field cameras, and will conduct unique scientific observations of Halley's Comet in the near-earth environment. ASTRO-1, as well as reflights of this instrumentation, is designed to allow scientific investigations of a broad range of objects, from nearby comets and planets to the most distant quasars.

Work is proceeding on instruments for the Shuttle High Energy Astrophysics Lab (SHEAL). The initial mission, SHEAL-1, which is planned for flight in early FY 1987, will study the celestial soft x-ray background and obtain information on the local interstellar medium. Instruments for a second mission, planned for early FY 1989, including a broad band x-ray telescope and an associated two-axis pointing system, are also under development.

Initial instrument development work is under way for Space Plasma Lab (SPL) missions planned for flight in the early 1990's. These missions are being developed to use the Earth's natural plasma environment as a laboratory to study in detail the behavior of plasmas as they are subjected to a variety of perturbances.

Mission management activities are continuing on several space science and applications missions. Examples include the Earth Observation Mission (EOM), the first of which is scheduled for launch in August 1986, and the Materials Science Laboratories, which comprise a series of material sciences experiments. Mission management activities also include integration, both analytical and physical, for other (non-OSSA) payloads. For example, the Space Station Heat Pipe Advanced Radiator Element heat pipe experiment payload is a test of a radiator system which has high potential for future space-borne heat rejection systems.

Spacelab-2 and Spacelab-3 were flown successfully in April and July of 1985. Analysis of scientific data from these dedicated spacelab flights continues with significant results expected in FY 1986.

CHANGES FRM FY 1986 BUDGET ESTIMATE

The decrease in the FY 1986 estimated budget is consistent with Congressional direction and reflects a decision not to develop SOT at this time.

BASIS OF FY 1987 ESTIMATE

In FY 1987, mission management of the ongoing Spacelab missions will be continued. Mission management for the non-physics and astronomy missions includes all Spacelab efforts except instrument development and data analysis. These include the Space Life Sciences Lab and the International Microgravity Lab, both of which are scheduled for initial flight in 1987. Development of instruments for the Space Plasma Lab will continue, as will development of instruments for the Shuttle High Energy Astrophysics Lab and for the ASTRO series. FY 1987 funding is also required for the development and operations of low-cost sounding rocket class payloads which will be flown on the Space Shuttle to provide more flight opportunities for the science community.

BASIS OF FY 1987 W I N G REQUIREMENT

EXPLORER DEVELOPMENT

	1985 Actual	1986 Budget Estimate	1986 Current Estimate	1987 Budget Estimate
		(Thousand of Dollars)		
Cosmic background explorer........	30,570	25,400	24,900	16,700
Extreme ultraviolet explorer	13,426	24,100	15, YOO	32,400
Roentgen satellite experiments........	1,200	2,200	2,200	1,500
Combined release ana radiation effects satellite...........................	1,500	---	3,300	2,200
Heavy nuclei collector................	2,900	3,300	1,700	1,300
Other explorers.......	2,304	200	2,700	2,600
Total..............................	51,900	55,200	50,700	56,700
Mission operations and data analysis	(19,761)	(19,700)	(18,700)	(23,100)
Transportation system operations	(4,600)	(17,700)	(17,800)	(30,900)

OBJECTIVES AND STATUS

The Explorer program provides the principal means of conducting investigations of stellar physics and of the near-Earth interplanetary environment that have limited specific objectives and that do not require major observatories. Included in the present program are studies of atmospheric and magnetospheric physics; the several magnetospheric boundaries; interplanetary phenomena; cosmic ray investigations; and x-ray, ultraviolet and infrared astronomy. Studies are conducted to define future high priority science explorer missions. NASA engages in cooperative missions with other federal agencies and other nations whenever such cooperation will assist in achieving the mission objectives.

Solar terrestrial and atmospheric explorers provide the means for conducting studies of the Earth's near-space environment. The program requires a wide variety of satellites in orbits extending from the very lowest reaches *of* the upper atmosphere to the interplanetary medium beyond the Earth's magnetosphere.

Astrophysics explorers have been instrumental in conducting the first astronomical sky surveys in the gamma ray, x-ray, ultraviolet, infrared, and low frequency radio regions of the electromagnetic spectrum.

In FY 1986, development will continue on the Cosmic Background Explorer (COBE), the Extreme Ultraviolet Explorer (EUVE), 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 1 micrometer and 9.6 millimeters. The detailed information which COBE will provide on the spectral and spatial distribution of low energy background radiation is expected to yield significant insight into the basic cosmological questions of the origin and evolution of the universe. Funding in FY 1966 will continue development and testing of the three COBE instruments and the spacecraft system. Mission design work will continue in FY 1986 on EUVE, which will carry out the first detailed all-sky survey of extreme ultraviolet radiation between 100 and 900 angstroms--a hitherto unexplored portion of the electromagnetic spectrum. In 1989 the EUVE mission will be launched using flight systems returned from the then completed Solar Maximum Mission (SMM). The EUVE/SMM spacecraft bus system will be available for in-orbit change-out of instruments, thus allowing the reuse of the original SMM spacecraft for missions like the X-Hay Timing Explorer, ROSAT a cooperative project between the Federal Republic of Germany and the United States, will perform high resolution imaging studies of the x-ray sky. The United States will provide the instrument and launch services, and Germany will provide the spacecraft and other instrumentation.

The Combined Release and Radiation Effects Satellite (CRRES) will be a NASA scientific experiment flown on an Air Force mission in 1988. The NASA CRRES experiment will be chemical releases in orbit to be observed from ground- and airborne-based instruments. The Heavy Nuclei Collector (HNC) will consist of an array of passive comic ray detectors to fly on the second Long-Duration Exposure Facility (LDEF). Scheduled for launch in 1986, the San Marco-D mission, a cooperative project with Italy, will include a group of U.S. experiments to study the relationship between solar activity and the Earth's meterological phenomena. FY 1986 funding will also support definition studies of potential future explorer missions, including the X-Ray Timing Explorer and the Far Ultraviolet Spectroscopy Explorer.

CHANGES FROM FY 1986 BUDGET ESTIMATE

The total funding for explorers in FY 1986 was reduced by $4.5 million primarily to accommodate continued technology activities for the Gravity Probe-B. In addition reallocations were made between individual explorers to meet mission requirements and to restore Advanced Study funding.

BASIS OF FY 1987 ESTIMATE

The FY 1987 funding is required to continue COBE integration and test, to complete the United States' instrument activities on ROSAT, and to continue the CRRES and HNC developments. In addition development for the EUVE will continue, including preparation for the recovery of the SMM spacecraft and interface definition for the EUVE/SMM bus.

BASIS OF FY 1987 W I N G REQUIREMENT

MISSION OPERATIONS AND DATA ANALYSIS

	1985 Actual	1986 Budget Estimate	1986 Current Estimate	1987 Budget Estimate
		(Thousands of Dollars)		
High energy astronomy observatory extended mission....................	5,632	4,500	4,700	3,500
Solar maximum mission extended mission.............................	1,507	4,300	3,500	8,500
Solar maximum mission retrieval/repair mission.............................	7,500	3,400	3,400	---
Hubble Space Telescope operations.....	54,100	57,300	57,300	68,500
Hubble Space Telescope maintenance and refurbishment.......................	20,600	30,700	30,400	69,100
Explorers.............................	19,761	19,700	18,700	23,100
Total...............................	109,100	119,900	118,000	172,700

OBJECTIVES AND STATUS

The purpose of the mission operations and data analysis effort is to conduct operations and analyze data received from the physics and astronomy spacecraft after launch. The program also supports the continued 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 operation control centers and related data reduction and engineering support activities, are typically carried out under a variety of mission support or center support contracts.

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 1986 BUDGET ESTIMATE

The total funding in FY 1986 was decreased by $1.9 million primarily to accommodate continued technology activities for the Gravity Probe-B. In addition a reallocation was made to meet HEAO data analysis requirements.

BASIS OF FY 1987 ESTIMATE

During FY 1387, the first year *of* Hubble Space Telescope (HST) operational use, HST mission operations and data analysis funding will primarily provide for scientific research and preparation for the first planned maintenance mission. Research funds will be granted to approximately 125 research teams selected for this initial period. Research and publication of results will be done at both the Space Telescope Science Institute and at researcher's home institutions. Funds also provide for an operations mission contractor, ground system maintenance and enhancement, design and development of second generation scientific instruments and development of orbital replacement units required during servicing. FY 1987 funds will provide support for the continued mission operations and data analysis activities for the International Ultraviolet Explorer and the Solar Maximum Mission, continued analysis of the extensive data obtained by the Infrared Astronomical Satellite and the High Energy Astronomy Observatories (HEAO). The FY 1987 funding will provide for the continued support of the data analysis and Guest Investigator programs on the HEAO-2 and -3 Missions.

BASIS OF FY 1986 FUNDING REQUIREMENT

RESEARCH AND ANALYSIS

	1985 Actual	1986 Budget Estimate	1986 Current Estimate	1987 Budget Estimate
		(Thousands of Dollars)		
Supporting research and technology..,.	22,300	27,900	30,700	30,300
(Gravity Probe-B Definition)	(3,900)	(800)	(9,000)	(9,000)
Advanced technology development.......	12,100	8,500	15,100	14,600
Data analysis......	5,500	5,900	5,700	6,200
Total................................	39,900	42,300	51,500	51,100

OBJECTIVES AND STATUS

This program provides for the research and technology base necessary to define, plan and support flight projects. Preliminary studies to define missions and/or payload requirements are carried out, as are theoretical and ground-based supporting research and advanced technology development (ATD). Activities included are supporting research and technology (SR&T), ATD, and data analysis.

o Supporting Research and Technology (SR&T): The objectives of supporting research and technology are to: (1) optimize the return expected from future missions by 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; and (4) strengthen the technological base for sensor and instrumentation development and conduct the basic research necessary to support our understanding of astrophysics and solar-terrestrial relationships.

  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 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 will probably enable spacecraft to carry instruments for astronomical observations which have increases of orders of magnitude in sensitivity and improved resolution over currently available detectors.

The SR&T program carries out its objectives through universities, non-profit 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 may be adequately defined before the missions are proposed for implementation.

  Candidate missions for the 1980's and early 1990's 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 and a resolution increase of nearly a factor of twenty. The SIRTF will observe faint, cool infrared sources in the universe and 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. During FY 1986, major emphasis will be on the AXAF competitive Phase B definition as well as continued technological preparation for SIRTF.

- Data Analysis: The acquisition, analysis and evaluation of data represents the primary purpose of the laboratory, balloon, rocket and spacecraft activities. While a considerable amount of analysis is done during the prime project phase, experience has shown that considerably more time is required to reap the full benefit from these programs. This will come about only when the data is correlated with other projects, when detailed cause-and-effect studies are made with data sets from other sources, when very long-term (e.g., one solar cycle) effects can be studied by using complementary sets of data, and when new ideas that originate from the results of the initial analysis can be tested. For example, astronomical image processing facilities have been developed to take advantage of high technology developed under the Landsat and planetary programs. This technology allows astronomers to extract a maximum amount of information from the data they obtain from standard photographic emulsions and more advanced imaging techniques such as the charge-coupled devices now being ground tested for use on the Hubble Space Telescope.

CHANGES FROM FY 1906 BUDGET ESTIMATE

The total funding in FY 1986 was increased by $9.2 million primarily to accommodate the continued technology activities for Gravity Probe-B. In addition reallocations were made to reflect the Advanced X-Ray Astrophysics Facility and Space Infrared Telescope Facility efforts in FY 1986.

BASIS OF FY 1907 ESTIMATE

During FY 1987, 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 1987 funding will also support continued studies on future 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 1987, 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-5 activities in FY 1987 are designed to verify the entire GP-B design, leading to confidence in the information necessary to decide if we should enter into the next phase of design and development activities.

BASIS OF FY 1987 FUNDING REQUIREMENT

SUBORBITAL PROGRAMS

	1985 Actual	1986 Budget Estimate	1986 Current Estimate	1987 Budget Estimate
		(Thousands of Dollars)		
Sounding rockets......................	25,680	25,700	25,400	26,500
Airborne science and applications.....	22,000	23,400	26,300	24,100
Balloon program......................	6,767	7,6013	6,100	7,900
Spartan............................	4,253	5,700	5,700	5,900
Total..............................	58,700	62,400	63,500	64,400

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 domestic and 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.

Of significant interest was a campaign in Greenland in FY 1985 to be followed by an additional campaign in FY 1987. Two launches will be conducted in FY 1986 to observe Halleys Comet.

o Airborne Science and Applications:

Research with instrumented jet aircraft has been an integral part of the overall NASA program in physics and astronomy since 1965. For astronomy research, the airborne science and applications program utilizes a C-141 instrumented with a 91-centimeter infrared telescope. The C-141 "Kuiper Airborne Observatory", which began operational flights in 1974, is a full-scale, manned facility. This aircraft provides a large payload capacity and facilities for extending observations over any region of the Earth, and can operate at high altitudes (nearly 13 kilometers), in order to provide a cloud-free site for astronomical observations and auroral geophysics experiments. The possibility of conducting observations at this altitude, above most of the infrared-absorbing water vapor of the Earth's atmosphere, has been essential in expanding astronomical observations in the infrared region of the electromagnetic spectrum from one micrometer to hundreds of micrometers.

In FY 1985 approximately 70 science flights were flown with the C-141 to make far-infrared observations, including exploration of the star-forming regions and of other areas in our own galaxy. A strong infrared source was detected near the galactic center, suggesting the presence of a black hole. In FY 1986, nearly 80 flights are planned, including an expedition to Australia in the spring in order to make detailed observations of Comet Halley near perihelion and to study other sources only visible in the southern hemisphere. C-141 observations in December 1986 have already discovered the presence of water vapor in Comet Halley.

This program also provides flight support to other major segments of the Space Science and Applications program, with an aircraft fleet currently consisting of two U-2C's, one ER-2, one Learjet, and one C-130. In addition, a replacement aircraft is being acquired to replace the CV-990 research facility, "Galileo II", which was destroyed in a fire in 1985. These aircraft serve as test beds for newly-developed instrumentation and permit the demonstration of new sensor concepts prior to their flight on satellites and the Spacelab. The data acquired during these flights are used to refine algorithms and to develop ground data handling techniques. An example of such activities is flights in the ER-2/U-2C's to acquire simulated thematic mapper data. Another principal use of ER-2/U-2C's is to 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 the study of stratospheric transport mechanisms.

o Balloon Program:

For the development of scientific experiments for space flight and for independent scientific missions, it is desirable to test the instrumentation in the space radiation environment and to make observations at altitudes which are above most of the water vapor in the atmosphere, particularly for observations in infrared, gamma ray, and cosmic ray astronomy. In many instances it is necessary, because of size and weight, as well as low cost, to fly these experiments on balloons.

In addition to the level of effort observing program, significant emphasis has and will be placed on R&D efforts to increase reliability in flight missions requiring a heavy lift capability (i.e. greater than 3500 lbs).

The balloon program funding is required for purchase of balloons, helium, launch services, tracking and recovery, and maintenance and operations of the National Science Balloon Facility (NSBF) at Palestine, Texas. This facility supports the launch of over 75 to 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 which are flown on balloons is provided from supporting research and technology programs.

o Spartan Program:

The Spartans are low-cost Shuttle payloads flown as autonomous subsatellites to be 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 currently underway. The Spartan program will continue to mature with a major milestone in 1986 being the launch of Spartan Halley, which will record ultraviolet light emitted by the comet's chemistry when it is closest to the sun and most active. A third Spartan mission, to be flown in FY 1987, will consist of a 17-inch diameter Solar Telescope and include an ultraviolet coronagraph and a white light coronagraph to measure the intensity and scattering properties of solar light.

CHANGES FROM FY 1986 BUDGET ESTIMATES

The total funding in FY 1986 was increased by $1.1 million. This increase is a net of actions to provide 6.9 million within the suborbital program, primarily to accommodate modifications to the replacement aircraft for the CV-990 which was destroyed in an accident.

BASIS OF FY 1987 ESTIMATE

FY 1987 funds will provide for continuation of the sounding rocket program, for continuation of the development of a full complement of Spartans and for the continuation of the balloon program as well as management and operation of the NSBF. This funding is also required to continue definition activities on potential future long-duration balloon flights. In FY 1987, the Airborne Science and Applications funding will be used to continue operation of the Kuiper Airborne Observatory, to fly the U-2C's, ER-2, and Learjet to continue infrared astronomy exploration, acquire stratospheric air samples, test newly developed instrumentation, permit the demonstration of new sensor concepts, etc.

LIFE
SCIENCES

RESEARCH AND DEVELOPMENT

FISCAL YEAR 1987 ESTIMATES

BUDGET SUMMARY

OFFICE OF SPACE SCIENCE AND APPLICATIONS

LIFE SCIENCES PROGRAM

SUMMARY OF RESOURCES REQUIREMENTS

	1985 Actual	1986 Budget Estimate	1986 Current Estimate	1987 Budget Estimate	Page Number
		(Thousands of Dollars)			
Life sciences flight experiments......	27,100	33,400	34,000	36,700	RD 4-5
Research and analysis..................	35,200	38,600	35,900	38,000	RD 4-7
Total..............................	62,300	72,000	69,900	74,700	
Distribution of Program Amount By Installation					
Johnson Space Center..................	22,329	26,550	22,058	26,860	
Kennedy Space Center..................	2,524	2,100	2,655	2,695	
Goddard Space Flight Center...........	310	200	383	410	
Jet Propulsion Laboratory..............	316	1,500	1,397	1,575	
Ames Research Center...	25,709	28,850	27,859	30,345	
National Space Technology Laboratories	50	100	47	55	
Langley Research Center...............	523	600	495	510	
Headquarters..........................	10,539	12,100	15,006	12,250	
Total..............................	62,300	72,000	69,900	74,700	

RESEARCH AND DEVELOPMENT

FISCAL YEAR 1987 ESTIMATES

BUDGET WARY

OFFICE OF SPACE SCIENCE AND APPLICATIONS — **LIFE SCIENCES PROGRAM**

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 wgightlessness; 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 ana 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 1987 FUNDING REQUIREMENT

LIFE SCIENCES FLIGHT EXPERIMENTS

	1985 Actual	1986 Budget Estimate	1986 Current Estimate	1987 Budget Estimate
		(Thousands of Dollars)		
Life sciences flight experiments......	27,100	33,400	34,000	36,700

OBJECTIVES AND STATUS

The objective of the Life Sciences Flight Experiments program is to assimilate information and scientific questions from the various life sciences disciplines and translate them into payloads designed to expand our understanding of the basic physiological mechanisms involved in adaptation to weightlessness. The program includes selection, definition, inflight execution, data analysis, and reporting on medical and biological investigations involving humans, animals and plants. Past experience indicates that humans clearly undergo physiological changes in weightlessness. Thus far these changes appear to be reversible upon return to Earth; however, many of the observed changes are physiologically significant and are not well understood. With weightless exposure beyond several months, these changes may prove irreversible. Shuttle/Spacelab missions are suitable for gaining a greater understanding of the early response to weightlessness, which will improve the management of several existing problems (e.g., space adaptation syndrome) and will enhance the confidence of estimating the physiological consequences of more sustained weightless exposure (e.g. Space Station).

Current activities include the development of life sciences flight experiments to be flown on the first dedicated Life Sciences mission (Space Life Sciences -1 (SLS-1)) which is scheduled for early 1987 and will concentrate on human investigations. Many of the experiments and associated flight hardware flown on earlier Shuttle flights have supported and enhanced the preparations for SLS-1 and subsequent missions, In addition, experiment development activities are currently underway to support the flight of the first International Microgravity Laboratory-1 (IML-1) mission in mid 1987. Human vestibular experiments, plant investigations, and animal support hardware test and checkout are planned.

BASIS OF FY 1967 FUNDING REQUIRMENT

RESEARCH AND ANALYSIS

	1985 Actual	1986 Budget Estimate	1986 Current Estimate	1987 Budget Estimate
	(Thousands of Dollars)			
Life sciences research and analysis...	35,200	38,600	35,900	38,000

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 investigations planned for SLS-1 and IML-1 explore the known problems of manned space flight through the use of both human and animal subjects, and also include key investigations in gravitational biology. Principal investigators will examine cardiovascular adaptation, space adaptation syndrome, muscle atrophy, bone demineralization, early anemia in weightlessness, and the effects of weightlessness on plant and animal development. The SLS-1 mission will 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 1986 BUDGET ESTIMATE

Increased funding is required in FY 1986 to provide $2.5 million for modifications to the Research Animal Holding Facility which is used on Shuttle Flights. This increase has been partially offset through changes associated with other flight projects.

BASIS OF FY 1987 ESTIMATE

FY 1987 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 and complement.

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 1986 BUDGET ESTIMATE

The decrease of 82.7 million in FY 1986 is due to a directed $4.0 million Congressional reduction which was partially offset by reallocations from other programs. The reduction will be accomplished by a general decrease in the level of activity.

BASIS OF FY 1987 ESTIMATE

The Space Medicine program will collect information on occupational exposures in zero-gravity on each Shuttle flight; conduct inflight clinical testing of countermeasures, especially in the areas of cardiovascular deconditioning, vestibular problems and muscle 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 making 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, muscle atrophy and cardiovascular deconditioning will be studied so that appropriate countermeasures can be devised. At the same time, problems 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 information will be required to determine the proper radiation shielding of humans in space. The performance and efficiency of flight crews will be emphasized by research of psychology and human factors.

The Advanced Life Support Systems program will continue to investigate basic biological processes and physical methods to control the interior environments of manned 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 animal gravity sensing systems and gravitational affects on plant and animal reproduction and development. Research which leads to or includes space flight experiments will be emphasized with the objective of resolving discrete biological problems.

The Exobiology program will emphasize the development of new flight experiment concepts to clarify the non-biological mechanisms for the synthesis of biologically significant molecules in space, and completing definition of systems 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 our estimating 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 1987 ESTIMATES

BUDGET SUMMARY

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

SUMMARY OF RESOURCES QU ME

	1985 Actual	1986 Budget Estimate	1986 Current Estimate	1987 Budget Estimate	Page Number
		(Thousands of Dollars)			
Galileo development	58.800	39.700	54.200	---	RD 5-5
Magellan (VRM)	92,500	112.000	109.300	66,700	RD 5-7
Ulysses (ISPM)	9.000	5.600	5.600	---	RD 5-9
Mars Observer (MGCO)	13.000	43.800	37.800	62.900	RD 5-11
Mission operations and data analysis	56.100	95.000	83.000	130.200	RD 5-13
Research and analysis	61.500	62.900	62.900	63.500	RD 5-15
Total	290.900	359.000	352.800	323.300	

Distribution of Program Amount by Installation

	1985 Actual	1986 Budget Estimate	1986 Current Estimate	1987 Budget Estimate
Johnson Space Center	10.482	11.105	10.770	10.873
Marshall Space Flight Center	16	100	11	8
Goddard Space Flight Center	3.751	3.620	5.601	11.884
Jet Propulsion Laboratory	225.878	284.755	284.262	249.734
Ames Research Center	8.593	10.159	9.478	10.462
Langley Research Center	25	---	26	26
Headquarters	42.155	49.261	42.652	40.313
Total	290.900	359.000	352.800	323.300

PROGRAM OBJECTIVES AND JUSTIFICATION

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 will then carry 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.

The Galileo orbiter/probe mission to Jupiter will be launched in May 1986 by the Space Shuttle/Centaur Upper Stage. 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 also be launched in May 1986 on the Shuttle/Centaur Upper Stage.

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 is scheduled for launch in 1988 from the Shuttle and will use a Shuttle/Centaur Upper Stage.

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 be a relatively low-cost mission utilizing a modified Earth-orbiting spacecraft, thereby benefitting from aerospace industry's earlier investment in development.

This past year 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 are continuing through our involvement with the 1986 encounters 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 continuing to study a Comet Rendezvous/Asteroid Flyby (CRAF) mission in which a Mariner Mark II spacecraft would make long-term observations of an active comet, together with a close flyby of an asteroid.

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 1987 FUNDING REQUIREMENT

GALILEO DEVELOPMENT

	1985 Actual	1986 Budget Estimate	1986 Current Estimate	1987 Budget Estimate
	(Thousands of Dollars)			
Spacecraft..............................	27,745	13,800	24,300	---
Experiments.......	10,275	7,900	9,300	---
Ground Operations	20,780	18,000	20,600	---
Total	58,800	39,700	54,200	---
Space transportation system operations	(36,600)	(44,200)	(41,100)	(---)

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.

The orbiter and probe will be launched together in May 1986 as a single combined payload using the Shuttle/Centaur Upper Stage. The mission plan includes an option for an encounter with the asteroid Amphitrite, a large (200km) main belt asteroid, in late 1986. The decision to implement the option will be made after launch, based on an assessment of the health and operational capability of the spacecraft. Subsequently, arrival at Jupiter will be in late 1988 when the orbiter 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 Themoelectric Generators (RTG's) being 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 1486, major activities of the Galileo program will include completion of testing and pre-launch acivities at JPL, retrofit of selected subsystems with more radiation resistant electronic components, and pre-launch and launch activities at the Kennedy Space Center in support of the May 1986 launch.

CHANGES FROM FY 1986 BUDGET ESTIMATE

The FY 1986 estimate reflects an increase of $14.5 million, the result of problems with the spin bearing assembly and changeout of the radiation-hardened parts on the Command and Data Subsystem and Attitude Articulation and Control Subsystem. The additional funds were made available through transfer from Galileo Mission Operations and Data Analysis ($9.5M); and by rephasing of Magellan (VRM) activity ($2.5M) and Voyager Extended Mission activity ($2.5M) to future years.

BASIS OF FY 1987 FUNDING REQUIREMENTS

MAGELLAN (FORMERLY VENUS RADAR MAPPER MISSION)

	1985 Actual	1986 Budget Estimate	1986 Current Estimate	1987 Budget Estimate
		(Thousands of Dollars)		
Spacecraft	64,325	75,800	66,400	24,800
Experiments	25,995	29,800	32,300	23,100
Ground Operations	2,180	6,400	10,600	18,800
Total	92,500	112,000	109,300	66,700
Space Transportation system operations	(28,400)	(27,500)	(39,500)	(47,800)

OBJECTIVES AND STATUS

The objective of the Magellan mission is to address fundamental 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 a bus structure, large antenna, and propulsion components from the Voyager program. Spare flight computers and other equipment will be obtained from the Galileo program after the Galileo launch in 1986.

In April 1988, the Magellan spacecraft will be launched by the Shuttle/Centaur Upper Stage on a direct trajectory to Venus. Arriving at Venus in July 1988, 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 the planet over a 243 day period (one Venus year).

During FY 1986, major activities will include completion of the design effort for the spacecraft, the radar instrument, and the mission operations system, and for the initiation of construction of the flight hardware. The major flight spacecraft subassemblies will be completed and delivered to the spacecraft contractor.

CHANGES FRM FY 1986 BUDGET ESTIMATE

The $2.7 million decrease is associated with a rephasing of activity to future years. Of this amount, $2.5 million has been reallocated for Galileo development to help solve technical problems and the balance reflects the application of the general reduction directed by Congress for Research and Development contained in the HUD-Independent Agencies Appropriation Act, 1986 (P.L. 99-160). In addition, reallocation of the funds within the project has been made based on the contractors' development schedule requirements.

BASIS OF FY 1987 ESTIMATE

FY 1987 funds will provide for completion of the radar sensor and for the assembly, integration and testing of the spacecraft system. The development of the mission operations system will be continued.

BASIS OF FY 1987 FUNDING REQUIREMENT

ULYSSES (FORMERLY INTERNATIONAL SOLAR POLAR MISSION)

	1985 Actual	1986 Budget Estimate	1986 Current Estimate	1987 Budget Estimate
		(Thousands of Dollars)		
Spacecraft............................	5,765	700	700	---
Experiments..........................	1,120	2,200	2,200	---
Ground Operations	2,115	2,700	2,700	---
Total	9,000	5,600	5,600	---
Space transportation system operations	(36,500)	(44,300)	(41,100)	(---)

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 Power Generators (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 will be launched in 1986 on the Shuttle/Centaur Upper Stage.

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 developing five of the nine principal investigator instruments, and three of the four European investigations have U.S. co-investigators. During FY 1983, the U.S. flight instruments were delivered to the ESA spacecraft developer for integration and system testing. All spacecraft testing has been completed and the spacecraft is being partially disassembled for storage until launch.

BASIS OF FY 1987 ESTIMATE

In FY 1987, operational support for ATS-3 will continue; NASA will maintain approval and policy control of the ATS 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 ATS-3 coverage. Efforts in support of a replacement system for ATS-1 will continue with low-cost, prototype ground terminal development, analyses of viable alternative satellite systems, and verifiction systems tests.

Major activities during FY 1986 include supporting U.S. principal investigators in their mission planning and for supporting ESA in pre-launch and launch activities at the Kennedy Space Center in support of the May 1986 launch.

BASIS OF FY 1987 FUNDING REQUIREMENT

MARS OBSERVER MISSION (FORMERLY MARS GEOSCIENCE/CLIMATOLOGY ORBITER)

	1985 Actual	1986 Budget Estimate	1986 Current Estimate	1987 Budget Estimate
		(Thousands of Dollars)		
Spacecraft development...........	2,010	28,600	22,400	33,100
Experiments...	8,7115	4,300	13,800	26,600
Ground Operations.....................	2,285	10,900	1,600	3,200
Total..........................	13,000	43,800	37,800	62,900
Space transporation system operations	(---)	(---)	(---)	(9,100)

OBJECTIVES AN) STATUS

The Mars Observer mission is the first planetary mission utilizing a new low-cost approach to inner solar system mission exploration. This approach, which was recommended by the 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 Mars Observer mission will be launched in 1990 using the Space Shuttle, and will be inserted into Martian orbit in 1991, where it will carry out geochemical, geophysical, and climatological mapping of the planet over a period of one Martian year which is approximately two Earth years.

In FY 1986, critical design reviews will be held for the instruments, as will the preliminary design review for the spacecraft. In addition, detailed design and fabrication of the spacecraft and instrument hardware will be initiated.

CHANGES FROM FY 1986 BUDGET ESTIMATE

The decrease of $6.0 million in the current estimate reflects Congressional direction contained in the FY 1986 NASA Authorization Act (P.L. 99-170) and the HUD-Independent Agencies Appropriation Act, 1986 (P.L. 99-160). This reduction has been accommodated by the rephasing of activity to future years. Current estimates have also been realigned to be in consonance with the procurement schedules for the spacecraft bus and for the science payload.

BASIS OF FY 1987 ESTIMATE

The FY 1987 funding is required for continuation of major fabrication efforts on both the instruments and the spacecraft, and for preparation for the critical design reviews for the flight system. Preliminary design reviews will be completed for all the instruments as well as for the mission operations development.

BASIS OF FY 1987 FUNDING REQUIREMENT

MISSION OPERATIONS AND DATA ANALYSIS

	1985 Actual	1986 Budget Estimate	1986 Current Estimate	1987 Budget Estimate
		(Thousands of Dollars)		
Galilee operations....................	---	20,000	10,500	48,000
Ulysses operations....................	---	2,000	2,300	5,300
Voyager extended mission..............	26,036	26,400	23,000	4,800
Pioneer programs.....................	6,300	7,600	7,600	8,300
Voyager/Neptune mission...............	---	9,000	9,000	30,300
Planetary flight support..............	23,764	30,000	30,600	33,500
Total..............................	56,100	95,000	83,000	130,200

OBJECTIVES AND STATUS

The objectives of the mission operations and data analysis activities are in-flight operation of planetary spacecraft and the analysis of data from these missions. Currently, two major classes of planetary spacecraft are operating--the Pioneer and the Voyager spacecraft. The planetary flight support activities are those associated with the design and development of planetary flight operation systems, and other activities that support the mission control, tracking, telemetry, and command functions for all planetary spacecraft.

The two Voyager spacecraft are now traveling through the outer solar system on trajectories that will take them into interstellar space. Voyager 1 continues to provide data on the interplanetary medium in that distant part of the solar system. In January 1986, Voyager 2 made a close flyby of the planet Uranus, the first time this planet has ever been visited by a spacecraft. The observatory phase of this encounter, which began in November 1985, will include detailed observations of the planet, its rings, and moons. After the Uranus encounter is completed, the spacecraft will continue on to the planet Neptune, where, in 1989, it will provide us with our first close look at this distant planet.

Pioneers 10 and 11 will continue to explore the outermost solar system. Pioneer 10 will soon enter the unexplored region beyond Pluto where the Sun's influence is secondary to those of true interstellar space. These spacecraft will continue the search for gravitational evidence of a tenth planet. Pioneers 6-9 are still collecting information on the interplanetary magnetic field and solar wind as they orbit the Sun. In 1986, these spacecraft are being used to observe Comet Halley as it passes in their vicinity.

The Pioneer Venus orbiter continues to obtain data from Venus' atmosphere and magnetosphere. In late 1985, the spacecraft's spin axis was adjusted to allow ultraviolet observations of Comet Halley. The Pioneer Venus is the only spacecraft able to observe the Comet at its closest approach to the Sun and is providing critical enhancements to the data to be gathered by foreign spacecraft making observations at other points later in the Comet's orbit.

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 at JPL. This facility will be a versatile, cost-effective means for carrying out multi-mission data acquisition, telemetry, image processing, and commanding of planetary and orbital spacecraft.

FY 1986 funding is supporting several major activities in 1986 -- the Voyager 2 encounter with Uranus in January, and initial operations of the Galileo and Ulysses missions, which are scheduled for launch in May. Operational support for the Voyager and Pioneer operations is also being continued, 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.

CHANCES FROM FY 1986 BUDGET ESTIMATE

The $12.0 million decrease was the result of *a* transfer of funds to Galileo development and was made available as a result of the rephasing of activity associated with Galileo Operations and Voyager Extended Mission to future years.

BASIS OF FY 1987 ESTIMATE

FY 1987 funding is required for the continued operation and data analysis activities in support of the Galileo, Ulysses, Voyager and Pioneer operations. Development activities will also be continued in FY 1987 on the Space Flight Operations Center at the Jet Propulsion Laboratory.

BASIS OF FY 1987 FUNDING REQUIREMENT

RESEARCH AND ANALYSIS

	1985 Actual	1986 Budget Estimate	1986 Current Estimate	1987 Budget Estimate
	(Thousands of Dollars)			
Supporting research and technology... .	45,100	46,000	46,000	47,400
Advanced programs.....................	9,500	10,100	10,100	10,100
Mars data analysis...	3,100	2,800	2,800	2,900
Halley's comet co-investigations and watch..........................	3,800	4,000	4, 000	3,100
Total	61,500	62,900	62,900	63 500

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 components (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 comparative studies to gain a fundamental understanding of the physical processes and laws which control the development and evolution of all planetary bodies, including the Earth. In this respect, data from the Magellan mission will be of crucial importance.

The planetary materials/geochemistry activity supports an active scientific effort to determine the chemistry, mineral composition, age, physical properties and other characteristics of solid material in the solar system through the study of returned lunar samples and meteorites and through laboratory and theoretical studies of appropriate geochemical problems. 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 development of state-of-the-art scientific instrumentation which is 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; their technological and fiscal feasibility is evaluated, and their 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 series of "low-cost" but scientifically important potential future missions.

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, more specifically, the Mars Observer mission. 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 is capitalizing on observing Comet Halley in 1985-1986 by supporting co-investigators on the European Space Agency's (ESA) Giotto mission, and by conducting complementary remote sensing investigations using both Earth-orbiting and ground-based facilities. The ESA Giotto mission will fly by Halley's Comet in 1986. Concurrently, an observation program called the International Halley Watch, coordinated by the United States, will conduct 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 instrumentation and observing techniques; (3) to help insure that data is properly documented and archived; and (4) to receive and distribute data to participating scientists.

BASIS OF FY 1987 ESTINATE

During FY 1987, 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 development of required technology to undertake future missions. Ground telescope observations will provide data complementary to that obtained from 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 1987, at specific problems in understanding the various processes that have shaped planetary surfaces, as well as geological analyses and a cartography effort based on the Galilean and Saturnian satellite imaging data acquired by Voyager. Analysis of lunar samples, meteorites, and extraterrestrial dust particles will be continued in FY 1987 to determine their chemical and physical properties and thereby derive their origin and evolutionary history. Instrument definition for potential future missions will be also be continued in FY 1987.

The FY 1987 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 the data acquired from Halley's Comet flyby of Earth.

The FY 1987 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 1987 ESTIMATES

BUDGET SUMMARY

OFFICE OF PACE SCIENCE AND APPLICATIONS — SOLID EARTH OBSERVATIONS PROGRAM

SUMMARY OF RESOURCE REQUIREMENTS

	1985 Actual	1986 Budget Estimate	1986 Current Estimate	1987 Budget Estimate	Page Number
		(Thousands of Dollars)			
Shuttle/Spacelab payloads....	12,100	23,100	23,100	21,600	RD 6-4
Geodynamics	29,900	31,700	31,700	32,100	RD 6-6
Research and analysis..	15,600	20,100	20,1110	20,400	RD 6-8
Total	57,600	74,900	74,9011	74,100	

Distribution of Program Amount by Installation

	1985 Actual	1986 Budget Estimate	1986 Current Estimate	1987 Budget Estimate
Johnson Space Center........	940	250	1,000	800
Marshall Space Flight Center..........	250	277	300	800
Goddard Space Flight Center...........	32,360	37,175	37,500	36,300
Jet Propulsion Laboratory.............	14,952	28,184	26,200	26,100
Ames Research Center.................	2,578	645	800	800
National Space Technology Laboratories	2,213	2,875	2,7011	2,800
Headquarters..................	4,307	5,494	6,400	6,500
Total.............................	57,600	74,900	74,900	74,100

RESEARCH AND DEVELOPMENT

FISCAL YEAR 1987 ESTIMATES

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

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 our understanding of the planet Earth through the study of its dynamics, the physical processes which affect its habitability, and its 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 possible commercialization upon completion of the research and development phase. 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 spectrometer 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.

BASIS OF FY 1987 FUNDING REQUIREMENT

SHUTTLE/SPACELAB PAYLOAD DEVELOPMENT

	1985 Actual	1986 Budget Estimate	1986 Current Estimate	1987 Budget Estimate
		(Thousands of Dollars)		
Imaging radar program.................	6,100	13,400	14,400	13,000
Large format camera..................	4u0	---	500	200
Advanced spectrometer.................	5,600	9,700	8,200	8,400
Total..............................	12,100	23,100	23,100	21,600

OBJECTIVES AN) STATUS

The objective of this program is to develop, test, and evaluate Earth-viewing remote sensing instruments and systems to obtain data for land remote sensing research.

Preparations are continuing for a reflight of the Large Format Camera (LFC) and the Shuttle Imaging Radar-B (SIR-B). The SIR-B will obtain a quantitative assessment of the effect of various radar viewing geometries on the mapping of surface texture and topographic features. The SIR-B instrumentation is based on an upgraded SIR-A instrument including the addition of a variable look angle antenna, digital data handling, and increased bandwidth and resolution. Data is recorded on-board and transmitted via the Tracking and Data Relay Satellite System (TDRSS). Following the reflight of SIR-B, use of the SIR-B components for use in building the next generation Shuttle Imaging Radar instrument will be reviewed. The SIR-C instrument will utilize multi-polarized, dual frequency sensor technology.

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 electronic scan, 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.

CHANGES FROM FY 1966 BUDGET ESTIMATE

The FY 1986 current estimate remains unchanged in total from the budget estimate, however funds have been provided from the previous Advanced Spectrometer estimate in order to provide funding for reflight activities under review in the Imaging Radar and Large Format Camera projects.

BASIS OF FY 1987 ESTIMATE

FY 1987 funding is required for reflight of the Large Format Camera and the Shuttle Imaging Radar-B (SIR-B) plus data analysis. FY 1987 funding is also 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 1987 FUNDING REQUIREMENTS

GEODYNAMICS

	1985 Actual	1986 Budget Estimate	1986 Current Estimate	1987 Budget Estimate
		(Thousands of Dollars)		
Crustal dynamics project..............	18,000	18,500	18,500	18,100
Laser network operations...	8,000	8,500	8,500	8,600
Research and technique development... .	3,900	4,700	4,700	5,400
Total...............................	29,900	31,700	31,700	32,100

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 five 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, new 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 ana have confirmed estimates of the viscosity of the Earth's mantle layer. Analysis of the magnetic field, using data from Magsat has confirmed (within a few percent) the diameter of the Earth's outer core (determined by seismological measurements) and has provided new data on secular variations of the magnetic field.

BASIS OF FY 1987 ESTIMATE

In FY 1987, 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 the western North America will continue in FY 1986 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 by 1988.

LAGEOS-1 and other satellites will continue to be used in FY 1987 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 1987.

Theoretical studies of crustal motion, internal Earth structure and composition, and the modeling and interpretation of geopotential fields will be continued in FY 1987. In addition, system studies of a second magnetic field satellite 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 be continued in FY 1987.

BASIS OF FY 1987 FUNDING REQUIREMENT

RESEARCH AND ANALYSIS

	1985 Actual	1986 Budget Estimate	1986 Current Estimate	1987 Budget Estimate
Biochemical processes.................	4,000	4,700	4,700	4,800
Geological processes..................	5,100	6,300	6,300	6,400
Hydrologic processes..................	2,900	5,100	5,100	5,100
Remote sensing science................	3,600	4,000	4,000	4,100
Total...............................	15,600	20,100	20,100	20,400

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, 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, the resulting algorithms are 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 spectrometery and field mapping efforts to verify spectral properties and interactions.

Biochemical processes are 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 1986 BUDGET ESTIMATE

In FY 1986 $1.5 million will be applied to modifications on the Galileo replacement aircraft.

BASIS FOR FY 1987 ESTIMATE

In FY 1987 emphasis will be 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. A major field experiment will be conducted in 1987 under the auspices of ISLSCP and the World Climate Research Program.

The FY 1987 activities will also emphasize studies to determine continental rock type and erosion processes in semi-arid regions in sedimentary basins. Newly developed sensor systems such as the Advanced Visible-Infrared Imaging Spectrometer (AVIRIS), quad-polarization L- & C-Band imaging radar and the Thermal Visible-Infrared Imaging Spectrometer (TIMS) 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 1987 ESTIMATES

BUDGET SUMMARY

OFFICE OF SPACE SCIENCE AND APPLICATIONS

ENVIRONMENTAL OBSERVATIONS PROGRAM

SUMMARY Of RESOURCES REQUIREMENTS

	1985 Actual	1986 Budget Estimate	1986 Current Estimate	1987 Budget Estimate	Page Number
	(Thousands of Dollars)				
Upper atmosphere research and analysis	31,UOO	33,000	33,000	33,400	RD 7-6
Atmospheric dynamics and radiation research and analysis.	28,500	30,300	30,300	30,900	RD 7-6
Oceanic processes research and analysis....	19,400	20,600	20,600	20,800	RD 7-11
Space physics/research and analysis..	16,700	17,800	17,800	18,000	RD 7-13
Payload and instrument development	7,800	5,600	5,600	12,000	RD 7-15
Earth radiation budget experiment.....	8,100	2,000	2,000	---	RD 7-18
Extended mission operations.	29,500	37,000	37,000	33,600	RD 7-19
Interdisciplinary research and analysis	1,000	1,000	1,000	1,100	RD 7-22
Tethered satellite payloads......	3,000	4,500	4,500	1,000	RD 7-23
Scatterometer.........................	12,000	31,700	14,000	35,900	RD 7-25
Upper atmosphere research satellite mission............................	55,700	134,000	124,000	152,200	RD 7-27
Ocean topography experiment..........	---	---	---	29.000	RD 7-29
Total.............................	212,700	317,500	289,800	367.900	

	1985 Actual	1986 Budget Estimate	1986 Current Estimate	1987 Budget Estimate
		(Thousands of Dollars)		
Distribution of Program Amount by Installation				
Johnson Space Center	170	477	200	200
Marshall Space Flight Center	8,200	10.315	11.200	8.500
Goddard Space Flight Center	126.416	206.466	190.300	219.500
Jet Propulsion Laboratory	31.266	56.057	31.800	82.900
Ames Research Center	5.559	3.662	2.700	2.700
Langley Research Center	10,516	10,503	19.200	18,600
National Space Techonology Laboratories	60	237	100	100
Headquarters	30.513	29.783	34.300	35.400
Total	212.700	317.500	289.800	367.900

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 knowleage 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 and dedicated spacecraft; 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 1987.

The Earth Radiation Budget Satellite (ERBS) was successfully launched in 1984, and data continues to be collected from the satellite. The ERBE instruments which will be flown on NOAA-G have been completed. NOAA-F was launched December 12, 1984, with a set of ERBE instrumentation; the NOAA-G launch is scheduled for March 1986. 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 1987 on a delayed basis on the NASA Scatterometer (NSCAT), which will be flown on the Navy Remote Ocean Sensing System (N-ROSS) in late 1990, to acquire global ocean data for operational and research use by both the military and civil sectors.

The Ocean Topography Experiment (TOPEX) is being proposed as a new start in FY 1987; 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 will also provide supporting solar wind measurements for the March 1986 Halley missions. In March-May 1986, the Polar Region and Outer Magnetosphere International Study (PROMIS) will coordinate 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 reflight activities, along with flight of opportunity instrument development efforts provide the spaceborne data necessary to conduct basic research projects as well as provide calibration, 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) spacecraft.

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 1987 FUNDING REQUIREMENT

UPPER ATMOSPHERE RESEARCH AND ANALYSIS

	1985 Actual	1986 Budget Estimate	1986 Current Estimate	1987 Budget Estimate
		(Thousands of Dollars)		
Upper atmospheric research............	18,700	19,900	19,900	20,100
Stratospheric processes........,.....	6,400	6,800	6,8011	6,9011
Tropospheric chemistry................	5,900	6,300	6,300	6,400
Total..............................	31,000	33,000	33,000	33,400

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.

CHANGES FROM FY 1986 BUDGET ESTIMATE

Although there is no change in total, in FY 1966, $1.4 million will be applied from benefitting research areas to modifications on the Galileo replacement aircraft.

BASIS OF FY 1987 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 1987, 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 1987 to aid in the understanding of large-scale atmospheric processes.

The comparison of balloon, aircraft, and ground-based measurements will be continued in FY 1987 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 1987 to ensure that new technologies are put to use in improving the capability and cost efficiency of tropospheric composition and upper atmosphere measurements.

BASIS OF FY 1987 FUNDING REQUIREMENT

ATMOSPHERIC DYNAMICS AND RADIATION RESEARCH AND ANALYSIS

	1985 Actual	1986 Budget Estimate	1986 Current Estimate	1987 Budget Estimate
		(Thousands of Dollars)		
Global-scale atmospheric processes research and analysis	13,400	14,200	14,200	14,400
Mesoscale atmospheric processes research and analysis	7,600	8,000	8,000	8,200
Climate research and analysis	7,500	8,100	8,100	8,300
Total	28,501,	30,300	30,300	30,900

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 capability 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 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 aynamics 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 the GOES-Next 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 detailed planning for the First ISCCP Regional Experiment (FIRE) has been completed through a national project office located within NASA. 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.

CHANGES FROM FY 1986 BUDGET ESTIMATE

Although there is no change in total, in FY 1986 $1.4 million will be applied from benefitting research areas to modifications on the Galileo replacement aircraft.

BASIS OF FY 1987 ESTIMATE

FY 1987 funding is required to conduct aircraft flights to study the detail of flows around thunderstorms and fronts, continue comparison of models, study atmospheric scale interactions, and develop techniques to display model outputs in 3-dimensions. In FY 1987 three major interagency field experiments will significantly improve our understanding of the atmosphere for air/ocean interaction which generate crippling New England snowstorms (GALE), the physics of small strong downdrafts called microbursts which are on the scale of tornadoes (MIST), and the mechanism of regional precipitation quantification (SPACE) through space, aircraft, radar balloon, and surface-based observations. 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 1987.

BASIS OF FY 1987 FUNDING REQUIREMENT

OCEANIC PROCESSES RESEARCH AND ANALYSIS

	1985 Actual	1986 Budget Estimate	1986 Current Estimate	1987 Budget Estimate
	(Thousands of Dollars)			
Research and analysis.................	19,400	20,600	20,600	20,800

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. The spaceborne observational technique of prime importance, and its corresponding scientific use for each area are as follows. 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 concentration, 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).

CHANGES FROM FY 1986 BUDGET ESTIMATE

In FY 1986 $.3 million will be reallocated from benefitting research areas to modifictions on the Galileo replacement aircraft.

BASIS OF FY 1987 ESTIMATE

In FY 1987, 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 for potential flight of an Ocean Color Imager for the NOAA-K spacecraft will be performed. 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. With the transition of the Pilot Ocean Data System from a technical demonstration to a scientific support facility completed in FY 1986, coordination activities with the Office of Naval Research, NSF, and NOAA will be pursued in order to assure that appropriate computing facilities and data archives will be available for the utilization of spaceborne observations from ocean-research 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 1987 FUNDING REQUIREMENT

SPACE PHYSICS RESEARCH AND ANALYSIS

	1985 Actual	1986 Budget Estimate	1986 Current Estimate	1987 Budget Estimate
	(Thousands of Dollars)			
Plasma physics SR&T and data analysis	10,500	12,300	10,600	12,300
Advanced technology development	2,900	2,000	3,800	2,100
Solar terrestrial theory..............	3,300	3,500	3,400	3,600
Total................................	16,700	17,800	17,800	18,000

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 the near planetary environment and neutral atmosphere. 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 the 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.

The major thrust of the space physics program is directed at studies of the near Earth 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 to the Earth sciences community, but also there are other practical components concerned with these aspects, 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, and the Active Particle Tracer Explorers (AMPTE) taking such measurements. PMPTE has carried out a program of coordinated chemical releases and plasma diagnostics to investigate solar wind plasma entry into the magnetosphere and energization as the plasma flows towards the atmosphere. The campaign called PROMIS (Polar Region and Outer Magnetosphere International Study) will take full advantage of these satellite systems during March-May 1986 when the Swedish Viking satellite contributes toward a unique opportunity for correlative measurements of the Earth's magnetosphere on a large scale. There is an active program of sounding rocket and balloon investigations aimed principally at spatially or temporally isolated atmospheric, ionospheric or magnetospheric phenomena. Active theoretical, modeling and supporting laboratory activities are also being conducted.

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 the solar terrestrial problem by using both fundamental process calculations and numerical models of large scale phenomena.

CHANGES FRM FY 1986 BUDGET ESTIMATE

In total, the FY 1986 current estimate remains the same as the budget estimate. However, within the program, $1.8 million has been transferred to ATD activities to enhance Solar-terrestrial instrument development.

BASIS OF FY 1987 ESTIMATE

During FY 1987, 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 continued during FY 1987 on such missions as the potential cooperative solar terrestrial research with the Japanese and Europeans, follow-on missions for the U.S.-Italian Tethered Satellite System, and on the chemical release investigations in support to the Combined Chemical Release and Radiation Effects Satellite (CRRES) which is being developed by the Department of Defense.

The solar terrestrial theory program will be continued during FY 1987. In addition, a comprehensive and quantitative aggregate model of solar-terrestrial interaction will continue to be developed.

BASIS OF FY 1967 FUNDING REQUIREMENT

PAYLOAD AND INSTRUMENT DEVELOPMENT (ENVIRONMENTAL OBSERVATIONS)

	1985 Actual	1986 Budget Estimate	1986 Current Estimate	1987 Budget Estimate
		(Thousands of Dollars)		
Measurement of Air Pollution from Satellites (MAPS).	700	500	5bb	800
Atmosphere Trace Molecules Observed by Spectroscopy (ATMOS)..	2,6011	1,800	1,600	2,400
Active Cavity Radiometer (ACR, ACRIM)	1,800	900	1,100	1,000
Light Detection and Ranging (LIDAR). ..	2,500	1,600	1,800	2,600
Principal investigator instrument development and reflight program....	200	800	600	200
Solar terrestrial instrument development......	(2,900)*	(2,000)*	(3,800)*	5,000
Total	7,800	5,600	5,6110	12,000

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

OBJECTIVES AND STATUS

The Space Transportation System offers the unique opportunity for frequent 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 Measurement of Air Pollution from Satellites (MAPS) experiment is a gas-filter correlation radiometer designed to measure the levels of tropospheric carbon monoxide and the extent of interhemispheric mass transport in the lower atmosphere. The instrument was flown successfully on two

Shuttle flights. It is approved for four 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 planned on both SRL-2 (Shuttle Radar Lab) and EOM 4 (Earth Observations Mission).

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; it will be reflown on the Earth Observation Mission (EOM) series starting in 1986. 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 response to an Announcement of Opportunity, a number of principal investigator class instruments were selected for development. Payloads currently under development include the Active Cavity Radiometer-I (ACR-1) which is designed to aid in the study of the Earth's climate and the physical behavior of the Sun. Reflights of ACR-1 on future EOM flights are planned. Other experiments have also been selected for reflight, including some instruments which were flown on the Shuttle orbital flight tests, Spacelab 1 and Spacelab 2.

Solar-terrestrial instrument development activities will provide state-of-the-art instrumentation for flight opportunities on international spacecraft and various U.S. spacecraft of opportunity including those of other U.S. agencies and the Space Shuttle. 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.

Discussions are continuing with other U.S. agencies--the USAF Air Weather Service, the DOD Space Test Program (STP) and NOAA--about joint missions to characterize solar activity, the solar wind and the reaction of the earth's environment as source measurements.

CHANGES TO FY 1986 BUDGET ESTIMATE

The FY 1986 current estimate remains unchanged from the budget estimate in total; however there has been some transfer of funds within the Shuttle/Spacelab Payload elements to allow for an increase in the LIDAR development and the provision of funding for ACR reflight.

BASIS OF FY 1987 ESTIMATE

FY 1987 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 1987 funding is required to support the reflights of ATMOS which includes continued science team activities, data processing and analysis, post- and pre-flight calibration and limited refurbishments.

FY 1987 funding is also required to continue the Active Cavity Radiometer (ACR) data processing, science team activities, and refurbishment for reflight on future Shuttle EOM flights, and development of a free-flyer version of ACR. The principal investigator instrument development and reflight program will be continued with research efforts concentrated on atmospheric chemistry, solar intensity and variability, and upper atmospheric winds.

Development activities will continue on the international (U.S. and French) Light Detection and Ranging (LIDAR) instrumentation following completion of conceptual definition, breadboard laboratory activities, and preliminary design reviews. 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 1987, Solar Terrestrial Instrument Development will begin with increased efforts focusing on continued activities with the Japanese Institute for Space and Astronautical Sciences (ISAS) for a mission to explore the earth's geotail. 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, the European Space Agency (ESA) and NASA will continue planning a joint solar-terrestrial research effort to make 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 SOHU 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 1987 FUNDING REQUIREMENT

EARTH RADIATION BUDGET EXPERIMENT

	1985 Actual	1986 Budget Estimate	1986 Current Estimate	1987 Budget Estimate
		(Thousands of Dollars)		
Earth radiation budget experiment.....	8,100	2,000	2,000	---

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 NUAA-F and NUAA-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 ana 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 EHBS spacecraft was launched by the Space Shuttle to an altitude of 30U 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 is planned for launch in early 1986.

The FY 1986 funding is required to support the operation of ERBS and analysis of the data collected by experiments on ERBS, NOAA-F and NOAA-G. Additional FY 1986 and subsequent funding for ERBE mission operations and data analysis will be provided through the Environmental Observations Extended Mission Operations budget.

BASIS OF FY 1987 FUNDING REQUIREMENT

EXTENDED MISSION OPERATIONS (ENVIRONMENTAL OBSERVATIONS)

	1985 Actual	1986 Budget Estimate	1986 Current Estimate	1987 Budget Estimate
		(Thousands of Dollars)		
Operations for the extended mission of:				
Nimbus 7	6,200	6,6011	6,200	5,000
Solar mesosphere explorer (SME)	1,000	2,300	2,000	900
Correlative measurement/solar backscatter ultraviolet instrument	2,300	1,400	2,200	3,9110
Earth radiation budget experiment extended operations	1,5110	7,100	7,200	8,900
Active magnetospheric particle tracer explorer extended operations	2,000	3,800	3,600	3,000
International sun-earth explorers	6,700	6,600	6,600	4,600
Interplanetary monitoring platform	800	600	700	700
Dynamics explorer extended operations	9,000	8,500	8,500	6,600
San marco extended operations	---	100	---	---
Total	29,500	37,000	37,0110	33,600

OBJECTIVES AND STATUS

The objectives of the extended mission operations 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-NOAA 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 1987 to support the stong 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 temperature. 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. WE 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, the Interplanetary Monitoring Platform (IMP), and the Dynamics Explorers which are still operational. Recent analysis of DE-1 data have shown coupling of plasma and mesospheric chemistry. IMP continues to provide the only available source of solar wind input measurements to the Earth. The combined measurements of ISEE-1 and -2 in the same eccentric orbit continue to provide important data to study the structure and motions of the essential magnetospheric boundaries, bow shock, magnetopause, plasma pause and sheet. ISEE-3 made important first time measurements of solar wind-magnetosphere interraction in the Earth's distant geotail. The ISEE-3 spacecraft, renamed the International Cometary Explorer (ICE), accomplished a successful encounter with Comet Giacobini-Zinner in 1985. ICE will also provide complementary solar wind measurements upstream of Comet Halley in late 1985 and early 1986.

CHANGES FROM 1986 BUDGET ESTIMATE

The FY 1986 current estimate remains unchanged from the budget estimate in total, however adjustments have been made within the extended operations program to better align the funding with the actual operating spacecraft requirements and to apply $.5 million to modifications on the Galileo replacement aircraft.

BASIS OF FY 1987 ESTIMATE

FY 1987 funding is required to support continuing mission operations and data analysis activities for the International Sun-Earth Explorers, the Interplanetary Monitoring Platform and the Dynamics Explorers. Extended operations support of the Active Magnetospheric Particle Tracer Explorer, which was launched in 1984, will be continued in FY 1987. 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 WE 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 1987; these ~~in situ~~ observations are needed to verify the quality of remote observations and improve our ability to interpret them.

In addition, FY 1987 funding is required for the operating EHBE instruments, payloads, and data set processing and analysis that will occur as the third set of instruments is launched on NOAA-G.

BASIS OF FY 1987 FUNDING REQUIREMENT

INTERDISCIPLINARY RESEARCH

	1985 Actual	1986 Budget Estimate	1986 Current Estimate	1987 Budget Estimate
		(Thousands of Dollars)		
Interdisciplinary research and analysis	1,000	1,000	1,000	1,100

OBJECTIVES AND STATUS

Interdisciplinary research activities need to be conducted to quantitatively characterize the Earth's chemical, physical, and biological 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 phenomena 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 1987 ESTIMATE

In FY 1987, 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 1987 FUNDING REQUIREMENT

TETHERED SATELLITE PAYLOADS

	1905 Actual	1986 Budget Estimate	1986 Current Estimate	1987 Budget Estimate
		(Thousands of Dollars)		
Tethered satellite payloads......... ..	3,000	4,500	4,500	1,000

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 scientific research using a conducting tether extended 20 km above the orbiter. NASA is providing the scientific payloads for the initial flight of the TSS.

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, for development and integration of the instruments, and flight on the Shuttle. Italy is developing the satellite and is responsible for development and integration of European investigations. An Announcement of Opportunity for investigations was issued in April 1984. Selection of investigators was completed in late 1905 and instrument design will be initiated in early 1986.

Some program delays are currently being encountered by the Italians in the development of the satellite, and the launch schedule is being reevaluated.

BASIS OF FY 1987 ESTIMATE

The **FY 1987** funding is required for final preparations and data analysis activities associated with the scientific instruments on the Tethered Satellite System.

BASIS OF FY 1987 FUNDING REQUIREMENT

SCATTEROMETER

	1985 Actual	1986 Budget Estimate	1986 Current Estimate	1987 Budget Estimate
		(Thousands of Dollars)		
Scatterometer.........................	12,000	31,700	14,000	35,900

OBJECTIVES AND STATUS

The purpose of the Navy Remote Ocean Sensing System (N-ROSS) is to acquire global ocean data for operational and research usage by both the military and civil sectors. A Scatterometer sensor is required to meet the objectives of this mission. NASA will provide the Scatterometer sensor and the Department of Defense will provide the N-ROSS spacecraft and launch services for a launch in late 1990.

The Scatterometer will provide accurate, global measurements of ocean surface winds which will be useful for both oceanography and meteorology. In addition to satisfying Navy operational requirements for 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 N-ROSS in late-1990 will provide an overlap of data gathering with the World Ocean Circulation Experiment and Tropical Ocean-Global Atmospheres Experiment planned by the international oceanographic community.

The feasibility of using the Scatterometer technique from space to accurately measure winds was demonstrated by Seasat in 1976. 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. In FY 1985, the design and development activities were initiated, not only on the Scatterometer instrument, but also on the ground data processor which will utilize research quality algorithms to process the scatterometer raw data into geophysical products for utilization by the oceanographic and meteorological research communities. An Announcement of Opportunity (AO) for specific research investigations using Scatterometer data was released in FY 1985. Contracts were awarded for the antennas and travelling wave tubes. In FY 1986, a Preliminary Design Review will be conducted and the AO selection process will be completed.

CHANGES FROM 1986 BUDGET ESTIMATE

The $17.7 million decrease is consistent with Congressional direction. This has resulted in a six month delay in the instrument delivery to the Navy without any immediate impact to the Navy N-ROSS launch date.

BASIS OF FY 1987 ESTIMATE

In FY 1987, design and development of the Scatterometer will be continued leading to the scheduled launch in late 1990. In particular, the antenna and travelling wave tube fabrication will be continued, fabrication of the radio frequency subsystem will be initiated, procurement of a ground based computer system will be undertaken, and a critical design review will be completed.

BASIS OF FY 1987 FUNDING REQUIREMENT

UPPER ATMOSPHERE RESEARCH SATELLITE PROGRAM

	1905 Actual	1986 Budget Estimate	1986 Current Estimate	1987 Budget Estimate
	(Thousands of Dollars)			
Spacecraft.	21,700	80,200	67,200	99,5011
Experiments	34,000	53,800	56,800	52,700
Total..............................	55,700	134,000	124,000	152,200
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 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 1986 BUDGET ESTIMATE

The total $10.0 million decrease is consistent with Congressional direction.

BASIS OF FY 1987 ESTIMATE

The FY 1987 funds are requried 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 1988. In addition, the spacecraft design and development activities will be continued in FY 1987 leading to the observatory critical design review in the latter half of FY 1987 and the initiation of flight hardware fabrication.

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 1387 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 1987 FUNDING REQUIREMENT

OCEAN TOPOGRAPHY EXPERIMENT

	1985 Actual	1986 Budget Estimate	1986 Current Estimate	1987 Budget Estimate
		(Thousands of Dollars)		
Ocean topography experiment (TOPEX). ..	---	---	---	29,000

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 mid-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) planned for flight on the U.S. Navy Remote Ocean Sensing System (N-ROSS) in late 1990, unique measurements of the oceans' driving force (winds) and the resulting ocean response (topography) will have been obtained.

BASIS OF FY 1987 ESTIMATE

During FY 1986, a Request for Proposals (RFP) to select a single satellite contractor and an Announcement of Opportunity to select a Science Working Team are planned to be issued. Once these selections have been made, NASA will be in a position to initiate full scale development of TOPEX, thus permitting a May 1991 launch. The resulting high degree of overlap with N-ROSS and WOCE will permit a truly unique set of coordinated spaceborne and in situ observations to be obtained.

In FY 1987 detailed design work in all areas of the project--satellite, sensors, ground data system, etc.--will be focused on preparing for a Critical Design Review (CDR) in early FY 1988 such that hardware fabrication can be initiated.

MATERIALS
PROCESSING
IN SPACE

RESEARCH AND DEVELOPMENT

FISCAL YEAR 1987 ESTIMATES

BUDGET SUMMARY

OFFICE OF SPACE SCIENCE AND APPLICATIONS

MATERIALS PROCESSING IN SPACE PROGRAM

SUMMARY OF RESOURCES REQUIREMENTS

	1985 Actual	1986 Budget Estimate	1986 Current Estimate	1987 Budget Estimate	Page Number
		(Thousands of Dollars)			
Research and analysis..................	11,700	12,400	12,400	12,9011	RD 8-3
Materials experiment operations.......	15,300	21,600	22,600	31,000	RD 8-4
Total...............................	27,000	34,000	35,000	43,900	

Distribution of Program Amount by Installation

	1985 Actual	1986 Budget Estimate	1986 Current Estimate	1987 Budget Estimate
Johnson Space Center..................	2,661	3,150	3,900	3,700
Marshall Space Flight Center..........	8,353	10,980	8,000	12,300
Lewis Research Center...............	5,767	6,700	6,600	6,700
Langley Research Center...............	1,256	1,200	1,300	2,300
Jet Propulsion Laboratory.............	4,544	8,075	6,600	9,700
Headquarters..........	4,419	3,895	8,600	9,200
Total................................	27,000	34,000	35,000	43,900

PROGRAM OBJECTIVES AND JUSTIFICATION

The Materials Processing in Space program emphasizes the science and technology of processing materials to understand constraints imposed by gravitational forces and the unique capabilities made possible by controlling these processes in the space environment. Ground-based research, technology development, and payload definition activities in FY 1986 are being concentrated on six major processing areas: metals and alloys, electronic materials, glass and ceramics, biotechnology, combustion, and fluid dynamics and transport phenomena. These activities will provide the scientific basis for future space applications of materials processing technology as well as provide a better understanding of how these processes occur on the ground. Definition studies will be performed for Shuttle experiment candidates in areas such as containerless experiments, combustion science, solidification and crystal growth, and blood storage. Also included are maintenance of capabilities for experimentation in drop tubes, towers, and aircraft. Studies and science support for Joint Endeavor and Technical Exchange Agreements are included in this program.

Materials Experiment Operations 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 Materials 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. In addition, reflight of investigations on Shuttle/Spacelab missions and the mid-deck is provided for in Materials Experiment Operations.

BASIS OF FY 1987 FUNDING REQUIREMENT

RESEARCH AND ANALYSIS (MATERIALS PROCESSING)

	1985 Actual	1986 Budget Estimate	1986 Current Estimate	1987 Budget Estimate
		(Thousands of Dollars)		
Ground-based investigations, analysis and studies................	11,700	12,400	12,400	12,900

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 commercialization 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 1986 funding is being used to support ongoing research in infrared detector materials, spherical shell technology, floating zone crystal growth, separation and synthesis of biological materials, fluid flow effects in materials processing, combustion science, and containerless processing techniques. Coordinated activities with the NASA Office of Commercial Programs will continue with studies of institutional arrangements associated with joint NASA/industry ventures, information activities directed toward industry involvement in microgravity science ana applications projects, and early negotiations and continuing technical support with companies interested in undertaking joint space endeavors with NASA.

BASIS OF FY 1987 ESTIMATE

Ground-based research and analysis will be continued in FY 1987 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.

BASIS OF FY 1987 FUNDING REQUIREMENT

MATERIALS EXPERIMENT OPERATIONS

	1985 Actual	1986 Budget Estimate	1986 Current Estimate	1987 Budget Estimate
		(Thousands of Dollars)		
Materials experiment operations.......	15,300	21,600	22,600	31,000

OBJECTIVES AND STATUS

The materials experiment operations program provides a wide range of opportunities for scientific and commercial experiments in microgravity science and applications. Development of Shuttle mid-deck and cargo bay experiments are supported under this activity. Preliminary data analysis on Shuttle experiments already flown has shown promising results.

CHANGES FROM FY 1986 BUDGET ESTIMATE

The funding increase of $1.0M will be used to augment the materials processing flight experiment activities, and to initiate the study of advanced experiment apparatus for research in glasses and ceramics.

BASIS OF FY 1987 ESTIMATE

FY 1987 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 conducted in glasses, electronic materials, biotechnology, metals and alloys, and combustion. Development will begin on a number of Physics and Chemistry Experiments (PACE) as well as continued development of several pieces of advanced equipment in the areas of electronic crystal growth, biotechnology, metallic casting, and particle combustion.

COMMUNICATIONS

RESEARCH AND DEVELOPMENT

FISCAL YEAR 1987 ESTIMATES

BUDGET SUMMARY

OFFICE OF SPACE SCIENCE AND APPLICATIONS — COMMUNICATIONS 'ROGRAI

SUMMARY OF RESOURCES REQUIREMENTS

	1985 Actual	1966 Budget Estimate	1966 Current Estimate	1987 Budget Estimate	Page Number
	(Thousands of Dollars)				
Advanced Communications Technology Satellite (ACTS).	45,000	90, OOD	85, 000*	---	---
Research and analysis..	9,100	10,600	10,400	14,000	RD 9-4
Search and rescue	2,400	1,300	1,301,	1,000	RD 9-6
Technical consultation and support studies	2, 900	3,100	2,600	3,200	RD 5-7
Experiment coordination and operations support.	1,200	1,200	1,000	1.300	RD 9-9
Total	60,600	106,200	100,300	19,500	

Distribution of Proqram Amount by Installation

	1985 Actual	1966 Budget Estimate	1966 Current Estimate	1987 Budget Estimate
Goddard Space Flight Center	3,792	2,720	4,220	5,087
Jet Propulsion Laboratory	4,579	6, DOC,	5,416	8,272
Ames Research Center	---	---	---	---
National Space Technology Laboratories	---	---	---	---
Langley Research Center	---	---	---	---
Lewis Research Center	48,955	94,200	87,535	5,100
Headquarters	3,274	3,2811	3,129	1.041
Total	60,600	106,200	100,300	19,500

*A proposed recission of $26,796 for this project is included in the President's Budget.

OBJECTIVES AND STATUS

The Communications Research and Analysis program continues to provide development of component and device 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, and Sweden also participate. A four satellite system is now in service (two U.S. and two U.S.S.R. satellites) and has been credited with saving over 500 lives in numerous worldwide incidents. The list continues to grow weekly. The resources requested reflect the fact that the primary responsiblity for this program has been transferred to NOAA.

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 and 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 demonstration flight. A proposed recission has been included in the President's Budget for this project.

BASIS OF FY 1987 FUNDING REQUIREMENT

RESEARCH AND ANALYSIS (COMMUNICATIONS)

	1985 Actual	1986 Budget Estimate	1986 Current Estimate	1387 Budget Estimate
		(Thousands of Dollars)		
Research and analysis..................	9,100	10,600	10,400	14,000

OBJECTIVES AND STATUS

The Communications Research and Analysis program emphasizes the development of high-risk technology required .to maintain U.S. preeminence in the international satellite communications market, to enable new and innovative public services, and to meet the communications needs of NASA and of other government agencies. This program focuses on the "interconnectivity ,technologies" of on-board switching, intersatellite links, and antennas, as well as the conventional RF technologies. Advanced studies are performed to determine the future satellite communications needs of the country, and to define the technology required to meet those needs. The technology is developed and tested through an advanced proof-of-concept (POC) program. The POC devices and components are then integrated into a multiple terminal, satellite communications network in a laboratory where they undergo comprehensive evaluation.

In 1986, work is continuing on intersatellite laser link technology. This advanced technology has the potential to significantly improve intersatellite communications by allowing high data rate transmission in the Space Station era. Technology development is also underway in the area of monolithic microwave integrated circuits (MMIC), which have significant potential for applications in multiport spacecraft matrix switches, low noise receivers, and multibeam antenna arrays and beam-forming networks. A number of industry studies are being sponsored to assess new areas of communications technologies required for the 1990's.

The mobile communications technologies activity is aimed at accelerating the introduction of a commercial mobile satellite service in the U.S., and developing power, bandwidth and orbital-slot efficient ground segment technology and networking techniques needed to insure its growth. An innovative cooperative agreement between NASA and industry was signed in FY 1985 as the basis for this effort. In early FY 1986, our technology development program received support of the industry at a major government/industry briefing. We are continuing to work with other government agencies to define an experimental test program aimed at emergency response and public service applications.

In FY 1986, development efforts on ground segment technology is continuing. Definition of low cost, high gain rooftop vehicle antennas that can at least double the number of orbital slots available has been completed and development of engineering hardware models is underway. Design is continuing on terminal and networking techniques that will result in power/bandwidth efficient voice transmissions (approximately six times greater than the new cellular terrestrial technology) and information (voice plus data) throughput increases. NASA will continue to work with the private sector and other government agencies to define a field test planned for late 1986. To achieve this, and to foster cooperation during the experimental phase, seven Memoranda of Understanding have been signed. These represent almost 30 government agencies.

CHANGES FROM THE FY 1986 BUDGET ESTIMATE

The decrease in the FY 1986 budget estimate reflects FY 1986 agency operating plan adjustments to provide for other higher priority requirements.

BASIS OF FY 1987 ESTIMATE

During FY 1987, advanced studies and selected technology development will be continued in the focussed high risk areas of satellite switching, RF (radio frequency) systems, intersatellite links and mobile communications. Work in these technology areas will support U.S. industry, NASA, and other government agencies and address national economic and security interests.

FY 1987 mobile communications technology activity will focus on field tests of advanced concepts in an operational-like environment. These initial tests, which will involve NASA, other agencies, U.S. industry, and Canada, are a critical first step in tying together the advanced technology elements under development for a future mobile satellite communications experiment.

BASIS OF FY 1987 FUNDING REQUIREMENT

SEARCH AND RESCUE

	1985 Actual	1986 Budget Estimate	1986 Current Estimate	1987 Budget Estimate
Search and rescue....................	2,400	1,300	1,300	1,000

OBJECTIVES AND STATUS

The Search and Rescue program, developed by NASA and its international partners, has demonstrated the feasibility of using satellites to significantly improve the ability to detect and locate general aviation aircraft and marine vessels during emergencies. The Search and Rescue satellite systems 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 500 lives to date. In addition, the system is demonstrating the potential to save millions of dollars annually in search logistics costs.

In FY 1986, 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 quickly locate those in distress.

BASIS OF FY 1987 ESTIMATE

In FY 1987, an experiment will be undertaken to evaluate the use of geostationary satellites for instant alerting of search and rescue forces. Work will also continue on the development and tests of other technologies with the potential to further enhance capabilities for effective search and rescue.

BASIS OF FY 1987 FUNDING REQUIREMENT

TECHNICAL CONSULTATION AND SUPPORT STUDIES

	1985 Actual	1986 Budget Estimate	1986 Current Estimate	1987 Budget Estimate
	(Thousands of Dollars)			
Technical consultation and support studies.....................	2,900	3,100	2,600	3,200

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.

NASA studies and participation in the Space World Administrative Radio Conference (SWARC) in the summer of 1985 contributed to the successful outcome of the conference. Propagation measurements, carried out during FY 1985 and FY 1986 with balloons, drone aircraft, and helicopters, are providing new insight to industry on the effects of trees and foliage on mobile satellite communications. NASA continues to respond to and support the rulemaking by the Federal Communictions Commission (FCC) to establish a commercial land mobile satellite service. The rulemaking, anticipated for early 1986, is expected to result in a new multibillion dollar industry with both domestic and foreign markets and a commercial service owned and operated by the private sector by the late 1980's.

CHANGES FROM FY 1986 BUDGET ESTIMATE

The decrease in the FY 1986 budget estimate reflects FY 1966 agency operating plan adjustments to provide for other higher priority requirements.

BASIS OF FY 1987 ESTIUATE

During FY 1987, studies and analyses will be performed to support preparations for the second session of the SWARC which is scheduled to be held in Geneva in 1988. Plans will be developed for the fixed-satellite service at that time and proper preparation is critical to U.S. objectives for maintaining flexibility in orbiting and operating communications satellites. NASA will complete preparations for and will participate in the 1987 WARC on mobile communiations services. Studies will continue for the purposes of identifying techniques to increase the efficient use of the limited orbit/spectrum resources and to understand and alleviate the adverse effcts of propagation phenomena on space communications.

BASIS OF FY 1987 FUNDING REQUIREMENT

EXPERIMENT COORDINATION AND OPERATIONS SUPPORT

	1985 Actual	1986 Budget Estimate	1986 Current Estimate	1987 Budget Estimate
	(Thousands of Dollars)			
Experiment coordination and operations support............................	1,200	1,200	1,000	1,300

OBJECTIVES AND STATUS

The objective of this program is to support and document a wide range of user experiments and demonstrations in the application of satellite communications. Past experiments on experimental satellites such as the Applications Technology Satellite (ATS) series ana the Communications Technology Satellite (CTS), have been successfully providing users with the experience necessary for making informed decisions regarding their communications functions. NASA's stimulus in encouraging use of these unique facilities has led to wider application of commercial satellites, which can better meet the needs of potential users.

ATS-1, a 19-year old experimental satellite that provided humanitarian telecommunications service to 23 Pacific island nations for the past 14 years was shut down when it would no longer respond to station-keeping commands. NASA is currently assessing replacement options. The remaining ATS satellite, ATS-3, will continue to provide two-way voice and data transmission for a number of experiments being conducted in North America, the Antarctic, and the Pacific and Atlantic oceans, in support of the National Science Foundation, the Department of the Navy, the Department of Commerce, a number of universities, and private industry. It continues to be an important link for emergency communications in the western hemisphere as was demonstrated during the recent Mexico City earthquake and Columbia volcanic eruption.

CHANGES FROM FY 1986 BUDGET ESTIMATE

The decrease in the FY 1986 budget estimate reflects FY 1986 agency operating plan adjustments to provide for other higher priority requirements.

INFORMATION
SYSTEMS

RESEARCH AND DEVELOPMENT

FISCAL YEAR 1987 ESTIMATES

BUDGET SUMMARY

OFFICE OF SPACE SCIENCE AND APPLICATIONS

INFORMATION SYSTEMS PROGRAM

SUMMARY OF RESOURCES REQUIREMENTS

	1985 Actual	1986 Budget Estimate	1986 Current Estimate	1987 Budget Estimate	Page Number
		(Thousands of Dollars)			
Data systems.	8,400	9,000	9,000	9,300	RD 10-2
Information systems	7,800	10,200	9,700	11,900	RD 10-2
Total	16,200	19,200	18,700	21,200	
Distribution of Program Amount by Installation					
Johnson Space Center	--	210	---	---	
Marshall Space Flight Center	125	130		---	
Goddard Space Flight Center	9,602	12,050	12,680	14,880	
Jet Propulsion Laboratory	5,034	5,050	4,609	4,909	
Ames Research Center	270	350	---	---	
National Space Technology Laboratories	240	210	190	200	
Headquarters	929	1,200	1,221	1,211	
Total	16,200	19,200	18,700	21,200	

OFFICE OF SPACE SCIENCE AND APPLICATIONS | INFORHATION SYSTEMS PROGRAM

PROGRAM OBJECTIVES AND WSTIFICATION

The objectives of the Information Systems program are to: develop and demonstrate advanced capabilities of managing, distributing, and processing data and information; implement 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 development of data system capabilities to meet the needs of flight missions and major space science and applications programs. The early demonstration of capabilities has a high potential for reducing ground data system development risks and for providing timely delivery of data to researchers.

CHANGES FROM FY 1986 BUDGET ESTIMATES

The decrease of $.5 million in FY 1986 reflects agency operating plan adjustments previously identified to Congress. The reduction will be accomplished by curtailing "grave yard shift" activities at the Space and Earth Science Computing Center.

BASIS OF FY 1987 ESTIMATE

The FY 1987 Information Systems funding is required to provide support for space science and applications programs. Funds are required to continue development 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 development of data management and data archiving to support flight projects, discipline program offices, and other NASA program offices. The FY 1987 funding levels will also provide the university/research community with improved access to NASA computational facilities and data archives by expanding network communications links, by increasing online data storage capacities, and by developing standards for data and protocols.

COMMERCIAL
PROGRAMS

NATIONAL AERONAUTICS AND SPACE ADMINISTRATION

FISCAL YEAR 1987 ESTIMATES

RESEARCH AND DEVELOPMENT BUDGET PLAN FOR COMMERCIAL PROGRAMS

Commercial Programs	1985 Actual	1986 Budget Estimate	1986 Current Estimate	1987 Budget Estimate
	(Thousands of Dollars)			
Technology utilization	9,500	11,100	11,100	13,300
Commercial use of space	(7,600)	30,000	17,000	32.000
Total	9,500	41 100	28,100	45,300

TECHNOLOGY
UTILIZATION

RESEARCH AND DEVELOPMENT

FISCAL YEAR 1987 BUDGET ESTIMATES

BUDGET SUMMARY

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

SUMMARY OF RESOURCES REQUIREMENTS

	1985 Actual	1986 Budget Estimate	1986 Current Estimate	1987 Budget Estimate	Page Number
		(Thousands of Dollars)			
Technology dissemination	5.800	6.300	6.300	7.600	RD 11-4
Technology applications	3.700	4.800	4.800	5.700	RD 11-5
Total	9.500	11.100	11.100	13.300	

Distribution of Program Amount by Installation

	1985 Actual	1986 Budget Estimate	1986 Current Estimate	1987 Budget Estimate
Johnson Space Center	2132	250	175	300
Kennedy Space Center	335	210	490	415
Marshall Space Flight Center	184	390	268	530
National Space Tech Laboratories	185	100	300	210
Goddard Space Flight Center	1.132	1.050	1.295	1.259
Jet Propulsion Laboratory	135	510	680	345
Ames Research Center	106	2.010	155	400
Langley Research Center	697	530	408	573
Lewis Research Center	412	310	443	1.007
Headquarters	6.112	5.740	6.886	8.261
Total	9,500	11.100	11.100	13.300

OFFICE OF COMMERCIAL PROGRAMS | TECHNOLOGY UTILIZATION PROGRAM

PROGRAM OBJECTIVES AND JUSTIFICATION

The objective of the NASA Technology Utilization Program is to enhance the national economy and industrial productivity through a series of interactive processes and mechanisms designed to transfer aerospace technology evolving from NASA's R&D programs to non-aerospace sectors of the U.S. economy. Almost every part of U.S. industry is touched by the transfer process, especially in such areas as automation, electronics, materials, and productivity. In the public sector, medicine, rehabilitation, transportation, and safety are but a few of the areas receiving benefits. The specific objectives of the program are:

o Accelerate application and use of aeronautics and space technology by the U.S. private sector;

o Facilitate multiple secondary uses and application of NASA technology by the public and private sectors and academia;

o Continue to improve NASA's technology transfer process;

o Promote applications of NASA's expertise and capabilities to non-aerospace needs of the Nation.

OBJECTIVES AND STATUS

NASA Tech Briefs is the Agency's principal technology announcement publication designed to promote and encourage the effective secondary use of new aerospace advancements. Conversion of NASA Tech Briefs to a commercially viable, private sector publication was accomplished on schedule with the first commercial issue released in February 1985. A subsequent agreement was reached with the private sector publisher and the Joint Committee on Printing in December 1985 for continuation of a commercial version of the NASA Tech Briefs journal for the next five years. This commercialization effort (a) allows the continued free distribution of this quarterly journal to current subscribers (100,0011 scientists, engineers and business representatives in U.S. industry), and (b) provides for circulation growth to meet the demand throughout industry, which is estimated at two to three times the present readership.

Thousands of U.S. industrial firms are being provided computerized access to NASA information through the NASA-sponsored dissemination center network. Technology transfer services growing out of this information access have focused a wide array of technologies on technological problems specified by industrial clients. These firms, especially those in the industrial manufacturing and research sectors, have found dissemination center information and technology transfer services to be beneficial in the development of new or improved products or processes. COSMIC, the NASA-supported center for computerized software dissemination, realized significant growth in sales and lease of NASA-developed computer programs for industrial use. Overall, the entire predominantly university-based dissemination network received approximately $7 million from industry last year for information products and technology transfer services, underscoring the continued interest and importance which this activity has throughout industry.

In applications engineering, emphasis during 1986 continues to be concentrated on developing new oportunities in automation, electronics and materials technology, and solidifying ongoing projects and studies in the allied medical fields (bioengineering and rehabilitation). The development of the Programmable Implantable Medication System was accelerated as Siemens Industries purchased Pacesetter, Inc. and the FDA approved human trials for morphine and insulin. During the same period INTEC, the manufacturer of the implantable defibrillator, was purchased by Cardiac Pacers, Inc. (CPI). The FDA has given CPI the authority to commercialize this life saving device. CPI is committed to accelerate the marketing of the device and development of the next generation of defibrillators. There are over 800 of these devices currently implanted in humans. In the automation, electronics and materials area, three new projects in materials technology were started at the Lewis Research Center. Each project has a major manufacturer involved. Two feasibility studies in electronics and automation were successfully completed and the next phase of engineering development intiated. Additionally, a materials project designed to measure residual stress in steel components without having a calibration standard was transferred to the U.S. industry. The National Space Technology Laboratories aquaculture treatment techniques to convert raw sewage to drinking water is all but complete as a pilot project with Federal and state support in the city of San Diego, California. The Library of Congress and NASA jointly agreed on preliminary specifications for a book deacidification facility at Fort Detrick, Maryland.

BASIS FOR FY 1987 ESTIMATE

	1985 Actual	1986 Budget Estimate	1986 Current Estimate	1987 Budget Estimate
		(Thousands of Dollars)		
Technology dissemination.............	5,800	*6,300*	*6,300*	7,600

OBJECTIVES AND STATUS

In FY 1987, NASA will continue to enhance, restructure, and refine NASA technology dissemination systems capabilities and techniques to heighten relevance and potential applicability of available technologies for industrial user needs, and provide technical information and technology transfer services to expanded user markets in the U.S. Technology dissemination efforts will be coupled with activities, where possible, of state-supported economic and industrial development programs to serve broader industrial markets nationwide, with particular emphasis on small and medium size manufacturing and high technology business firms. Enhancements in the NASA dissemination systems will continue by expanding the use of remote interactive and high speed data base search methods. Moreover, selected computer interface improvements will be explored. Increased use of telecommunications will also be pursued to provide rapid and effective delivery of technologies to meet the critical needs of U.S. industrial firms engaged in a wide range of scientific, engineering, manufacturing, and commercial pursuits. Industrial profile analyses will continue to be conducted. Market planning strategies will be pursued for emerging aerospace technologies, thus enhancing NASA's ability to accelerate the flow of research and development results to -- and their effective use in -- the U.S. industrial marketplace. Additionally, special emphasis will be placed on providing broader coordination and support to NASA's Industrial Application Center network through access to NASA laboratory expertise engaged in ongoing research and development activities that have a direct bearing on the nonaerospace industrial sector's technology needs. These coordination and support activities will include an expansion of the NASA Technology Counselor network as well as establishment of a Technology Transfer Institute. This effort will enhance the computerized systems interfaces with technology databases and heighten cost effectiveness and efficiency throughout the nationwide network.

	1985 Actual	1986 Budget Estimate	1986 Current Estimate	1987 Budget Estimate
		(Thousands of Dollars)		
Technology applications.	3,700	4,800	4,800	5,700

OBJECTIVES AND STATUS

The Technology Applications Program is designed to respond to a national "pull" for technology that is needed by U.S. industry, state or federal government in order to meet the specific objectives of the user. Goals are defined in terms *of* enhancing the quality of life, increasing the marketability of U.S. industry and utilization of a national resource. This is accomplished by the transfer of new technology and information resulting from NASA R&D efforts to the non-aerospace segment of the economy. The main thrusts of the technology transfer effort will be in automation, electronics, materials, bioengineering and rehabilitation.

Additionally, in FY 1987, NASA will continue its efforts to reengineer, adapt, or otherwise apply existing aerospace technologies and capabilities to problem areas of national significance in both the public and private sectors of the economy. In the public sector, special emphasis will be placed on enhancing and expanding technology applications activities and projects to meet needs identified in biomedical and rehabilitation areas. This will be done in conjunction with user agencies such as the National Institutes of Health, the Veterans Administration, and other organizations concerned with the elderly, disabled and the handicapped. These areas of increased emphasis in FY 1987 will augment continuing technology applications program activities in other areas of public and human concern, such as public safety, transportation and the environment.

With regard to the private sector and its industrial entities, applications engineering activities will be pursued directly with them to determine their long range requirements and needs and determine how NASA's aeronautics and space technologies can be applied to solve recurring operational problems. Special emphasis will be directed to the involvement of applications projects essential to development of new products and processes to revitalize industries critical to the U.S. economy's research and development and manufacturing sectors, in addition to reshaping productivity capabilities of industries threatened by foreign competition. Important to this undertaking will be the development of proactive relationships with the U.S. private sector in all aspects of industrial activities.

COMMERCIAL USE
OF
SPACE

RESEARCH AND DEVELOPMENT

FISCAL YEAR 1987 ESTIMATES

BUDGET SUMMARY

OFFICE OF COMMERCIAL PROGRAMS — COMMERCIAL USE OF SPACE PROGRAM

W A R Y Of RESOURCES REQUIREMENTS

	1985 Actual	1986 Budget Estimate	1986 Current Estimate	1987 Budget Estimate	Page Number
	(Thousands of Dollars)				
Commercial Applications R&D..........	(6,350)	28,500	15,500	30,100	RD 12-3
Commercial Development Support.	(1,250)	1,500	1,500	1,900	RD 12-4
Total............................	(7,600)	30,000	17,000	32,000	

Distribution of Program Amount by Installation

	1985 Actual	1986 Budget Estimate	1986 Current Estimate	1987 Budget Estimate
Johnson Space Center...............	(450)	1,600	600	1,600
Kennedy Space Center................	(36)	1,500	200	1,500
Marshall Space Flight Center.........	(1,443)	6,200	4,000	6,200
National Space Technology Laboratories	(---)	400	200	400
Goddard Space Flight Center..........	(50)	800	450	800
Jet Propulsion Laboratory.............	(---)	700	50	700
Ames Research Center...............	(130)	900	400	90u
Langley Research Center..............	(300)	3,600	1,300	3,600
Lewis Research Center................	(750)	2,000	1,800	2,000
Headquarters..	(4,441)	12,300	8,000	14,300
Total............................	(7,600)	30,000	17,000	32,000

PROGRAM OBJECTIVES AND JUSTIFICATION

The objective of the commercial use of space program is to increase private sector awareness of space opportunities and encourage increased industry investment and participation in high technology, space-based research and development. Expansion of the level of private sector investment in commercial space activities will help the U.S. to retain its leadership in science and technology and accrue associated benefits to our nation. This program will be built on shuttle and related space-based operational capabilities. The program is responsive to the President's national space strategy and national policy on the commercial use of space, both of which direct NASA to expand private sector investment and involvement in space activities.

CHANGES FROM FY 1986 BUDGET ESTIMATE

The commercial use of space program was reduced $13.0 million by Congressional direction. This reduction was made in commercial applications research and development and will be accomodated by reducing the rate of establishment of new Centers for the commercial development of space and development of supporting research equipment.

OBJECTIVES AND STATUS

The goal of the commercial use of space program is to provide a national focus in support of the expansion of U.S. private sector investment and involvement in civil space activities, while emphasizing new high technology commercial space ventures and promoting the development of new markets for the space transportation system (STS) and other NASA space services. The specific objectives of 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 improved access to available NASA capabilities.

- Encourage an increase in private sector investment in the commercial use of space independent of NASA funding.

- Develop a national commercial space policy and provide for NASA-wide implementation.

FY 1986 activities include the implementation of the national policy on the commercial use of space, the maintainance of an organizational focal point for commercial programs at NASA, and the initiation of efforts specifically intended to foster commercial use of and access to space. These specific efforts include the establishment of additional centers for the commercial development of space (CCDS), increasing accessibility to NASA facilities and equipment, small focused research efforts on processes having commercial potential, and the incorporation of other functions designed to facilitate private sector utilization of space for commercial ventures.

BASIS FOR FY 1987 ESTIMATE

	1985 Actual	1986 Budget Estimate	1986 Current Estimate	1907 Budget Estimate
	(Thousands of Dollars)			
Commercial Applications R&D...........	(6,350)	28,500	15,500	30,100

FY 1987 activities will provide a continuation and some enhancement of the FY 1986 program initiatives. These efforts are designed to encourage significant private investment in commercial enterprises that take advantage of the unique characteristics of space, such as hard vaccum and microgravity.

In FY 1907, the third round of CCDS selections will occur, which will complete the constellation of centers at around fifteen to eighteen. These consortia of industry, academia and non-NASA government participants are expected to effectively encourage the development of high technology space-related research having direct commercial interest and application. FY 1987 will also see a number of projects begun in FY 1985/86 move into final assembly stages or completion. In particular, the middeck galley rack will fly in FY 1987, carrying as its first payload the experiment of a U.S. company participating in commercially-oriented research through a NASA/industry joint endeavor agreement. In addition, the protein crystal growth system, building upon and expanding the capability of current rudimentary systems, will greatly increase the number and type of protein crystals which can be produced on a single STS mission. The production of these crystals in sufficient quality and size is a crucial step in drug design, enzyme engineering, molecular computing development, and bio-chip engineering.

Joint endeavor and other space act agreement activities are expected to substantially increase as the CCDS move forward in their research activities and as companies further define their research interests and programs. As of January 1986, NASA has executed 65 space act agreements with U.S. companies, of which 52 are research related (joint endeavor agreements, technical endeavor agreements, and industry guest investigators), nine are commercial hardware related, and two represent diverstitures of government programs (expendable launch vehicles).

Commercial Development Support.	(1,250)	1,500	1,500	1,900

These efforts will endeavor to increase the awareness of space as a potentially attractive environment for commercial development. Through studies, surveys and outreach efforts, U.S. industry particularly the non-aerospace sector, will be informed of and acquainted with the opportunities to work with NASA in space. FY 1987 will see the complete consolidation of all NASA user development activities. These efforts are associated with identifying and developing working partnerships with U.S. firms that will allow these firms to assess whether there are profitable product-related opportunities enabled through space-based R&D. An interactive network of all participants involved in user development will be in operation together with a reporting system which should minimize user costs and duplication while maximizing the effective application of existing NASA personnel and financial resources.

AERONAUTICS
AND SPACE
TECHNOLOGY

NATIONAL AERONAUTICS AND SPACE ADMINISTRATION

FFISCAL YEAR 1987 ESTIMATES

RESEARCH AND DEVELOPMENT BUDGET PLAN FOR AERONAUTICS AND SPACE TECHNOLOGY

	1985 Actual	1986 Budget Estimate	1986 Current Estimate	1987 Budget Estimate
		(Thousands of Dollars)		
Aeronautical research and technology...........	342,400	354,000	354,000	376,000
Transatmospheric research and technology.......	---	---	---	45,000
Space research and technology.....................	150,000	168,000	168,000	180,200
Total....................................	492,400	522,000	522,000	601,200

AERONAUTICAL
RESEARCH AND
TECHNOLOGY

RESEARCH AND DEVELOPMENT

FISCAL YEAR 1987 ESTIMATES

BUDGET SUMMARY

OFFICE OF AERONAUTICS AND SPACE TECHNOLOGY

AERONAUTICAL RESEARCH AND TECHNOLOGY PROGRAM

SUWRY OF RESOURCES REQUIREMENTS

	1585 Actual	1986 Budget Estimate	1986 Current Estimate	1987 Budget Estimate	Page Number
	(Thousands of Dollars)				
Research and technology base...........	223,298	239,300	240,300	272,900	RD 13-6
Systems technology programs.......... ..	119,102	114,700	113,700	103,100	RD 13-38
Total................................	342,400	354,000	354,000	376,000	

Distribution of Program Amount by Installation

	1585 Actual	1986 Budget Estimate	1986 Current Estimate	1987 Budget Estimate
Johnson Space Center..................	1,055	1,000	1,100	1,100
Marshall Space Flight Center...........	949	1,000	1,100	1,100
Jet Propulsion Laboratory...............	188	200	200	200
Goddard Space Flight Center.,..........	290	300	300	30U
Ames Research Center...................	132,933	146,200	150,100	165,600
Langley Research Center................	116,430	101,300	101,400	118,400
Lewis Research Center..................	84,903	97,800	93,100	82,600
Headquarters..........................	5,652	6,200	6,700	6 700
Total................................	342,400	354,000	354,000	376,000

RESEARCH AND DEVELOPMENT

FISCAL YEAR 1987 ESTIMATES

OFFICE OF AERONAUTICS AND SPACE TECHNOLOGY

AERONAUTICAL RESEARCH AND TECHNOLOGY PROGRAM

PROGRAM OBJECTIVES AND JUSTIFICATION

The objective of the aeronautical research and technology program is to conduct an effective and productive program that contributes materially to the enduring preeminence of U.S. civil and military aviation by: (1) conducting disciplinary and systems research at the leading edge of technology in those areas critical to the continued superiority of U.S. aircraft; (2) maintaining the research centers in positions of excellence in facilities and technical staff; (3) assuring timely transfer of research results to the U.S. aeronautical industry; (4) assuring appropriate involvement of universities and industry; and (5) providing aeronautical development support to other government agencies and U.S. industry. Additional emphasis has been given to emerging technologies with potential for order-of-magnitude advances in capability or performance. The far-term focus of the program provides results well in advance of specific applications and provides long-term, independent research and technology which is not driven by the development and operational pressures often encountered by the Department of Defense (DOD) and industry. Both fundamental research in the aeronautical disciplines and systems research directed at interaction among disciplines, components, and subsystems applicable to general classes of advanced aircraft are included. The program involves participation by aeronautical manufacturers from the industrial base to ensure that the technology is compatible with practical design considerations and to effect a rapid transfer into superior military and civil aircraft.

CHANGES FROM FY 1986 BUDGET ESTIMATE

The aeronautical research and technology program reflects no change in total funding from the original budget request; however, the FY 1986 program has been adjusted to accommodate authorization action in the aeronautics program. Funding for the research and technology base is increased by $1.0 million by reallocation from high performance aircraft systems technology/oblique wing technology. In addition, there are reallocations as a result of several actions taken within the research and technology base. The altitude wind tunnel effort is reduced by $2.0 million and the activities will be brought to a logical conclusion in FY 1986. The specific recommendation in the FY 1986 authorization conference report to reduce research efforts in wind tunnel adaptive wall and model magnetic suspension have been accommodated. Rotorcraft research and technology has been maintained at the FY 1985 level of activity. The funding for high-speed aeronautics/hypersonics has been increased by $5.7 million to focus additional effort in critical technologies. Systems technology programs are reduced because $1.0 million of the funding for oblique wing technology has been reallocated to the research and technology base, consistent with the authorization action.

BASIS OF FY 1987 FUNDING ESTIMATE

The FY 1987 estimate is based on an increased effort to aggressively pursue the highest payoff technologies with potential for order-of-magnitude advances in capability or performance. A unique opportunity in high-speed flight is focusing substantially increased emphasis in generic hypersonic technologies supporting the transatmospheric research and technology program for a potential future aerospace plane. Subsonic transport and rotorcraft needs are addressed primarily through fundamental research aimed at the critical technology areas. Key high-performance aircraft technology efforts are accelerated, and a small effort in supersonic cruise technology is being maintained. The estimate also reflects the need to continue important efforts in the fundamental aeronautical disciplines and systems research and to support specialized facilities essential to aeronautics research.

The base research and technology program includes generic research which is broadly applicable to all classes of aircraft (general aviation/commuter, transport, rotorcraft, supersonic cruise, fighter/attack, and hypersonic) and focused research which is specific to one class of aircraft. Systems technology programs are more focused in applications and/or have the characteristics of specific projects, i.e., advanced turboprop, X-wing, and oblique wing. Funding for the technical operations of wind tunnels, propulsion facilities, computational facilities, simulators, and flight research operations is covered in the most appropriate discipline elements of the research and technology base. In FY 1987 research and technology base funding will support the operating cost for the numerical aerodynamic simulation (NAS) program, and systems technology funding covers the final NASA commitment to the X-wing program. A brief summary of some of the major thrusts for both the research and technology base and systems technology programs follows.

In fluid and thermal physics research, strong emphasis will continue on three-dimensional computational fluid dynamics (CFD) methods that will increase the speed and efficiency of flow solvers by two orders of magnitude and on novel techniques and devices to reduce aircraft drag by up to 60 percent. Benchmark experiments for CFD code validation and turbulence modeling will be strengthened.

Applied aerodynamics research efforts in high angle-of-attack aerodynamics will include wind tunnel and flight evaluations to improve the understanding of performance in both the low- and high-speed flight regimes and to correlate with predictions. Research efforts in test techniques will address laser holographics and nonintrusive measurement techniques which will provide an order-of-magnitude improvement in test accuracy.

In propulsion and power research, continued attention will be given to the technologies for small engines which will enable up to 50-percent improvement in fuel efficiency. Internal computational fluid mechanics efforts will address the physical modeling of complex internal flows and the validation of codes as part of the goal to reduce calculation times by an order of magnitude. Supersonic combustion ramjet (scramjet) and combined cycle engine research will be strengthened to address the technologies critical to the flight of high-speed vehicles from takeoff to orbital speeds.

Materials and structures research will increase in the area of composite materials, which can provide up to a 50-percent weight savings for future aircraft. Initial efforts will focus on thermoplastics and ceramic-matrix composite materials, as well as structural concepts exploiting their anisotropic properties. Research emphasis will also be increased in high-temperature materials and structures and thermal-barrier coatings with high-erosion resistance. A focused effort will be initiated in rotorcraft airloads to correlate noise and vibration predictions as part of the goal to reduce noise and vibration by 80 percent.

Information science research will continue to focus on flight-crucial software and concurrent processing to provide an order-of-magnitude improvement of efficiency and reliability. Controls and guidance and human factors research will focus on the application of artificial intelligence technology to enhance the operations of future aircraft. Increased emphasis will be placed on controls research for highly maneuverable aircraft. Human factors research will continue to address the critical man-machine interface issues which affect the safety and operational limitations of aircraft.

Flight systems research will provide focus on highly maneuverable aircraft capable of high angle-of-attack operation at low speeds, high-speed maneuverability, and short takeoff and vertical landing. Analytical and experimental investigations will be conducted on thrust-vectoring concepts to enhance high angle-of-attack maneuverability. Supersonic vertical/short takeoff and landing (V/STOL) concepts will be studied as the initial part of a joint United States/United Kingdom (U.S./U.K.) program. Other studies, conducted as part of the systems analysis effort, will determine the overall benefit of synergistic integration of component and subsystem technologies for hypersonic aircraft applications.

Rotorcraft systems technology efforts will include publication of an external noise prediction methodology aiming toward a three order-of-magnitude increase in accuracy and wind tunnel testing of an advanced bearingless rotor. Activities in technology for next-generation rotorcraft with more than a twofold increase in speed will be focused on completion of flight testing of the X-wing rotor system on the rotor systems research aircraft to include conversion from rotary to stopped-rotor flight mode.

Areas of continued emphasis in high-performance aircraft research are high angle-of-attack, with initial testing up to 20 degrees, integrated propulsion/flight controls to allow 10-15 percent performance improvements, supermaneuverability, short takeoff and vertical landing technology, and forward swept wing technology. The oblique wing technology program, being conducted jointly with the Navy to exploit the potential for high performance at subsonic and supersonic speeds, will include the detailed design and fabrication of the oblique wing and associated modifications of the NASA F-8 aircraft. Flight testing is planned to begin in FY 1989. Ceramic and ceramic-matrix research for turbine engines with operating temperatures up to 2300 degrees Fahrenheit will continue, along with the development of the analysis tools to accurately predict the life and assess the durability of turbine engine hot section components.

In the advanced turboprop program, aimed at a 30-percent reduction in transport fuel consumption, flight testing of the large-scale single-rotation propeller to build a performance data base for high-speed propeller aerodynamics and structures will be conducted. Geared counter-rotation propeller model tests will also be conducted. The general aviation/commuter engine research will include the definition of reference engines to focus and drive component technology development to large-engine performance levels and to provide a quantitative measure of the performance impact of advances as they are made.

In the NAS program, the initial operating configuration and the second high-speed processor for the extended operating configuration, allowing four to six times more computing power, will be installed in the new NAS facility. All subsystem upgrades will reach full capability early in FY 1989.

BASIS OF FY 1987 FUNDING REQUIREMENTS

RESEARCH AND TECHNOLOGY BASE

	1985 Actual	1986 Budget Estimate	1986 Current Estimate	1987 Budget Estimate	Page Number
	(Thousands of Dollars)				
Fluid and thermal physics research and technology..........................	28,498	48,500	30,400	39,500	RD 13-7
Applied aerodynamics research and technology	50, 900	43,700	55,300	57,100	RD 13-11
Propulsion and power research and technology..........................	33,636	31, 000	33,800	35,700	RD 13-15
Materials and structures research and technology..	27,800	28,000	29,500	39,000	RD 13-19
Information sciences research and technology..........................	21, 100	22,500	24,900	26, 800	RD 13-24
Controls and guidance research and technology.	20,600	22,100	22,100	24,500	RD 13-26
Human factors research and technology.....	20,300	22,000	22, 000	24, 000	RD 13-31,
Flight systems research and technology......	17,864	18,300	18,300	21,500	RD 13-33
Systems analysis......................	2,600	3,200	4,000	4,800	RD 13-36
Total	223,298	239,300	240,300	272,900	

	1985 Actual	1986 Budget Estimate	1986 Current Estimate	1987 Budget Estimate
	(Thousands of Dollars)			
Fluid and thermal physics research and technology	28,498	48,500	30,400	39,500

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/efficiency of three-dimensional (3-D) flow solvers by two orders of magnitude for the prediction and/or simulation of complex fluid flows over aircraft. A second objective is the validation of prediction ana simulation methods, with particular focus on accurate 3-D turbulent models for attached/separated flows by means of a coordinated experimental test program. This activity provides improved insight into the fundamentals of flow physics, as well as the detailed flow measurements required for verification of the computations. Other program objectives include establishing a detailed aerodynamic data base for new high-performance transport aircraft configuations and conducting drag reduction research with emphasis on developing specific devices and design techniques to reduce overall aircraft drag by up to 6U percent. Rapid progress is being made in the development of computational and experimental 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 develop advanced computational methods for predicting the aerodynamic flow field for complete aircraft/missile configurations under all conditions of attitude, speed, and altitude. 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 are being developed; in particular, a transonic thin-layer Navier-Stokes solution for fighter-like wing-body configurations has been perfected. Vectorizable algorithms are being 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. In this respect, significant progress has been made in linking gas dynamics and chemical kinetics in codes that will simulate the viscous, real-gas, external flows about hypersonic flight vehicles. The advancement of 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, which dominates many complex flows and remains one of the most vexing of all aerodynamic phenomena.

Increased emphasis has been placed on drag reduction research because drag reduction equates directly to fuel savings and improved aircraft range/payload performance. Significant progress has been made in skin friction arag reduction research. Passive techniques have provided appreciable drag reductions in pressure gradient flows, and the performance of the riblet and large eddy break-up devices has been shown to be additive at high Reynolds numbers. In natural laminar flow research, the effects of engine noise-induced acoustic disturbances on the maintenance of laminar flow have been investigated in flight. The results indicate that the benefits of laminar flow achieved by wing surface contouring will not be negated by engine noise. Laminar flow control research on the JetStar leading-edge flight test aircraft has progressed to the investigation of environmental effects under realistic operational conditions. The test aircraft has operated from the Atlanta and Pittsburgh airports, and the simulated operational environment testing will be moved to Cleveland for winter environment investigations.

Experimental and analytical aerodynamics research is centered around the testing and analysis of aircraft components and configurations. Although analytical methods for attached and vortical flows have been improved aramatically, experimental tests must be performed to validate new designs and prediction techniques and to obtain off-design data that cannot yet be calculated. Analytical techniques for separated, high angle-of-attack flows have emerged as useful design tools. Advanced supercritical technology and transonic computational methods have been generated and integrated into wing and canard design methods for high performance aircraft. As a result of recent progress in subsonic airfoil research, special purpose designs can now be rapidly and accurately generated. Recent examples include a medium-speed, benign-stall general aviation airfoil and a high-speed, shock-free airfoil.

CHANGES FROM FY 1986 BUDGET ESTIMATE

The decrease of $18.1 million in this program primarily reflects the transfer of fundamental aeroacoustics, test techniques, and national transonic facility (NTF) operations costs ($12.5 million) to applied aerodynamics and the transfer of internal computational fluid mechanics ($5.0 million) to propulsion and power for management and budgeting purposes. The transfer of laminar flow integration activities ($2.4 million) from the applied aerodynamics line has been offset by consolidation of the Ames Research Center's central computer facility costs into the information sciences line. In addition, $0.6 million was transferred to applied aerodynamics in support of priority hypersonics research and technology.

BASIS FOR FY 1987 ESTIMATE

In FY 1987, support of NAS operations will increase to reflect accelerated utilization of enhanced NAS capability. The CFD program will continue to emphasize improved 3-D configuration analysis and design. This will be principally accomplished 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. In addition, development of applications codes will be broadened to include greater integration among aerodynamics, structures, propulsion, and controls.

Increased emphasis will be placed on experiments designed to validate CFD techniques and to provide data for flow modeling. Data will be acquired to improve the modeling of complex flows which experience separation, vortical motions, and streamwise/transverse curvature.

Research to achieve significant reductions in overall aircraft drag will emphasize in FY 1987 the flight testing of a number of skin friction reduction concepts. Transonic and supersonic flight tests will be performed on riblets, which are longitudinal grooves that have shown significant turbulent drag reductions in wind tunnel tests. Another surface geometry modifier which has shown promise in ground-based testing is the large eddy break-up (LEBU) device. Transonic flight tests of the LEBU will be accomplished on the Langley B-737 aircraft. Supersonic viscous flow research will be increased with detailed wind tunnel investigation of boundary layer transition sensitivity to incident noise, roughness, waviness, and other disturbances. Additionally, a supersonic stability prediction method will be calibrated in the pilot low-disturbance wind tunnel. Other efforts in viscous drag research will include the F-14 variable sweep transition flight experiment on a natural laminar flow wing glove, completion of the JetStar laminar flow control flight tests, and supersonic laminar flow fundamental experiments on the Langley F-106 and the Ames-Dryden F-15 aircraft. New research into the reduction of induced drag (drag due to lift) and form drag will be initiated, to be followed shortly by research on wave drag reduction in which leading-edge modifications will be studied. Theoretical efforts in drag reduction will include development of a fully three-dimensional subsonic/supersonic viscous flow design code and the generation of near-field acoustic theory to model the interaction of noise with boundary layers.

A significant milestone in experimental aerodynamics projected for FY 1987 will be the completion of the Ames fluid mechanics laboratory. Fundamental tests and analyses will be conducted in this facility in unsteady boundary layers, vortical flows, advanced test techniques, and a variety of other flow physics phenomena. The theoretical efforts will be closely integrated with the corresponding experiments, which will be conducted primarily for the validation of computational aerodynamic methods and the exploration of fundamental flow mechanisms. The acquisition of detailed data to support turbulence model development will be pursued. Improved analysis/design capability for supercritical flows and vortical flows will be developed. In the Ames fluid mechanics facilities and in other aerodynamic research facilities, such as the national transonic facility, a major effort will be made to improve the transonic performance of advanced aircraft and missile configurations and to improve the understanding of high Reynolds number flows. Wing vortical flows will be analyzed in detail to develop prediction methods for high angle-of-attack flows and other complex phenomena. Supercritical technology and analytical transonic methods will be developed and applied to wing and canard design at cruise ana maneuver conditions for advanced aircraft. Leading-edge extensions and cavity flap concepts will be explored to capitalize on vortex-thrust and vortex-lift phenomena. Airfoil research will include basic aerodynamic tests of a swept porous laminar flow control airfoil and complete performance testing of a natural laminar flow airfoil. A high-lift data base will be established for an advanced four-component airfoil, with special attention given to confluent boundary layer behavior.

	1985 Actual	1986 Budget Estimate	1986 Current Estimate	1987 Budget Estimate
	(Thousands of Dollars)			
Applied aerodynamics research and technology........................	50,900	43,700	55,300	57,100

OBJECTIVES AND STATUS

The objective of the applied aerodynamics research program is to generate, by conducting analytical and experimental programs relevant to specific vehicle classes, advanced technology to improve performance and flight dynamics of future aircraft and missiles. The program is directed at specific technology goals associated with particular types of vehicles: (1) increased efficiency for subsonic aircraft through airframe/propulsion integration, stall-spin resistance, improved takeoff and landing performance, and a 60-percent reduction in cruise drag; (2) accurate prediction and reduction of rotorcraft noise and vibration, and improvement of rotorcraft performance permitting a fivefold increase in productivity; (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/ 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 to achieve an order-of-magnitude improvement in the accuracy of wind tunnel data. In addition, the program includes aeroacoustics research that develops the basic understanding required to examine specific noise problems such as the effect of advanced turboprop noise on structure and laminar flow.

In subsonic powered-lift research, the current emphasis is on large-scale testing of new concepts, including some in cooperative programs with industry, the Department of Defense (DUD), and allied governments. A large-scale model of the subsonic Grumman 698 tilt fan (V/STOL) aircraft is being readied for cooperative NASA/Navy testing in the 80x120-foot wind tunnel. Planning is in progress for cooperation with the DOD in further technology development for future aircraft such as the advanced technology transport being considered by the U.S. Air Force.

The emphasis in the rotorcraft aerodynamics research program is to provide technology required for low vibration for safety, speed, durability, and comfort and for the design and certification of civil and military helicopters producing 80 percent less noise than current helicopters. Basic acoustic analysis is showing promise for the reduction of certain types of noise, but higher order computer codes and experiments are needed to provide the accuracy required for design and certification of improved rotorcraft. In vibration research, cooperative efforts with industry have shown the need for structural detuning between the rotor and the fuselage and the need for better modeling of fuselage modes. Fundamental to these efforts are several small-scale wind tunnel tests for rotor airloads and interference. In full-scale flight research, the rotor systems research aircraft will complete a high-speed rotor performance survey. Support for the advanced light helicopter (LHX) and the V-22 programs continues, using the upgraded 40x80-foot wind tunnel and the XV-15 tilt rotor aircraft. In general aviation research, with spin-resistant design technology sufficiently developed to support the Federal Aviation Administration (FAA) certification of single-engine airplanes, the focus is shifting to twin-engine aircraft. The natural laminar flow research for drag reduction continues, emphasizing propeller slipstreams and three-dimensional fuselage shapes. Newly developed liquid crystal coatings will aid this effort by providing instantaneous measurement of fluctuations of boundary layer transition.

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, nonlinear, attached-flow computer codes for optimum design of supersonic configurations are being developed. Store carriage and separation at supersonic conditions are also being investigated, with emphasis on cavity flows with experimental validation. In high angle-of-attack research, analytical methods for calculating the typical vortex and separated flows from aircraft at high maneuver angles are being developed, with subsonic tests being used for correlation. Active control with blowing and passive design techniques are both being investigated 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 closely coupled with the research flight experiments conducted under the systems technology element for high-performance flight research. In supersonic fighter STOVL, a generic ejector lift model is investigating augmentation concepts, and 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 for tandem fan and remotely augmented lift system concepts.

Activities in hypersonics were expanded in FY 1986 in both the experimental and theoretical areas. The Langley Research Center program addresses the experimental wind tunnel model testing of advanced configurations that show promise for application in atmospheric cruise and airbreathing launch vehicles. The Ames Research Center activities concentrate on the application of computational fluid dynamics to the simulation and analysis of complex flow fields.

In support of the above efforts, new testing capability and techniques are being pursued. 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. Increased emphasis is being placed on nonintrusive measurement devices, such as lasers, with large payoffs in accuracy and productivity. In the aeroacoustics research effort, flight testing has been conducted to determine the effect of engine acoustic loads on the natural laminar flow of a nearby wing, and an effort is in progress in supersonic plume flow to examine the acoustic fatigue loads on the aft end of high-performance fighters.

CHANGES FROM FY 1986 BUDGET ESTIMATE

The increase of $11.6 million resulted from the realignment of fundamental aeroacoustics, test techniques, and NTF operations costs ($12.5 million) to this program and a general increase of $1.5 million, $0.7 million of which supports hypersonics technology. These increases were partially offset by the transfer of laminar flow integration research ($2.4 million) to fluid and thermal physics.

BASIS OF FY 1987 ESTIMATE

FY 1987 activities in rotorcraft aerodynamics research will include the acquisition of aerodynamic interference data on a main rotor/fuselage/tail rotor test apparatus in the 40x80-foot wind tunnel. A bearingless main rotor will be tested to define high-speed dynamic stability and loads. A simplified method of higher harmonic control for vibration reduction will be tried on a full-scale rotor in the 40x80-foot wind tunnel. Initial runs of a three-dimensional, viscous, transonic, unsteady flow analysis will be made for rotor blade tips.

High-performance aerodynamic research in sustained supersonic cruise will continue to develop analysis and experimental correlation of supersonic wing design and store carriage and separation. High angle-of-attack maneuverability research will investigate stability and control at angles to at least 80 degrees and will focus on three areas: (1) development of a data base for improved understanding of flow and flight dynamics phenomena and for subsequent support of planned flight research on the F-18 vehicle for high angle-of-attack testing; (2) aerodynamic data necessary for piloted simulations of maneuvers using thrust vectoring for control; and (3) the effect of vortex flaps on the control system requirements.

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.

The FY 1987 general aviation research will emphasize the acquisition of aerodynamic data in support of research on automatic control of engine-out conditions on twin-engine airplanes. It will also include research on unconventional configurations using forward sweep, canards, and aeroelastic tailoring. Criteria for fuselage designs having natural laminar flow will be developed. In the area of test techniques and instrumentation, the national transonic facility will continue 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. In other test techniques activity, laser holography visualization will permit the calculation of turbulence quantities. Adaptive walls will be operational in the Langley Research Center 0.3-meter and the Ames Research Center 2-foot wind tunnels. Fluorescent techniques will be developed for sensing temperature, density and skin friction parameters. The liquid crystal coatings for boundary layer research will be extended to supersonic and hypersonic flows.

The FY 1987 aeroacoustics research for fixed wing aircraft will continue the study of supersonic plume dynamics. This effort will be used in the analysis of ground and F-15 flight experiments that are investigating the structural fatigue loads associated with the acoustics of the dual-engine installation.

Hypersonic cruise/transatmospheric concepts will be designed, tested, and analyzed to establish a data base for this evolving vehicle class. Wind tunnel models will be constructed and tested over a wide speed range, (through hypersonic Mach numbers) to 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.

	1985 Actual	1986 Budget Estimate	1986 Current Estimate	1987 Budget Estimate
	(Thousands of Dollars)'			
Propulsion and power research and technology........................	33,636	31,000	33,800	35,700

OBJECTIVES AND STATUS

The objective of the propulsion and power research and technology program is to provide the understanding of the governing physical phenomena occurring at the disciplinary, component, and subsystem levels that will support and stimulate future improvements in propulsion system efficiency, performance capability, fuel flexibility, reliability, and durability. Research is being performed on a wide variety of subsystems with application ranging from the general aviation class through the hypersonic/transatmospheric class of aircraft. Ongoing disciplinary research on instrumentation, internal computational fluid mechanics and aerothermodynamic concepts is providing the foundation necessary to support progress at the component and subsystem levels. These 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 to support development of future systems. Near-term goals are the demonstration of good high-speed performance and, through a series of well thought-out experiments, the development of an understanding of the concept's governing principles. In FY 1985 a step-strut scramjet engine module operating at Mach 4 demonstrated a 21-percent increase in thrust over previous configurations and eliminated the combustor-inlet interaction previously observed. Tests will be run in FY 1986 to verify performance at Mach 7. Piston-driven shock-tunnel simulations for scramjet combustor conditions were carried out and showed good correlation with well established theoretical predictions proving it a useful tool for obtaining skin friction, wall heat transfer, and flow visualization. The reaction enhancement properties of silane were also demonstrated, providing a means to expand the envelope of conditions in which reactive tests can be conducted. Checkout measurements of temperature and concentration *of* nitrogen and oxygen in a subsonic flame using coherent anti-Stokes Raman spectroscopy were successfully completed proving this instrument ready for use on a supersonic flame.

For supermaneuverability and powered-lift applications, in which the goal is the development of technology to support propulsion systems capable of powered-lift and in-flight thrust vectoring capability, work is focusing on understanding ejector applications and the effects of thrust vectoring. The vectored-thrust model intended for determining thrust-vectoring performance and inlet ingestion is scheduled for testing in the Lewis Research Center 9x15-foot wind tunnel. Fabrication of a new powered-lift test rig at the Lewis Research Center will be completed in FY 1986 for later testing of the air ducting of a representative ejector system. Fabrication of a short diffuser for a supersonic 2-D inlet is near completion and will be tested to determine if engines can be installed farther forward on aircraft to get them closer to the center of gravity for improved control.

In small engines the objective is to achieve a specific fuel consumption reduction of 50 percent and, in addition, a multifuel capability for rotary engines. Near-term emphasis for the rotary engine is to obtain sufficiently improved understanding of the physical processes to enable accurate performance predictions and determination of advanced engine operating boundaries. For small gas turbines the specific fuel consumption goal can be met through the use of improved materials and advanced aerodynamic design, the concepts of near-term focus. The computer modeling for performance and heat transfer analyses of direct injection stratified-charge rotary engines has been completed, and the finite-element stress model for determination of the rotor and housing stresses was made operational. Castings of graphite-reinforced magnesium, for housings, which will provide increased stiffness for improved sealing, were successfully fabricated. The baseline performance characterization and evaluation of a high flow rate, low fuel injection, and high-voltage ignition system stratified-charge rotary test rig were initiated and will be completed in FY 1986.

Instrumentation research is progressing toward advanced high-temperature sensors and optical nonintrusive measurement systems. The first optical instrumentation system that allows flow measurement of all three velocity components through a single viewing port has been fabricated and successfully bench tested. The system is capable of measuring complex flows in turbomachinery passages, thus making possible a fundamental understanding of secondary flows. The system will be used to generate detailed secondary flow measurements during compressor tests in FY 1986. An advanced optical pressure sensor that is capable of operation at temperatures up to 840 degrees Fahrenheit was also demonstrated.

Internal computational fluid mechanics (ICFM) is emerging as a highly important tool for improved understanding of flow physics and for application in aeropropulsion systems. This will prove increasingly true as the ability to calculate complex three-dimensional flows with fast, validated techniques improves. Toward this end, improvements are sought in algorithm speed, ability to predict important physical phenomena, and proper validation of the prediction techniques. In FY 1985 a three-dimensional inviscid code was developed and used to analyze a radial flow turbine to determine secondary flow components, and rigorous viscous subsonic compressible flow analysis for two-dimensional and axisymmetric ducts has been developed that allows calculation of fully developed turbulent flows. The Institute for Computational Mechanics in Propulsion is now operational, and the first two institute members are on site at Lewis Research Center performing algorithm development research. The Lewis Research Center operates a Cray XMP computer system to provide state-of-the-art high-performance computational facilities for aeronautics research in fluid dynamics and heat transfer.

CHANGES FROM FY 1986 BUDGET ESTIMATE

The increase of $2.8 million reflects the transfer of internal computational fluid mechanics research ($5.0 million), offset by a reduction of $2.2 million in altitude wind tunnel modeling support and other study efforts; $1.5 million of this latter amount was transferred to the materials and structures line in support of priority hypersonics technology efforts. In addition, $2.9 million is being directed toward hypersonics technology requirements within this program.

BASIS OF FY 1987 ESTIMATE

The hypersonic propulsion activities will continue with design and fabrication of the large-scale scramjet engine hardware to show that the technology which was recently demonstrated can be applied to larger-scale engines. Low-speed performance will be verified with wind tunnel tests at both subsonic and low supersonic speeds. Coherent anti-Stokes Raman spectroscopy will be used to obtain instantaneous measurements of turbulence and heat release for aid in future model development. This will be the first time this information is obtained in a turbulent supersonic flame. Hydrogen injection into a Mach 18 flow will be investigated using the newly validated shock tunnel to obtain combustion and mixing rates for developing an understanding of the physics at extremely high speeds. The joint NASA/Defense Advanced Research Projects Agency (DARPA) program on combined cycle engines will continue into the fabrication phase.

In supermaneuverability and powered-lift propulsion technology for vertical and short takeoff and landing applications, determination of the performance of the U.S./Canadian ejector model for thrust augmentation will be conducted in FY 1987. The ejector system will be calibrated at the Lewis Research Center prior to testing with air flow in the 40x80-foot wind tunnel at the Ames Research Center. The complete General Dynamics E-7 ejector system will be tested at the Lewis Research Center on the new powered-lift rig to determine the details of pressure drop and flow distribution on a representative configuration. Testing of the vectored-thrust model for hot gas ingestion evaluations will be completed in FY 1987.

Under small engines, designs will be completed on rotating and stationary components for small gas turbines utilizing materials such as ceramic and ceramic composites that will enable the system to operate at higher temperatures with minimal cooling for increasing cycle efficiency and reducing cooling penalty. Development will begin on analytical 3-D viscous codes with moving coordinates which will guide new designs for high-efficiency components for high-temperature and stress conditions. In intermittent combustion research, the digital electronic high-pressure fuel-injection system design will be completed and fabrication begun. Comparison between the baseline performance of the rotary test rig and computer model will be complete and improvements to the code undertaken. High wear-resistant inserts will be cast into the graphite-reinforced magnesium housings to provide a better seal surface.

In the area of advanced instrumentation research, with its focus on high-temperature sensors for use with ceramics and other high-temperature materials, research will be continued on development of technology for high-temperature electronic devices based on silicon carbide. Emphasis is on improving crystal purity, obtaining a new crystalline structure capable of operation at 600 degrees centigrade, and the successful fabrication in FY 1967 of a silicon-carbide diode.

Research emphasis in ICFM will be placed on advanced algorithm development to decrease computation time for high-speed flows, by investigating efficient techniques for use with parallel processors, and to extend state-of-the-art external flow algorithms to internal flows, in particular, those with periodic unsteadiness as occur in turbomachinery. Additional emphasis will be placed on grid generation techniques to eliminate errors that can develop in calculations of high-speed flows by small grid errors occurring in the extremely thin shock layer regions. In addition, advanced computational techniques will be applied in areas of special interest including unsteady flows with shear layers to investigate the effect of shear layer excitation on mixing control; critical physical phenomena for high-speed flows to determine the characteristics and extent of imbedded regions, such as subsonic pockets; two-phase mixing flows to study ways to improve combustion and determine stability boundaries; reacting flows including chemical kinetics and heat transfer; and detailed experimental studies of highly sheared flows. Benchmark validation experiments will be performed for high Mach number flows in complex ducts, variable geometry supersonic inlets, and unconventional variable geometry nozzles with expansion on the vehicle afterbody.

	1985 Actual	1986 Budget Estimate	1986 Current Estimate	1987 Budget Estimate
		(Thousands of Dollars)		
Materials and structures research and technology	27,800	28,000	29,500	39,000

OBJECTIVES AND STATUS

The objectives of the materials and structures research and technology program are to: (1) investigate and characterize advanced metallic, ceramic, polymer, and composite materials; (2) develop 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 environments; and (4) generate research data to promote improvements in performance, safety, durability, and economy in aircraft. Areas of emphasis include high-temperature engine and airframe materials and structural concepts; composite materials application, life prediction, and thermal and dynamic response, including aeroelasticity; and more accurate and efficient integrated design methods for airframes and engines.

Significant improvements in the performance of turbine engines and airframe structures can be realized through research in the rapid solidification of metals. Ongoing studies are directed toward developing a greater understanding of the interrelationships among alloy composition, microstructure, processing parameters, and mechanical properties. This is particularly important in the exploitation of the innovative rapidly solidified superalloys and intermetallics now under study for high-temperature application. The opportunity for an operating temperature increase of up to 200-degrees Fahrenheit appears possible. Furthermore, recent results indicate that rapidly solidified aluminum powder alloys can be processed to achieve 20 percent greater strength-to-weight ratios with acceptable toughness for advanced airframe application.

Advances in structural mechanics are required for design verification of efficient, fault-tolerant advanced composite aircraft structural concepts subjected to various loads and discontinuities. Computational structural mechanics, a major thrust beginning in FY 1986, is focused around the development of advanced structural analysis and computational methods that exploit advances in computer hardware such as the application of multiple processors and concurrent processing capability. Initial studies address analysis problems of large displacements in flat and curved stiffened composite panels.

Analytical studies with experimental validation testing have continued to show that composite panels can exhibit substantial post-buckling strength of up to 80 percent of the unbuckled strength under combined compression and shear loading. Interior damage mechanisms for quasi-isotropic laminates subjected to bending have been characterized with and without open cutouts. Advances in nonlinear analysis capability to predict compressive strength in thick sections continue to be made with significant progress in code development.

The aeroelasticity program continues to develop and validate the technology required for active control of structural response for increased aircraft performance through relaxed static stability, flutter suppression, and gust load alleviation. Theoretical and experimental studies on unsteady aerodynamics, with major emphasis on the transonic region, have developed the capability for accurate analysis of a thick supercritical transport wing. Advanced nonlinear code development has been successfully extended to include strong shock conditions and the effect of oscillating control surfaces and has been correlated with wind tunnel results.

Research on composite materials places high emphasis on the toughness and durability of highly loaded structures. New materials, including semicrystallines and hybrids, have been developed to be 50 percent more resistant to impact and fracture through a better understanding of the relationships between material/structural mechanics and the molecular structures. Research on advanced structural concepts and configurations that exploit the advantages of composite materials continues. The primary effort is focused on the prediction and correlation of structural behavior of post-buckled stiffened composite panels and development of failure theories for composite structures.

The research program to develop ceramic materials for hot section components for gas turbine engines is continuing. Ceramics provide for higher temperature capability than metals (up to 2300 degrees Fahrenheit) but currently suffer from reliability problems. During FY 1986 processing studies for flaw-free silicon-nitride and silicon-carbide materials continued to show advancement. Research into the fabrication of ceramic composites for greater toughness was initiated. Considerable progress has been made in the understanding of the chemistry, kinetics and effects on strength of hot corrosion attack on silicon nitride. Fracture mechanics research has concentrated on the development of reliable crack growth characterization methods for monolithic ceramic materials at elevated temperatures. Initial results show promise for the development of improved models in these areas.

Hypersonic materials and structures research is a new area of emphasis in FY 1986. Innovative airframe and propulsion concepts are being explored. In both areas, research will be directed toward the development of new lightweight structural material systems that will withstand the extremely high temperatures and pressures encounterea in the hypersonic flight regime. These systems include metallic and intermetallic composites for engine application and advanced titanium honeycomb, metal matrix and box-stiffened fuselage substructure concepts for airframe application. Advanced 3-D analysis codes which deal with complex thermal/structural/flow interactions are a major thrust of the research for this area. Analysis tools ranging from conceptual design evaluation through detail structural optimization will be developed.

CHANGES FROM FY 1986 BUDGET ESTIMATE

The materials and structures research and technology program has been increased by $1.5 million to support hypersonics technology.

BASIS OF FY 1987 ESTIMATE

Research on high-temperature engine materials will emphasize improved durability and reliability of ceramics, thermal barrier coatings for turbine blades, and advanced intermetallics. Research efforts will focus on the development of a detailed understanding of the sintering, hot isostatic pressing, and powder processes in order to limit the number of strength-reducing flaws in high-temperature ceramic materials and achieve at least a doubling of the Weibull failure modulus. Increased emphasis will be placed on the development of tough ceramic and advanced intermetallic matrix composites and studies of matrix/fiber interface effects. New thermal barrier coatings with twice the resistance to erosion and foreign object damage will be identified. Advanced intermetallic alloys will be developed with a 40-percent ductility and strength increase at elevated temperatures.

Studies to understand the fundamental fatigue and fracture behavior of experimental and engineering materials will continue in order to develop reliable life prediction methods. The work will concentrate on the determination of the fatigue behavior of powder aluminum alloys and the development of fracture theories for these ductile metals. Special attention will be given to developing nonlinear analysis that predicts the growth rates of very short cracks. Advanced metallic fabrication concepts such as superplastic forming of high-strength aluminum will be developed to provide 40 percent lighter weight efficient airframe structures.

Composites research and technology efforts will emphasize toughness, durability, and processability of materials and low-cost, efficient, and highly loaded advanced structural concepts. In addition to the development and characterization of newer thermoset and thermoplastic resin systems, materials research will concentrate on advanced material forms and fabrication technology, such as 3-D weaving, to achieve a 100-percent increase in resistance to impact and interlaminar strength. Primary emphasis of the program will be to understand the interaction and relationship between new fiber and resin system properties and structural characteristics and failure modes, and to develop micromechanical behavior models.

In the structures area, significant effort will be devoted to the development of concepts ana configurations which effectively utilize the anisotropic properties of composites to achieve the most efficient structural designs by a factor of two in terms of cost, weight, and damage tolerance. The major thrust of this effort will be the development of structural sizing and analysis methods based on structural tailoring for stiffness and strength at both the local and global levels. Local tailoring at sites of load introduction and discontinuities can have a significant impact on increased resistance to damage and weight aavantages associated with joints, attachments, and local stress risers. Global or component level structural tailoring for stiffness and strength, including aeroelastic effects, provides major advances in structural weight efficiency ana becomes interdisciplinary because of the attendant effects on flight controls and aerodynamics. The unconventional placement of composite material with highly directional properties to achieve the desired effects will require significant advances in understanding properties, loading effects, failure characteristics, and the development of 3-0 analysis and prediction methods. New testing methods will be required to define failure models and verify analysis procedures.

The dynamics and aeroelasticity program will continue to emphasize the development of improved analytical tools for predicting unsteady aerodynamic pressures, particularly in the transonic speed range, and the aeroelastic response of wings and engine turbine blades. Analysis methods will be verified through systematic tests of both idealized and true-scale airfoils and will concentrate on nonlinear 3-D flow effects. This effort will provide the basis for a significant advance in the development of active control technology.

In the area of integrated analysis and optimization, efforts will concentrate on the development of methods in computational structural mechanics for the analysis of complex aerospace vehicles. Emphasis will be placed on methods for predicting nonlinear transient dynamics and on the development of new solution techniques that take advantage of advanced computer hardware/software concepts, e.g., parallel processing and hybrid analysis techniques. In addition, work will continue in the development of methodology for multidisciplinary design of aircraft vehicles. The number of parameters taken into account in the optimization procedures will be expanded to include vehicle aerodynamic shape and active controls, as well as structural design constraints. A focused study will be initiated to validate the approach on an advanced fighter configuration.

An augmented effort will concentrate on the detailed airloads experiments needed to correlate predictions of rotorcraft noise and vibration. Pressure-instrumented blades will be flown on the Boeing Model 360 and the UH-60 helicopters. Also, detailed pressure measurements will be taken of the new high-speed conditions in the 40x80-foot wind tunnel on a full-scale rotor. Simultaneous acoustic and loads measurements will be taken for the first time. This activity will be the beginning of the use of powerful computer codes and the comprehensive data bases that will lead to concepts for the desired 80-percent noise reduction and the reduction of vibration to transport levels. Promising noise and vibration reduction techniques will be pursued to demonstrate quiet, "jet-smooth" operation. The previous rotorcraft structural dynamic modeling results will form the basis for this effort. The other major technical thrust in this program will involve the development of rotorcraft-coupled rotor-airframe dynamic response prediction capability. This will then enable airframe structural optimization for complex vibration and acoustic loads. This activity will include the dynamic testing of all critical rotorcraft components to generate a comprehensive data base for validation of advanced analytical methods. The program will also allow unique rotor and airframe concepts to be defined and evaluated and will encompass efforts to enhance basic understanding of aeroacoustics, blade dynamics and aeroelasticity, and effective utilization of advanced materials for airframe design concepts.

In FY 1987, more emphasis will be placed on hypersonic research. Material and structural concepts to enable a high-speed, high-temperature vehicle will continue to be developed. Innovative fabrication schemes for ultra-lightweight, high stiffness ana strength structures will be explored. Thermal/structural/flow analysis and multidisciplinary optimization techniques will be expanded to cover the entire flight regime. Evaluation of tankage concepts for cryogenic fuels and methods for active thermal management of integrated engine/airframe designs will be developed.

	1985 Actual	1986 Budget Estimate	1986 Current Estimate	1987 Budget Estimate
	(Thousands of Dollars)			
Information sciences research and technology....	21,100	22,506	24,900	26,800

OBJECTIVES AND STATUS

The objectives of the information sciences research and technology program are to explore the fundamental principles underlying aerospace computing, to understand the relationship and tradeoffs between algorithms and computing architectures, and to develop advanced computational concepts and system architectures. The program supports research in concurrent processing, reliable computing, software engineering, and large-scale scientific computational facilities for aeronautics research.

Concurrent processing research addresses system architectures and algorithms for computationally intensive problems in aeronautics, such as computational fluid dynamics, computational chemistry, and structural dynamics. The benefits obtained from these computations are both essential and substantial but remain limited by the performance of the most advanced equipment and software. The concurrent processing work is concentrating on exploiting parallel processing techniques to increase computational power for aeronautics computations. In 1985 the ability to simulate parallel processing and architectures was demonstrated. This demonstration proved the concept and is the basis for continuing work along this line to improve the fidelity and the scope of the simulation. That simulation provides a powerful tool for developing improved computer software and architectures. Work is also underway to develop parallel and distributed computer systems that are practical for aerospace vehicles.

The Research Institute for Advanced Computer Science (RIACS) is just beginning the final year of its three-year start-up phase and has established itself in the nation's computing research community. Much of the effort is concentrated on analysis of new parallel processing computers. An Intel hypercube machine is now being used to support the research into the class of highly parallel machines that do not share common memory.

Software engineering work concentrates on the production of reliable software and computers. A study and experiment concerning the fundamental basis for fault-tolerant designs led to a surprising finding that redundant versions of software did not give nearly the expected improvement in reliability due to the fact that software faults are not independent. This important finding is the basis for additional studies and experiments with software and fault-tolerant designs. Work is underway to develop techniques for testing and verifying reliable software.

A major objective of the computer science and applications program is to provide state-of-the-art high-performance computational facilities for aeronautics research. Ames Research Center operates a Cyber 205 and Cray XMP-22 at the central computer facility. This system provides vital computational support to researchers in fluid dynamics, chemistry, and thermal and structural analysis.

CHANGES FRM FY 1986 BUDGET ESTIMATE

The information sciences research and technology program includes an increase of $2.4 million, which reflects the consolidation of funding for Ames Research Center's central computer facility into this budget line.

BASIS OF FY 1987 ESTIMATE

In concurrent processing, work will focus on using concurrent processing to speed solutions to increasingly complex aerospace computational problems. RIACS will direct its energies on technology to greatly improve the productivity of aeronautics research scientists through computational systems employing artificial intelligence and very high-performance computing architectures. Computer science researchers at RIACS will work in conjunction with computational physics experts in advancing capabilities to solve aerospace computational problems.

Efforts initiated in FY 1985 will continue to involve universities in fundamental computer science research. Research areas include multiprocessor parallel architectures, distributed processing architectures, and multiple-instruction/multiple-data architectures for supercomputers. Techniques to automate the production, evaluation, and validation of software to enable the cost-effective production of highly reliable software are research topics.

Cooperation with DOD in software development will include interfaces with the Software Engineering Institute and software technology for adaptable reliable systems programs. Development of software engineering techniques needed to produce reliable and affordable software will continue with some emphasis on maximizing the benefits of utilizing the Ada programming language.

Support for the supercomputer facilities at Ames Research Center will be continued. Marshall Space Flight Center will complete development of a digital high-speed network to link agency supercomputer facilities at Lewis Research Center, Ames Research Center, and Langley Research Center. That capability will merge with the program support communications network and will become an operational network at the conclusion of the development.

	1985 Actual	1986 Budget Estimate	1986 Current Estimate	1987 Budget Estimate
		(Thousands of Dollars)		
Controls and guidance research and technology	20,600	22,100	22,100	24,500

OBJECTIVES AND STATUS

The objectives of the controls and guidance research and technology program are to: (1) develop advanced controls and guidance theories and analysis methods for extending the performance envelope and reliability of highly augmented future aircraft; (2) investigate emerging controls, guidance, artificial intelligence and display technologies which offer future alternative approaches for continued aviation safety, effectiveness, and efficiency; (3) develop architectures for flight-crucial systems for future aircraft and devise analytical methods and techniques for assessing the reliability and performance of complex integrated fault-tolerant systems; (4) develop methods for more efficient and safe transport aircraft operations in the national airspace system; and (5) explore new concepts for achieving integration of multidisciplinary technologies. Major generic program elements are control theory, guidance and display concepts, and flight-crucial systems. Vehicle specific program elements address subsonic transports, rotorcraft, high-performance aircraft, and hypersonic vehicles.

Control theory research includes activities on analytical methods, criteria and guidelines, controls modeling, and applications. Methods for analyzing and simulating reconfigurable/restructurable control systems continue to be a major focus, with the objective of automatic failure detection and identification, parameter estimation, and controller design to accommodate unanticipated failures in real time. Centralized and decentralized failure detection and identification (FDI) techniques are being investigated. The initial assessment of centralized FDI techniques indicates the orthogonal series generalized likelihood ratio method offers the most potential. Handling qualities criteria research, which has concentrated on new time domain methods for superaugmented aircraft, will be terminated at the end of 1986.

Guidance and display concepts research investigates advanced methods for achieving desired flight-path guidance in all-weather conditions and advanced display technology to improve the presentation of information to the flight crew. 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 an expert system to assist air traffic controllers. Display concepts research has focused on flat-panel displays, graphic display generation, and three-dimensional display techniques. A two-primary-color, thin-film, electroluminescent, flat-panel test specimen display was fabricated successfully for the first time using superimposed red and green phosphor layers.

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 which are critical for successful flight. 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. Two new reliability analysis computer programs have been developed to improve assessment methodology for flight-crucial systems. One of these, the semi-Markov unreliability range evaluator, has received very favorable comments from industry because it is very fast and can directly utilize experimental data. The other, the hybrid automated reliability predictor, extends the capability of a previously released program which is widely used by aircraft manufacturers and guidance and control companies.

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. A unique transport control system concept, called the total energy control system, was flight tested successfully in the transport systems research vehicle. This multi-input, multi-output control system design demonstated that throttle activity due to flight path perturbations could be reduced by integrating a full-time autothrottle to control the total energy of the aircraft with the elevator to distribute the energy between speed and flight-path angle. Extensive planning and coordination with the FAA has taken place to establish a practical integrated four-dimensional flight management/time-based air traffic control system program which would include experimental flight operations at one of the FAA's regional centers.

Rotorcraft guidance and controls research involves unique concepts to improve the overall effectiveness and utilization of rotorcraft for military and civil missions. A highly portable, low-cost beacon landing guidance system using airborne radar technology has been developed and successfully flight tested. The tests demonstrated that the system could provide precision instrument approach capability for helicopter operations at remote sites. In conjunction with this activity, NASA also has worked with the U.S. Air Force in the development and flight testing of a portable tactical approach guidance system which shows great promise for use in a battle-damaged airfield mission scenerio for both fixed-wing and rotorcraft applications.

Controls and guidance research directly applicable to fighter/attack aircraft includes the integrated airframe/propulsion control system architecture program aimed at the development of validation methodology for complex integrated control systems and the multidisciplinary dynamics integration effort focused on functional integration of aerodynamic, structural, propulsive, and control system dynamics. In addition, research is underway on advanced automated air combat guidance laws for high-performance aircraft. Included are both heuristic and expert system approaches involving artificial intelligence techniques for automation of fighter/attack aircraft control and other functional tasks.

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 at 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 planning and conceptual research are now underway in this area.

CHANGES FRM FY 1966 ESTIMATE

The total funding for this program has not changed; however, $0.2 million has been redirected within the program to support hypersonics technology.

BASIS OF FY 1987 ESTIMATE

In the control theory area, research on reconfigurable/restructurable control systems has the goal of extremely highly reliable adaptation to failures. The emphasis on failure detection and identification techniques will shift from selected centralized methods to decentralized techniques and adaptive methods. Complementary research on systems identification aims to achieve real-time methods. Initial activities to merge expert systems techniques with modern control theory design methods will begin in the field of analytical design methodology.

Guidance and display concepts research includes the application of artificial intelligence technology to military and civil aircraft operations. The major focus will be the "automated wingman" program undertaken in cooperation with the 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 capability for rapid prototyping of 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 which could have a significant effect on the use of N-version software as a means for achieving extremely reliable systems. 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 be tested to assess its ability to achieve high levels of function reliability, through graded redundancy and software function migration, and its capability for graceful degradation in the presence of faults.

Controls and guidance research directed at subsonic transports includes advanced transport operating systems, highly reliable digital control system architectures, and safety. The major focus in advanced transport operating systems will be four-dimensional (4-D) flight management system equipped aircraft integration with the air traffic control 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 FAA, as will the research on airborne systems for the detection and avoidance of wind-shear safety hazards.

Rotorcraft controls and guidance research involves the application of artificial intelligence and expert systems technology to the difficult military rotorcraft mission of all-weather nap-of-the-earth (NOE) operations. The objective of this research is to develop flight path management and planning concepts for terrain following/terrain avoidance and manually controlled helicopter flight, leading to automated flight with assumed sensor-derived data, A rule-based expert system will be developed for invoking on-board mission replanning during NOE flight, and pilot/system interface concepts will be formulated. This research will be performed in cooperation with the U.S. Army.

Controls and guidance research directed at fighter/attack aircraft applications will stress the efforts underway on integrated airframe/propulsion control system architectures and multidisciplinary dynamics integration and will be expanded to include supermaneuverability considerations. Reconfigurable/restructurable control system concepts and artificial intelligence/expert systems technology will be investigated as potential solutions to the critical problem of transient thrust loss during propulsive control supermaneuvering flight.

Hypersonic vehicle guidance and controls research will explore new and unconventional guidance and outer-loop control modes for flight path control to achieve optimum performance and efficiency. In addition, concepts to integrate aerodynamic and propulsion controls for hypersonic cruise vehicles will be formulated.

	1985 Actual	1986 Budget Estimate	1986 Current Estimate	1987 Budget Estimate
		(Thousands of Dollars)		
Human factors research and technology..	20,300	22,000	22,000	24,000

OBJECTIVES AND STATUS

The objective of the human factors research and technology program is to provide the capability to design crew interfaces with new cockpit technologies (e.g., expert systems, voice interaction, flat-panel and virtual-image displays) which will permit maximum advantage to be taken of the potential of these technologies to enable increased capability, efficiency and safety in rotorcraft, air carrier, and general aviation. This is accomplished by developing an understanding of crew capabilities, limitations, and tendencies in interacting with these systems and delineating guidelines for implementing that understanding. There are four areas of emphasis in the human factors program: (1) flight management, (2) human engineering methods, (3) rotorcraft, and (4) subsonic transport/commuter/general aviation.

The flight management research program has continued to focus on crew interaction with cockpit automation and advanced information input/output methods. Having developed an expert system for fault monitoring and diagnosis of electrical systems, expert systems are under development for hydraulic and propulsion systems, so that crew capability to perform supervisory control functions over multiple expert systems can be evaluated. Another expert system has been developed for designing and selecting type fonts and symbols for electronic displays. A rule-based system has been initiated which will aid in the design of electronic display formats by providing an interactive data base on what is known in that area. Techniques have been developed for designing flight computer data bases consistent with how pilots organize the relevant data and for measuring the consistency of crew-computer interaction protocols in various computer modes.

Human engineering methods are focused on developing techniques for design and evaluation of cockpit equipment and operations. Current work is in workload measurement and simulation technology. A new model was developed for constructing simulator scenarios with predicted workload levels. This will enable increased flexibility in evaluating alternative cockpit technologies. In simulation technology, a methodology has been developed to optimize simulator motion systems by predicting the effect of motion washout algorithms on crews.

In the rotorcraft area, the focus is on providing the technology for single pilot capability in poor visibility for both military and civilian missions. A wide field-of-view head-up display is being developed. In addition, workload measures are being developed to assess the effects of potential cockpit improvements.

In the subsonic transport/commuter/general aviation area, the focus was on jet lag in air transport crews and on the potential use of data-link by general aviation pilots in instrument flight rules. Management of the aviation safety reporting system (ASRS) for the FAA has continued. Also, a high-resolution, 2-D model of wind shear was developed using computational fluid dynamics to simulate actual wind-shear conditions. Simulations of the Dallas-Fort Worth wind-shear accident were provided to the National Transportation Safety Board (NTSB). The man-vehicle system research facility, a high-fidelity simulation facility with a B-727 cockpit and an advanced concepts cockpit, became fully operational and was used for evaluation of sidearm contollers and wind-shear simulation models.

BASIS FOR FY 1987 ESTIMATE

The focus of the FY 1987 human factors research and technology program will shift from air transport and generic research to rotorcraft and high-performance aircraft. The generic human/automation interface research will be focused on problems associated with these specific classes of aircraft. The rotorcraft program will develop voice interaction capability, automated crew aids, and innovative information management concepts to enable night NUE flight and increased capability for commercial operations in foul weather. This will include the development of methods to evaluate alternative cockpit designs. Rotorcraft human factors research will utilize the Cobra surrogate trainer pilot night vision system facility. Previous accomplishments in automation interface and workload analysis will be applied specifically to rotorcraft cockpit design. Of particular importance will be the further development of techniques for consistent pilot-matched system interactions and reliable measures of automation-induced cognitive workload. Continuing studies of vestibular models for simulator motion systems will be especially important for accurate and cost-effective NOE rotorcraft simulation. The high-performance human factors research will focus on developing "electronic copilot" features for crew control of emerging artificial intelligence capabilities such as the automated wingman concept. It will also begin exploring the crew-related aspects of hypersonic/transatmospheric vehicles. Continuing expert system interface studies will offer increasingly quantified insight into pilot/automation interaction issues so that verified methods and models are available to guide hardware and software designers. This work benefits from a high degree of synergism with the space human factors program. In air transport, the jet lag program will be completed; management of the ASRS will continue; and guidelines will be developed for crew monitoring and control of multiple integrated expert systems. The manned vehicle systems research facility (MVSRF) will be used in support of the FAA for evaluation of threat alert and collision avoidance system displays. It will also be used for high-fidelity full-mission evaluation of human/automation interaction design guidelines. The ASRS data base of aviation incidents will be especially useful for identifying the most significant system and crew factors which require experimental investigation. It is expected that the extensive data on automation-induced incidents will be particularly important for guiding research in the advanced technology cockpit of the MVSRF.

	1985 Actual	1386 Budget Estimate	1386 Current Estimate	1987 Budget Estimate
		(Thousands of Dollars)		
Flight systems research and technology ...	17,864	18,300	18,300	21,500

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, DOD, and FAA. The program is organized into the following main categories: (1) aviation safety, (2) convertible engine rotorcraft propulsion, (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) developing convertible engine propulsion concepts which provide both thrust and shaft power that will enable military aircraft to retain the low-speed advantages of helicopters while allowing highly maneuverable high-speed flight; 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 systems, establishment of a flight-validated lightning strike data base for development of design criteria for advanced materials and digital avionics systems, and the quantification of the effects of heavy rain on aircraft aerodynamic and propulsion system performance. NASA has completed the technology development of an electro-impulse deicer concept, reported the results in an industry symposium, and assisted the Army in resolving the A-10 inlet icing problem. The instrumented F-106 severe storms research aircraft is completing the characterization of direct lightning strikes to the aircraft in convective weather. The resulting first-of-a-kind data base is providing the basis for the development of threat 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 convertible engine rotorcraft propulsion technology program are to provide technoloyy readiness in experimental propulsion systems for rotorcraft and V/STOL aircraft incorporating advanced convertible engine concepts providing both shaft and thrust power requirements. The steady state power modes have been demonstrated, and the crucial transient conversion requirement for application to compound configurations, such as the X-wing, has been successfully accomplished. The convertible engine concept will provide designers of future rotorcraft and V/STOL aircraft a new dimension with a single powerplant capable of providing turboshaft power and turbofan thrust power simultaneously or individually. This program will be completed in **1986.**

The objectives of the high-performance aircraft program are to refine and validate aerodynamic predictive tools at high angle-of-attack flight conditions, and to demonstrate the performance benefits and utility of propulsive flight control. Negotiations have also been conducted with the United Kingdom for cooperative investigations of several design concepts for a supersonic advanced short takeoff and vertical landing (ASTOVL) aircraft 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 Ames-Dryden aging F-104 high-performance support aircraft with Navy-loaned full-scale development F-18 aircraft has been initiated.

CHANGES FRM FY 1986 ESTIMATE

The total for this program has not changed. A decrease to support hypersonics technology ($0.6 million) and systems analysis studies ($0.4 million) has been restored with the application of $1.0 million from the oblique wing systems technology program.

BASIS OF FY 1987 ESTIMATE

In FY 1987, the aviation safety program will emphasize coordinated wind tunnel, analytical, and flight research investigations and analyses leading to an understanding of ice accretion and its effects on fixed- and rotary-wing aircraft performance and handling qualities. Research to establish a flight-validated severe storms/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.

The high-performance aircraft program will continue in FY 1967. Wind tunnel and analytical research will be conducted to investigate the potential benefits and 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-16 high alpha research vehicle. Wind tunnel research will be completed to support the flight validation of the aerodynamic performance benefits of a leading-edge vortex flap for enhanced maneuvering performance. In the U.S./U.K. ASTOVL program, propulsion system and airframe design studies will be conducted to identify the advantages and disadvantages of alternative propulsion system concepts for a supersonic V/STOL 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 helicopters and aircraft described under high-performance aircraft systems technology (X-29A, F-15, F-16, YAV-8B). The test support activity also provides for flight crew training, maintenance of flight data facilities, aircraft instrumentation, and flight data processing.

	1985 Actual	1986 Budget Estimate	1986 Current Estimate	1987 Budget Estimate
		(Thousands of Dollars)		
Systems analysis.	2,600	3,200	4,000	4,800

OBJECTIVES AND STATUS

The objective of the systems analysis effort is to examine the technology needs and opportunities for future vehicle concepts and to provide performance data and sensitivity analysis for effective long-range planning. The studies identify high-payoff, emerging technologies that can lead to new plateaus or major improvements in civil or military vehicle performance, creation of new markets, and potential economic benefits. The following vehicle classes are addressed by the studies: subsonic, rotorcraft, supersonic cruise, high performance, and hypersonic for a variety of civil and military applications.

The systems analysis studies for the subsonic aircraft, which include general aviation, commuter, and transport aircraft, concentrated on the benefits associated with laminar flow and advanced turboprop concepts in FY 1986. The studies addressed the economics of commuter aircraft and small subsonic advanced propfan transports utilizing advanced technologies. Studies were conducted to assess the impact of very advanced materials and structures for subsonic transport applications.

The study efforts for sustained supersonic cruise technology are examining innovative configurations incorporating advances in aerodynamics and propulsion system technologies for advanced military and civil aircraft and the payoff of efficient, economical, advanced processing methods that exploit the full weight-savings potential of advanced metals. Supersonic throughflow fan engine concepts are also being examined.

An ongoing study effort is assessing the benefits of new emerging technologies to the fighter/attack class of aircraft. Also, as part of a cooperative U.S./U.K. ASTOVL program, multidisciplinary analysis and design studies are exploring concepts that utilize high thrust-to-weight engines and thrust-vectoring control. The conceptual studies will form the basis for selection of the most promising concepts for technology development.

Studies in FY 1986 for hypersonic vehicles concentrated on performance and weight estimates associated with turboramjet, ejector ramjet, and air-turboramjet concepts. Studies have been initiated to assess unique far-term hypersonic propulsion concepts.

CHANGES FROM FY 1986 BUDGET ESTIMATE

The increase of $0.8 million in systems analysis reflects increased emphasis on study activities primarily directed toward high-speed and hypersonic propulsion technology.

BASIS FOR FY 1987 ESTIMATE

In FY 1987, studies will investigate the benefits of emerging small-engine technologies for applicability to general aviation and commuter aircraft. Rotorcraft systems analysis will be assessing the potential impact on civil transportation opened by the high-speed tilt rotor and X-wing concepts. These concepts have tremendous potential for both the civil and military markets, especially as emerging new technologies, such as convertible engines and folded or stowed rotors, are developed.

The studies for sustained supersonic cruise in FY 1987 will focus on defining the technology requirements and vehicle characteristics necessary to meet projected opportunities and requirements. Technologies will be identified and assessed for long-range, economically viable high-speed aircraft with particular emphasis on aerodynamic, structural, and propulsion concepts for speeds ranging from Mach 2.5 to 5.0.

Technology integration studies for advanced fighter concepts will focus on new capabilities enabled by key emerging technologies. Thrust-to-weight ratio of fighter engines is expected to double over the next decade. Combined with advances in lightweight materials and structures, this could result in small lightweight fighters with high overall thrust-to-weight ratio. Configurations will be assessed that vector and/or deflect the thrust for control augmentation and direct lift generation.

In terms of our military posture, hypersonic speed and high-altitude performance characteristics in both airplanes and missiles have obvious advantages for national defense as well as for hypersonic transports, which could cut the trip time in half relative to a Mach 2 or 3 transport. Aircraft productivity will be improved with increasing Mach number. Vehicle design matrices 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. These formulations will employ the synergistic integration of aerodynamic, aerothermal, propulsion, structural, and controls technologies with emphasis on propulsion options and will be used to guide NASA's technology development in this important area.

BASIS OF FY 1987 FUNDING REQUIREMENTS

SYSTEMS TECHNOLOGY PROGRAMS

	1985 Actual	1986 Budget Estimate	1986 Current Estimate	1987 Budget Estimate	Page Number
	(Thousands of Dollars)				
Rotorcraft systems technology.........	26,000	20,500	20,500	18,700	RD 13-39
High-performance aircraft systems technology.	21,53b	21,800	20,800	26,000	RD 13-41
Subsonic aircraft systems technology..	19,000	---	---	---	
Advanced propulsion systems technology	26,100	44,200	44,200	28,400	RD 13-45
Numerical aerodynamic simulation......	26,472	28,200	28,200	30,000	RD 13-47
Total...............................	119,102	114,700	113,700	103,100	

	1985 Actual	1986 Budget Estimate	1986 Current Estimate	1987 Budget Estimate
		(Thousands of Dollars)		
Rotorcraft systems technology				
Advanced rotorcraft technology	9,632	2,700	2,700	2,000
Technology for next generation rotorcraft..........	16,368	17,800	17,800	16,700
Total..............................	26,000	20,500	20,500	16,700

OBJECTIVES AND STATUS

The rotorcraft systems technology program conducts research on two fronts. The first thrust consists of efforts in the broad systems technology areas of comprehensive noise prediction and full-scale wind tunnel tests. The goal of this thrust is to predict overall vehicle noise to ±1.5 decibels accuracy and to acquire airloads for new design techniques for "jet-smooth" vibration. The second thrust involves the X-wing rotor demonstration test on the rotor systems research aircraft (RSRA).

In the noise program conducted with the American Helicopter Society (AHS), an updated, comprehensive noise prediction code was released to industry. Accuracy is expected to be ±3 decibels in most cases for existing designs. Also, the first prediction of blade-vortex interaction noise was made using new analytical tools. A full-scale flight test of a Hughes 500 helicopter, with engine noise muffled, was initiated to determine the contribution of individual sources to varying noise levels due to turbulence and wind.

In full-scale testing, an Army LHX main rotor was tested in the newly upgraded 40x80-foot wind tunnel. The first full-scale test of main rotor/tail rotor aerodynamic interference was also run in the 40x80-foot wind tunnel. Acquisition of a pressure-tapped main rotor and a hingeless rotor will be started for an FY 1987 tunnel entry to investigate high-speed airloads and rotor-dynamic stability. These data previously did not exist for correlation for noise and vibration prediction/reduction.

In the joint DARPA/NASA RSRA/X-wing rotor investigation, the prime objective 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. Completed to date are the RSRA airframe modification; the propulsion and pneumatic system; the propulsion system testbed (PSTB) facility; an integrated, mobile data acquisition facility; *a* prototype, digital fly-by-wire flight control computer; and high-temperature composite rotor blade components. Testing has been initiated in the PSTB, wind tunnel, and flight control computer laboratory.

In 1986 the fabrication and assembly of the X-wing rotor system will be completed, and the rotor system will be installed on the PSTB and subsequently on the aircraft. Preceding flight, the X-wing rotor system will be extensively tested on the PSTB, an "iron bird" ground-based facility, and the reliability of the flight control system will be extensively tested in the vehicle management system laboratory which was specifically developed to test the unique X-wing flight control system. Supporting research includes upgraded piloted simulations in the Ames Research Center's vertical motion simulator and upgraded scale-model wind tunnel tests. These tests will concentrate on the flight mode in which the aircraft "converts" from rotary to stopped-rotor at speeds near 200 knots.

BASIS OF FY 1987 ESTIMATE

The NASA/AHS program will continue with the release of new subroutines for rotor loads and rotor wakes. Blade vortex interaction noise will be emphasized to determine the benefits of airfoil nose shape using more powerful 3-0 predictions. Aerodynamic interference will also be incorporated in the comprehensive prediction code. Prediction accuracy is expected to approach ±1.5 decibels for takeoff and flyover conditions for existing designs. Advanced designs and landing conditions will await better analysis.

In FY 1987 the X-wing flight test program is planned to be completed. The program will also be generating ground-based piloted simulation PSTB data, and vehicle management systems data in support of the flight investigation of the X-wing rotor on the RSRA. This fast-paced, advanced technology program will require extensive, coordinated testing in 1987 which is crucial to the success of the flight investigation and will require special NASA capabilities to support the contractor's efforts. In particular, the flight testing will culminate in the historic demonstration of conversion from rotary to stopped-rotor flight for cruise and a reconversion to rotary flight for landing.

	1985 Actual	1986 Budqet Estimate	1986 Current Estimate	1967 Budqet Estimate
		(Thousands of Dollars)		
High-performance aircraft systems technology				
High-performance flight research.. ..	9,730	9,800	9,800	10,400
Turbine engine hot section technology	9,300	5,2110	5,200	5,000
Ceramics for turbine engines.	2,500	2,100	2,100	2,200
Oblique wing technology.............	---	4,700	3,700	8,4011
Total	21,530	21,800	20,800	26,000

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.

In the joint NASA/Air Force advanced fighter technology integration (AFTI) program, the AFTI/F-16 automated maneuvering attack system flight phase is being completed. The AFTI/F-111 mission adaptive wing project will complete the flight research activity to validate predicted performance improvements, including range increase of 25 percent, resulting from its variable camber airfoil. 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 has begun to validate 10- to 15-percent aircraft performance improvements through integrated digital electronic controls. In the NASA/DARPA X-29A forward-swept wing flight demonstration program, the aircraft will complete the baseline flight program in 1986 to validate predictive tools and exploit the advanced technologies designed into the experimental aircraft. The F-18 high angle-of-attack flight testing will begin in the third quarter of FY 1986 on an unmodified F-18. The goal of the program is a flight-validated data base for design of highly maneuverable aircraft with a 90-degree angle-of-attack capability. Initial flight tests will focus on the development of a flight-validated aerodynamic data base for correlation with wind tunnel and analytical predictions. Design studies and wind tunnel testing are leading to the modification of an F-106 aircraft to validate the predicted improvements on aircraft takeoff, landing, and maneuver flight performance resulting from use of vortex flap technology. Flight testing of a YAV-8B Harrier is continuing for validation of wind tunnel, analytical, and simulator predictions of V/STOL aircraft characteristics.

During FY 1986 the turbine engine hot section technology (HOST) program continues to address the issues involved in engine durability. The objectives are to establish predictive methods for the structural response and life of hot section components by developing analysis methods, instrumentation and verification test methodology. During this year the new high-temperature structures and fatigue laboratory at Lewis Research Center began operation. This unique national facility allows for the study of the behavior of turbine blade and burner liner materials under realistic, complex, thermomechanical loading conditions. Improved numerical schemes for 3-D aerothermal flow interaction with combustor liners have been developed and benchmark experimental tests conducted. Progress on the development of specialized 3-D nonlinear analysis methodology to predict component response and life has been substantial. Constitutive laws have been developed which actually predict single crystal blade response. The ability to predict coolant passage heat transfer during blade rotation has been achieved, greatly increasing our understanding of cooling effects. Improved theories of salt deposition on rotating airfoils have been developed, leading to better models for coating performance in corrosive turbine environments.

As part of the activity to develop higher performance longer life turbine blade materials, the ceramic research program has continued to make progress in FY 1986. Critical processing variables in the preparation of silicon-nitride and silicon-carbide powders have been determined. Hot isostatic pressing of sintered ceramic bodies has shown a 100-percent improvement in flaw reduction. A new nondestructive evaluation approach, laser-acoustic microscopy, has demonstrated the ability to accurately find 50-micron surface flaws in silicon nitride. In this year an advanced brittle design code, developed in-house at Lewis Research Center using Batdorf statistics, has demonstrated greater accuracy in describing ceramic material failure response. This code has been released to industry and is seen as a major advance. Initial studies on the application of ceramic composites for turbine blades have shown promise for the development of "tough" ceramics.

The objective *of* the joint NASA/Navy oblique wing 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 investigatea 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 aircraft carrier airplane spotting ratios for Navy flight deck operations.

The oblique wing technology development will be completed by 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. A wing preliminary design contract has been awarded and will provide the basis for the final design and initiation of the fabrication of the wing, pivot mechanism and required modifications to the F-8 DFBW testbed. This activity will lead to the start of the flight test program in 1989.

CHANGES FROM FY 1986 BUDGET ESTIMATE

The reduction of $1.0 million in high performance aircraft systems technology reflects a reduction in the oblique wing technology program in accordance with Congressional direction. This funding has been redirected to cover high priority requirements in the flight systems research and technology base program.

BASIS Of FY 1987 ESTIMATE

The flight research activity in FY 1987 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 will complete flight test validation of performance improvements resulting from propulsion system variable operating line control. The NASA/DARPA X-29A aircraft program will be expanded to include Air Force participation in a follow-on flight research program on the first aircraft within the established envelope (angle of attack less than 20 degrees). The second 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 F-18 high angle-of-attack testing will continue. Included will be measurements of forebody aerodynamics with vortex interactions and 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 STOVL aircraft concept design studies.

During FY 1987, the turbine engine hot section technology program will continue to concentrate on developing improvements in high-temperature instrumentation, methods for structural analysis, aerothermomechanical environment modeling, and life prediction. Research will continue on the development of an accurate model for dilution jet effects on combustor flow. Additionally, an improved laser anemometer system for the measurement of high-temperature flow in the combustor will be completed. Heat transfer research will concentrate on developing an advanced turbine airfoil turbulent flow model, including rotor-stator interaction. Once developed, the more accurate heat loads can be applied to predict the airfoil structural response characteristics. Studies of the nonlinear 3-D response of combustor components under high heat gradients will continue. Time-dependent crack propagation prediction methodologies will be emphasized leading to a greatly improved life prediction ability of liners, vanes, and blades.

The research on monolithic silicon-nitride and silicon-carbide ceramics will continue to develop improved understanding of the processing steps necessary to achieve highly reliable turbine blades. The corrosion response of ceramic in the aggressive gas turbine engine environment will be modeled. This next year will see increasing emphasis on ceramic matrix materials. Processing variables for silicon carbide with embedded continuous ceramic fibers will be a major focus. Related deformation and fracture mechanics will be studied and initial constitutive analysis begun. Nondestructive evaluation techniques will be continued with emphasis on near surface flow detection.

In 1987 the contract for final design, fabrication, and ground qualification testing of the oblique wing and F-8 DFBW aircraft system interfaces/modifications will be awarded. In-house NASA/Navy wing aerodynamic design and direct project support research and technology activities will be continued. The in-house program will include wind tunnel investigations, simulations, and the application of advanced aerodynamic and structural analysis computer codes.

	1985 Actual	1986 Budget Estimate	1986 Current Estimate	1987 Budget Estimate
		(Thousands of Dollars)		
Advanced propulsion systems technology				
Advanced turboprop systems.	24 ,000	42, 000	42 ,000	26 ,000
General aviation/commuter engine.. ..	2 ,100	2 ,200	2,200	2.400
Total..............................	26,100	44,200	44 ,200	28 ,400

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 componen'ts.

Activities in the advanced turboprop systems program are devoted to establishing concept feasibility and providing the broad research and technology data base necessary for achieving the concept's full potential. Information on aerodynamic performance, aeroelastic stability, and acoustic environment will be obtained for the data base and used partially to support flight test programs for verification and for obtaining data under actual flight conditions. The 9-foot-diameter large-scale advanced propeller (LAP), to be used during flight tests, and the 2-foot-diameter aeroelastic model of the LAP have been fabricated. Wind tunnel tests of the aeroelastic model confirmed stability up to a Mach number of 0.85, the highest planned during flight testing. The LAP was static ground tested at the Wright-Patterson Air Force Base for takeoff performance, blade stress levels, and stall flutter, and all were found to be as predicted. During FY 1986 the LAP will be tested in a high-speed wind tunnel for performance and flutter boundaries. One-ninth scale model tests of the propeller test assessment flight test aircraft with the turboprop installed have provided flutter and high-speed drag characteristics. In 1986 the aircraft model will be used to determine low-speed stability and control characteristics, and a ground test will be performed on the LAP mated with the flight gearbox and turboprop power section. Ground tests of the General Electric unducted fan engine, a gearless counter-rotation propfan concept, were initiated in September 1985 and will be completed in March 1966. Initial results show propulsion and aeroelastic performance as predicted, as well as good propeller speed control. Propeller/wing installed aerodynamic data for analytical code verification was obtained in a wind tunnel investigation. To develop a firm understanding of how propeller parameters, such as sweep and spacing, affect acoutics, a parameteric study is being conducted with 2-

foot-diameter geared and gearless counter-rotation propellers. These tests show that good performance can be maintained at reduced noise levels.

In the general aviation/commuter engine systems technology program, aimed at raising the performance level of small turbine engines to more proportionately match that of large engines, work is focused on providing fundamental measurements to lead to a detailed understanding of how improvements can be made. The multistage compressor facility was used to obtain fundamental data such as velocities, pressures, and surge margin for verification of 3-D analytical codes. Turbine blading was installed in the new experimental facility for determining loss mechanisms in small turbines. Tests were continued to prove centrifugal compressor scaling laws and will be completed in FY 1986. In the joint NASA/Air Force program for cruise missile technology, the combustor was assembled for experiments to evaluate temperature profiles. Small engine systems studies to identify efficient cycles and high-yield technology areas were completed and will provide the foundation for a long-range plan for advanced small turbine engines.

BASIS OF FY 1987 ESTIMATE

In FY 1987 advanced turboprop systems research will emphasize the flight test of the LAP in a propeller test assembly for concept verification and broadening of the data base to flight conditions and supporting technology for cabin acoustics and turboprop/airframe installation aerodynamics. The LAP, nacelle, and turboprop power section will be installed on a modified Gulfstream II aircraft for flight testing in FY 1987. The flight tests will evaluate large-scale structures, aeroelastics, propeller source noise, and untreated cabin environment at a variety of flight conditions up to a Mach number of 0.85 and an altitude of 35,000 feet. More fundamentally, cabin acoustics research is being performed and will include development of analytical techniques to predict cabin environment for various inputs of propeller source noise and cabin treatment concepts that have the potential to achieve attenuation levels required for high-speed propellers. Installation aerodynamics research will include analytical and experimental technology development to determine high-speed performance and low-speed stability and control for configurations of practical interest not yet studied in detail, including wing- ana aft-mounted, single- and counter-rotation concepts.

The general aviation/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. Fabrication of the large low-speed centrifugal compressor, to be used for definition of the flow field, will be completed. Combustor pattern factor studies to understand how to improve the temperature profile for longer turbine blade life will be undertaken, and laser measurements to aid in understanding loss mechanisms in turbine flow fields will be made. Regenerator/recuperator heat transfer studies will be started. Based on the small engine systems studies, an overall technology development plan will be developed.

	1985 Actual	1986 Budget Estimate	1986 Current Estimate	1987 Budget Estimate
		(Thousands of Dollars)		
Numerical aerodynamic simulation......	26,472	28,200	28,200	30,000

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.

The NAS program study and planning phase was initiated in the research and technology base in FY 1983, with system development beginning in FY 1984. The system design review was held in FY 1984 and formalized the design of the NAS system. The system software development contractor began development of the network language and protocols during FY 1984. Major hardware procurements were initiatea in FY 1984, leading to assembly of the initial operating configuration during FY 1985. Full-scale development of the NAS network hardware began with the delivery of the integrated support processor complex (front-end computers and supporting equipment) in mid-FY 1985. The first high-speed processor, a Cray 2 supercomputer, was delivered late in FY 1985 and integration into the NAS network begun. The first part of FY 1986 is an intense test and integration period leading to operational status of the NAS initial operating configuration (IOC) during the third quarter of FY 1986. During FY 1986 construction will be completed for the NAS facility.

BASIS OF FY 1987 ESTIMATE

FY 1987 will be the key year in the development of the NAS system. The NAS building will be occupied and the second high-speed processor (HSP-2), which will be four to six times more powerful than HSP-1, will be installed. Secure (classified) processing will be initiated with the move into the new building. During FY 1987 the IOC, built around HSP-1, will be used to obtain the first solution for subsonic and transonic viscous flow about complete aircraft configurations. It will also be used to provide pathfinding viscous flow solutions to supersonic/hypersonic airframe/propulsion integration for advanced configurations being studied in the national aerospace plane program and to obtain complete flow field solutions for complex nonequilibrium, chemically reacting, and radiating flows about candidate aeroassisted orbital transfer vehicles. The acquisition and installation of the HSP-2, which constitutes the NAS extended operating configuration (EOC), will complete the initial planned architecture of the NAS system. It will serve as the foundation for the upgrading of the major subsystems in the building toward the EOC. The mass storage subsystem will be expanded to handle the additional archival storage required for support of the HSP-2. The graphics subsystem development will be accelerated to accommodate both high-speed processors. During this period, system software development will continue, and all new components will undergo extensive test and integration.

TRANSATMOSPHERIC
RESEARCH
AND TECHNOLOGY

RESEARCH AND DEVELOPMENT

FISCAL YEAR 1987 ESTIMATES

BUDGET SUMMARY

OFFICE OF AERONAUTICS AND SPACE TECHNOLOGY — TRANSATMOSPHERIC RESEARCH AND TECHNOLOGY

SUMMARY OF RESOURCES REQUIREMENTS

	1985 Actual	1986 Budget Estimate	1986 Current Estimate	1987 Budget Estimate	Page Number
	(Thousands of Dollars)				
Transatmospheric research and technology	---	---	---	45,000	RD 14-2
Distribution of Program Amount by Installation					
Ames Research Center	---	---	---	6,250	
Langley Research Center	---	---	---	23,000	
Lewis Research	---	---	---	15,750	
Total	---	---	---	45,000	

PROGRAM OBJECTIVES AND JUSTIFICATION

NASA, in conjunction with the Department of Defense, is developing the technology base for a potential national aerospace plane. The objective of the NASA transatmospheric research and technology program is to accelerate the development of the critical enabling technologies for a potential revolutionary new class of hypersonic/transatmospheric vehicle in the future. Such a vehicle could be capable of horizontally 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. This augmentation of previous NASA in-house research and technology base efforts would accelerate the development and validation of key technologies through fabrication of components and subsystems by testing in ground-basea facilities and small-scale flight experiments. The critical technologies include efficient airbreathing propulsion with emphasis on scramjet techniques that provide net 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 acceleration, cruise, and maneuvering flight conditions. A necessary precursor to possible future year decisions on a demonstrator research aircraft program, these validated technologies could 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 program (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.

BASIS FOR FY 1987 ESTIMATE

Supporting activities ongoing in the NASA research and technology base include research in airbreathing hydrogen-fueled scramjet propulsion technology, advanced high-temperature materials and thermal structural concepts, and computational fluid dynamics -- the three critical technologies for transatmospheric vehicle applications. The FY 1987 program will focus on development of analysis and prediction techniques and validation of the performance for airbreathing propulsion concepts, actively cooled high-temperature structures, cryogenic insulated tankage, configuration aerodynamics, and propulsion system/aircraft integration characteristics.

SPACE RESEARCH
AND
TECHNOLOGY

RESEARCH AND DEVELOPMENT

FISCAL YEAR 1987 ESTIMATES

BUDGET SUMMARY

OFFICE OF AERONAUTICS AND SPACE TECHNOLOGY

SPACE RESEARCH AND TECHNOLOGY PROGRAM

SUMMARY OF RESOURCES REQUIREMENTS

	1985 Actual	1986 Budget Estimate	1986 Current Estimate	1987 Budget Estimate	Page Number
		(Thousands of Dollars)			
Research and technology base	136.358	140.000	132.800	133.600	RD 15-5
Systems technology programs	8.742	20.000	27.200	37.40b	RD 15-35
Standards and practices	4.900	8.000	8.000	9.200	RD 15-46
Total	150,000	168.000	168.000	180.200	

Distribution of Program Amount by Installation

	1985 Actual	1986 Budget Estimate	1986 Current Estimate	1987 Budget Estimate
Johnson Space Center	12.947	11.600	10.600	10.800
Kennedy Space Center	3Y6	60U	400	100
Marshall Space Flight Center	14.162	20.200	17.800	19.400
Goddard Space Flight Center	6.492	6.600	6.70b	7.000
Jet Propulsion Laboratory	24.983	23.400	23.700	27.900
Ames Research Center	15.770	15.300	16.200	18,900
Langley Research Center	37.953	45.000	46.100	48.400
Lewis Research Center	30.524	37.800	37.300	37.900
Headquarters	6.773	7.5u0	9.200	9.800
Total	150,000	168.000	168.000	180.200

PROGRAM OBJECTIVES AND JUSTIFICATION

The overall goal of the space research and technology program is to advance the technology base in support of NASA's role as an effective, productive, and long-term contributor to the continued preeminence of the United States in space. The specific objectives of this program are to: (1) support a broad-based advanced technology program designed to provide new concepts, materials, components, devices, software, and subsystems for use in United States space activities; (2) assure preeminent national capability through extensive participation in the program by the NASA centers, other government agencies, universities, and industrial research and technology organizations; and (3) support a strong institutional base to maintain NASA centers in positions of recognized excellence in critical space technologies. The space research and technology program is comprised of two major elements: (1) the research and technology base to support advanced disciplinary technologies that provide the necessary base of understanding to create new opportunities for future national, civil, military, and commercial space mission objectives; and (2) systems technology programs which extend research and technology base efforts by providing system-level and in-space experiment capabilities which permit the generation of data not possible in ground facilities and the in situ validation of advanced technology in support of its transfer into space projects.

CHANGES FROM FY 1986 BUDGET ESTIMATE

The space research and technology program total remains unchanged from the FY 1986 budget estimate; however, within this program, realignments have been made to cover high priority requirements, as described in the individual program statements. In addition, the OTV technologies program ($3.0 million) has been transferred from systems technology to the space research and technology base, and the automation and robotics effort ($10.2 million), previously budgeted and managed in various programs within the space research and technology base, has been consolidated and established as a systems technology program beginning in FY 1986 for management focus.

BASIS OF FY 1987 ESTIMATE

The FY 1987 program in space research and technology will continue to be directed towara providing the broad base of innovative technology essential to the conduct of future space missions. As such, it supports agency goals in space transportation, space station, and space science and applications, as well as providing synergistic support to military and commercial space user needs.

In aerothermodynamics, continued program emphasis will be on developing analytical and predictive techniques for the transition regime and linking between continuum and rarefied flow regimes. Additional emphasis will be placed on investigating aerodynamic and aerothermodynamic performance of aeroassist orbit transfer vehicles (AOTV) and transatmospheric vehicles. The space energy conversion program will continue its emphasis on high-capacity power and thermal systems for evolutionary space station needs and on technology for high-specific power, low-weight systems for low-earth and geosynchronous orbits and planetary missions. Propulsion technology will be directed toward understanding performance and life parameters for advanced cryogenic engines, stressing component and integrated diagnostic instrumentation techniques; orbit transfer engine technology to enable development of space-based, throttleable, reusable systems; and technology for gaseous oxygen-hydrogen propellant systems for evolutionary growth station or OTV auxiliary propulsion needs. The electric propulsion effort will address auxiliary propulsion applications, with continuing attention on fundamental life and performance limiting mechanisms and thrusters. Materials and structures activities will continue with research in large-area space structures, emphasizing erectables and deployables, and analysis of dynamic response and controls interaction. The work on improved thermal protection systems and related thermal-structural analysis methodology for OTV aerobraking and other 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 placed on advanced information processing, high-capacity, high data-rate storage systems to increase the capabilities of on-board data systems and advanced microwave and optical communications technology. The information sciences program will emphasize software technology, reliable computing, concurrent processing, radiation-tolerant electronics, and sensing technology for potential spacecraft and space station applications. Emphasis in the controls and guidance area will be placed on precise control of large, flexible space structures; the 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 improved crew stations with "human engineered" information management techniques and extravehicular work stations.

Efforts in space flight research and technology will continue to be directed toward the orbiter experiments program, which will exploit the operational flights of shuttle to investigate the aerodynamic and aerothermodynamic phenomena of the current shuttle as a means of validating experimental and predictive techniques for the design and development of future space transportation systems; the design definition for the aeroassist flight experiment to provide the data base for future space-based orbital transfer vehicles; the cryogenic fluid management flight experiment to develop the technology base for space station operations and a space-based orbital transfer vehicle; the development of a shuttle common carrier for structure and **control/structure** interaction experiments (called STEP -- space technology experiments platform); and the in-space experiments program which will provide access to space on NASA vehicles for the conduct of user (industry and university) space experimentation. The systems analysis area will focus on the identification of requirements and high-leverage technologies for the development of future space missions, such as a priority earth-to-orbit transportation vehicle and the evolutionary space station. The analysis efforts provide scope and direction to the base research programs and identify system-level technology programs required to assure transition of identified technologies into flight programs.

In systems technology, the advanced earth-to-orbit technology program will focus on providing system-level data for modeling performance and life and on evaluating advanced technology components designed to improve life and reduce maintenance costs in advanced engines. The components will be installed on a testbed engine and instrumented to provide the overall understanding and data base on performance in the realistic hot-fired engine environment. This is a joint program in which the Office of Space Flight will provide a non-flight space shuttle main engine as the testbed engine. The control of flexible structures flight experiments address structural dynamics and controls issues which must be understood prior to the deployment of large space structures having precision control requirements. This program will focus on developing and validating analytical methods for predicting coupled structural dynamics and control response for multibody space structures. A flight test program will be conducted with a series of four or more shuttle sorties, building progressively from modeling and modal characterization of large space structures to more complex flexible-body interactive control issues. The first flight article, the mast flight system, will address beam dynamics and control and will be flown on the shuttle in FY *1989.* The automation and robotics program will provide the fundamental technology for space telerobotics and system autonomy to enhance operational capability and decrease the cost of space operations.

BASIS OF FY 1987 FUNDING REQUIREMENTS

RESEARCH AND TECHNOLOGY BASE

	1985 Actual	1986 Budget Estimate	1986 Current Estimate	1987 Budget Estimate
	(Thousands of Dollars)			
Aerothermodynamics research and technology	10,100	10,600	10,800	11,200
Space energy conversion research and technology	22,312	22,900	21,200	20,400
Propulsion research and technology	20,500	20,900	22,300	21,000
Materials and structures research and technology	18,800	19,300	18,600	18,900
Space data and communications research and technology	16,500	16,900	16,000	13,600
Information sciences research and technology	17,590	18,000	9,900	10,200
Controls and guidance research and technology	6,600	8,900	7,500	7,500
Human factors research and technology	3,700	4,000	2,300	2,300
Space flight research and technology	11,468	11,900	17,400	22,400
Systems analysis	6,788	6,600	6,800	6,100
Total	136,358	140,000	132,800	133,600

	1985 Actual	1986 Budget Estimate	1986 Current Estimate	1987 Budget Estimate
	(Thousands of Dollars)			
Aerothermodynamics research and technology.	10,100	10,600	10,800	11,200

OBJECTIVES AND STATUS

Future aerospace vehicles, such as aeroassisted orbit transfer vehicles (AOTV), the aerospace plane, and the hypersonic cruise and maneuver vehicles, will have to 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) develop advanced numerical algorithms for continuum, transitional, and free molecular flow regimes; (2) develop accurate and detailed finite-rate chemistry and turbulent flow models; (3) correlate ground and flight (shuttle orbiter experiments) experimental data with calculations; (4) establish a detailed aerothermal loads data base and integrated analysis technique; and (5) provide a fully integrated design and analysis capability to support future vehicle/mission requirements.

Progress in the ability to predict flow fields about vehicles entering/maneuvering in the earth's atmosphere has been greatly accelerated by the rapid increase in computational capability in memory and speed, as well as efficient algorithm development. The predominant emphasis in continuum flow calculations has shifted from the inviscid (Euler) flows to the more realistic viscous shock layer methodology to the full Reynolds-averaged Navier-Stokes equations. One of the latest and most promising techniques is a thin-layer Navier-Stokes algorithm developed at the Ames Research Center. This "breakthrough" method has been applied to the axisymmetric flow past an AOTV, and the results indicate a substantial increase in computational speed - a significant benefit toward design optimization of future AOTV's.

For rarefied flow regimes, the direct simulation Monte Carlo (DSMC) technique has been found to be particularly well suited to understanding and modeling complex flow problems as represented by the interaction of vehicle airframe, ambient rarefied atmosphere, propulsion system exhaust, and material outgassing. In the DSMC, the gas is modeled by thousands of simulated molecules. Velocity components, internal energy states, and position coordinates of these molecules are stored in the computer and are modified with time as the molecules are followed through representative collisions and boundary interactions in simulated physical space. To date, the DSMC technique has been successfully applied to a number of complex flows including a hypersonic reentry problem and the analysis of large solid-propellent rocket engine exhaust plumes. These advances in computational capability, for both the continuum and rarefied flow regime, will allow us to accurately and confidently predict the detailed flow field environment experienced by advanced aerospace vehicles and thus will be a key element in the successful design of these vehicles.

The direct correlation of flight data, ground experiments, and computations is critical to the development of verified predictive tools required for preliminary configuration analyses and vehicle performance optimization. The completion of recent flights of the space shuttle has provided just such an opportunity for correlation of ground and shuttle data over a diverse range of flight conditions. Flight-derived aerodynamic heat transfer data for the orbiter leeside centerline and wing surfaces have been compared with appropriate ground test results. Flight heating levels are, in general, less than those which are inferred from the ground test results. This result is apparently due to laminar-to-turbulent transition of the flow in the separated region occurring at a much larger Reynolds number in flight than in the wind tunnel.

A detailed aerothermal loads data base is essential to permit proper vehicle structural design while avoiding the tendency to overdesign which can introduce significant mass/volume penalties. Consequently, there has been continued emphasis on the development of an integrated fluid-thermal-structural analysis technique using a finite-element approach that will allow rapid, accurate, structural analysis and optimization of advanced vehicle concepts. The use of finite-element modeling in both the fluid and solid structure will produce a unified analysis with common terminology/methodology throughout. However, the finite-element approach typically requires the solution of large systems of equations and extensive numerical integration which make the analysis of compressible flows prohibitively expensive. Recent advances in solution algorithms are overcoming these limitations by taking full advantage of computer vectorization schemes. Two- and three-dimensional inviscid and viscous flow codes are achieving competitive speeds on modern vector computers. A recent application was successful in describing the complex flow in the shuttle's wing-elevon region where other techniques had failed.

CHANGES FROM 1986 BUDGET ESTIMATE

The increase of $0.2 million in aerothermodynamics research and technology reflects a realignment within the research and technology base to support computational capability for direct simulation techniques.

BASIS OF FY 1987 BUDGET ESTIMATE

Continued emphasis will be placed on computational aerothermodynamics in FY 1987. In the development of advanced continuum flow simulations, generalized three-dimensional geometry modeling, adaptive grid generation, and accurate chemical reaction, models necessary to describe the complex configurations and environments of future hypersonic vehicles will be actively pursued. In the area of DSMC techniques, the current methodology will be extended to cope with entry velocities anticipated for AOTV and lunar return aerobraking missions and for complex vehicle configurations. This will involve the addition of ionization reactions and the mechanisms for nonequilibrium emission and absorption of radiation.

The shock layers about the airframes of high-altitude, high-speed vehicles are characterized by nonequilibrium distributions in chemical composition and energy states of the low-density shock layer gases. These nonequilibrium conditions, particularly nonequilibrium radiative heating, will have very significant influence on aerodynamic and aeroheating environments experienced by these vehicles. To successfully design flight control and thermal protection systems will require a detailed understanding of, and predictive capability for, these phenomena. 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 occurring at high-temperature/low-density conditions. In FY 1987, emphasis will be placed on computing chemical and physical properties of air species to simulate the specific conditions of nonequilibrium shock layers. Energy profiles and rate constants for electron-ion and electron-neutral molecule collisions will be computed.

FY 1987 will also be a period of increased activity in hypersonic research ground facilities. The 3.5-foot hypersonic tunnel at the Ames Research Center, currently undergoing reactivation, will be the focus of much of this effort. This tunnel provides a test capability from Mach 4 to 14 and covers much of the hypersonic flight range of anticipated airbreathing vehicles. The initial research program will be a joint Ames/Langley Research Center effort to investigate hypersonic airframe/propulsion interaction effects. This will involve early use of the Ames numerical aerodynamic simulation facility to provide numerical solutions to complex flow problems and for computational configuration analysis coupled with testing in the 3.5-foot tunnel to provide experimental verification.

	1985 Actual	1986 Budget Estimate	1986 Current Estimate	1987 Budget Estimate
		(Thousands of Dollars)		
Space energy conversion research and technology........................	22,312	22,900	21,2011	20,400

OBJECTIVES AND STATUS

The objectives of this program are to increase the performance, capacity, and cost effectiveness of space electric power generation and energy storage subsystems; provide the technology for efficient, reliable, and low-cost management and distribution of electrical and thermal energy for space systems; and advance the technology of life support systems for large manned space platforms. In FY 1985, two significant advances in photovoltaic cell technology were achieved. First, the demonstration of a 50-micron lithium counterdoped silicon cell with less than ten percent power degradation after exposure to the equivalent of ten years' radiation in geosynchronous earth orbit was demonstrated. This compares with greater than 25 percent degradation with current operating systems. Second, the superiority of indium phosphide solar cells under 10 million electron volt proton irradiation to any other available space cell, including silicon and gallium arsenide (GaAs), was also demonstrated. A multiyear program was initiated to optimize the efficiency of such cells while maintaining their radiation performance and to demonstrate a 20.4 percent efficient gallium arsenide concentrator cell operating at 80 degrees centigrade and sunlight concentration of 100 times normal levels. Efficiencies above 21 percent are ultimately anticipated. Concentrator photovoltaic systems enable significant reductions in the solar array area and correspondingly in requirements for drag makeup. By focusing the sun's energy, they allow high levels of power to be produced with a relatively low number of cells, permitting the use of efficient but costly cell materials such as GaAs. In addition, concentrators provide protection against damage by natural solar radiation. Concentrator systems appear to be attractive for use in the low-earth-orbit (LEO), relatively high-power space station detached platforms, particularly the planned polar orbiting platform, where radiation levels are more severe. In late 1984, the successful deployment and retraction of a 105x13-foot lightweight solar array demonstrated the technology for power-to-weight ratios of 66 watts per kilogram. A multiyear contract effort was started in 1985 to advance the power-to-weight ratio capability to 130 watts per kilogram. Doubling of the power-to-weight ratio will provide for additional scientific capability by reducing the weight and size of photovoltaic power systems for weight-limited geosychronous and planetary spacecraft. Both welded and soldered interconnects to 2x4cm silicon solar cells survived after 60,000 cycles in a simulated LEO thermal environment (+80 to -80 degrees centigrade), equivalent to a ten-year exposure. Testing of a thin, flexible coating demonstrated atomic oxygen durability of the protective coating on Kapton solar array blanket material equivalent to 21 years of life for space station orbit. Changes in the chemistry and design of nickel-hydrogen batteries have resulted in a sixfold increase in the cycle life and show promise of meeting a 50,000-cycle requirement of LEO systems. As a result of these advances, nickel-hydrogen batteries are now a prime candidate for energy storage on the space station and associated scientific platforms.

In space nuclear power research, a high-temperature liquid metal cooled reactor/thermoelectric conversion system was selected for a Department of Defense (DOD)/Department of Energy (DOE)/NASA ground engineering system test. In research on dynamic conversion systems, development of a Stirling engine for use with solar dynamic and/or advanced nuclear power systems continued. The free-piston Stirling engine offers the potential to provide high efficiency and long life. Projections of power requirements for the evolutionary space station are increasing dramatically, and solar dynamic or nuclear systems are expected to be required to meet these higher power needs. In 1985, the largest free-piston Stirling engine ever built was successfully operated with a linear alternator conversion system. In the thermal management area, technology for use of 5U-meter pumped heat pipes/contact radiators for cooling of the space station habitat was demonstrated. Technology for capillary heat pipes for cooling experiments has been successfully ground tested in conjunction with the space station thermal bus system and in zero gravity experiments on the space shuttle. Experimental efforts continued to provide fundamental data on the fluid dynamics and droplet formation processes for liquid droplet and liquid belt radiators. Under the power management program, the development of critical technologies for the space station power management subsystem was completed. This included technology for 20-kilohertz alternating current resonant power distribution, 100-kilowatt class fast-switching transistors and diodes, high-frequency lightweight transformers and capacitors, and high-power roll ring power transfer devices. In the advanced life support technology area, efforts continued on regenerative techniques aimed at achieving a higher degree of closure of the water-air-waste cycle for extended duration manned missions. Technology development has been successfully completed on the electrochemical and solid amine carbon dioxide concentrators and is continuing on low-energy water filtration and supercritical waste oxidation systems.

CHANGES FROM FY 1986 BUDGET ESTIMATE

The decrease of $1.7 million in the space energy conversion research and technology program reflects reductions primarily in the areas of environmental control/life support and thermal management to provide funding for support of other high priority requirements, including the aerospace industry/university space flight experiments research effort, cryogenic fluid management technology, and transatmospheric technology efforts.

BASIS OF FY 1987 ESTIMATE

Prior to FY 1986, the principal focus of the space energy conversion program was to develop the power and life support technology that would be applicable to the initial space station. This goal had largely been accomplished by the end of FY 1985. In FY 1986, the program was redirected to address the needs of other advanced manned applications and planetary programs and to emphasize innovative technologies that will enable distant, future, ambitious space missions such as lunar base and manned planetary missions. In FY 1987, technology development for high-capacity, long-life solar dynamic and space nuclear power will dominate. Added emphasis will be placed on technologies such as advanced radiators, liquid metal heat pipes, and high-power lightweight power systems, all of which are essential for the high-power systems of the foreseeable future. In addition, development of innovative technologies will be continued. Revolutionary concepts, such as laser power transmission, use of extraterrestrial resources and supercritical water reclamation systems, may be necessary to accomplish ambitious future missions such as planetary exploration and sample return. In space nuclear power, technology development will continue for advanced dynamic and passive thermal-to-electric conversion systems which offer the potential to reduce the weight and nuclear fuel requirements to one-third of current technology systems. Development of high-temperature receivers, thermal' storage, concentrators and high-efficiency conversion systems which will double the operating temperature and offer a fourfold reduction in area will continue. Since it is expected that all commercial and most military and NASA scientific satellites will continue to use photovoltaic power systems, a major effort to increase the efficiency and life and reduce the cost and weight of these photovoltaic and associated energy storage systems will continue.

	1985 Actual	1986 Budget Estimate	1986 Current Estimate	1987 Budget Estimate
		(Thousands of Dollars)		
Propulsion research and technology. ...	20,500	20,900	22,300	21,000

OBJECTIVES AND STATUS

The objective of the propulsion research and technology program is to provide the analytical tools and design activity necessary for improving the life, performance, reliability, and maintainability of chemical and electrical propulsion systems for future space transportation vehicles, manned and unmanned platforms, and spacecraft systems. The program includes efforts dicected at providing longer life, reusable, fault-tolerant propulsion systems for future lower cost earth-to-orbit (ETO) operations; high-performance, variable thrust propulsion for increased orbit transfer mission flexibility and capability; efficient, long-life, on-board auxiliary propulsion for precise attitude control, stationkeeping and drag makeup functions; and very advanced concepts capable of greatly exceeding the performance limits of conventional chemical propulsion systems.

Advanced technology for high-thrust (500 thousand *to* 2 million pounds) high-pressure, reusable propulsion systems is focused on extending the service life of engine components subjected to severe internal dynamic environments, both mechanical and thermal, typical of engines of this class and on understanding and controlling heat transfer in order to enable long combustor service life. These technology advances are directly applicable to next generation hydrogen-fueled and hydrocarbon-fueled engines. Improved single-crystal turbine blades constructed by an advanced processing technique have demonstrated extended low-cycle thermal fatigue life compared to existing directionally solidified blade designs in burner rig testing. A new theory for predicting the life of parts subjected to both low-cycle and high-cycle fatigue has been developed and will be verified initially in laboratory scale tests. A cryogenic bearing thermal model design tool is now in,operation and is being validated by bearing tester temperature measurements. Isotope and fiberoptic bearing-wear detectors have been successfully demonstrated in laboratory testing and will be installed in pumps for evaluation in real engine hardware as a part of the advanced earth-to-orbit systems technology program. Finally, in liquid-oxygen/methane combustion tests, experimental heat transfer data has been generated and used to better understand the effect of carbon deposition on heat transfer models for high-combustion pressure operating conditions.

Orbital transfer vehicle propulsion requires very high-performance, variable thrust, long-life concepts, and on diagnostics for the condition monitoring of critical high wear-rate components. Vehicle studies have clearly indicated that multiple, small, lower thrust engines are optimum for aeroassist compatibility and man rating. Subcomponent OTV technologies are currently the focus of the research and technology base program. Enhanced heat transfer combustor wall designs, key to high-pressure combustion operation, have been successfully demonstrated in laboratory scale tests. The compatibility of turbine blade materials with oxygen has also been demonstrated in the laboratory. This is an alternate technique for providing more turbine power for higher combustion pressure operation. High-expansion-ratio nozzle performance prediction will be enhanced through a test program just getting underway that is designed to obtain experimental nozzle performance data. A program to assess advanced materials and fabrication techniques for lightweight high-expansion-ratio nozzles is also underway. Techniques for improving the efficiency of small turbopumps, such as partial admission turbines, high-velocity-ratio diffusing interstage crossovers, and soft wear ring seals, have all shown promise in rig test programs.

Auxiliary propulsion technology is focused on demonstrating the performance and durability of gaseous- oxygen/gaseous-hydrogen thrusters; electrothermal thrusters, including low operating power arc jets; and ion thrusters operating with inert gases such as xenon and argon. Oxygen-hydrogen thrusters designed for long life and high-performance space station auxiliary propulsion requirements have been successfully tested at 25 pounds of thrust for over two hours, delivering higher-than-predicted performance. Electrothermal thruster heating elements, based on tungsten alloys, have demonstrated increased life capability, and the stable operation of arc jet thrusters, operating with a 500-watt and less power level, has also been demonstrated.

Studies are continuing to identify very advanced propulsion concepts and to define the technology that would offer system performance far in excess of conventional propulsion systems. Experimental efforts aimed at reducing cathode erosion in magnetoplasmadynamic (MPD) thrusters continue for pulsed designs. Evaluation of steady-state MPD thrusters is being initiated. In addition, the design, fabrication, and test of a laser-heated hydrogen-powered thruster is underway.

CHANGES FRM FY 1986 BUDGET ESTIMATE

The increase of $1.4 million in propulsion research and technology reflects the realignment of the propulsion portion of the orbital transfer vehicle (OTV) systems technology program to the research and technology base ($1.5 million) which has been offset by a $0.1 million reduction in the propulsion program to support priority transatmospheric technology requirements.

BASIS Of FY 1987 ESTIMATE

Technology efforts for advanced, high-pressure, reusable ETO propulsion systems will continue to be directed toward the development of analytical models designed to simulate internal engine environments and to predict the life of components operating in those environments; the development of components designed for longer operating service life, including advanced bearings, advanced turbine blade materials and thermal barrier coatings, rotor damping devices, improved combustion preburners and main combustors; and the development of high-performance hydrocarbon-fueled combustors. Advanced instrumentation will continue to be developed to more accurately measure the internal dynamic environments of high-pressure engines, as will diagnostic sensors designed to monitor the condition of high wear-rate components. These technology advances will provide the basis for the design of longer life, higher performance engines with automated between-flight inspection, servicing and checkout operation, leading to lower cost access to space.

Technology for variable-thrust orbit transfer propulsion will continue to focus on subcomponent research with the objective of generating analyses and design criteria for engine components critical to achievement of performance, life and maintainability goals for a space-based, man-rated orbital transfer vehicle. Critical components include high-performance, long-life, enhanced transfer combustors; highly efficient variable flow rate turbopumps; and integrated diagnostic instrumentation. Test rigs will be used to validate analytical models and advanced component designs as they evolve. These technologies are key to the operational capabilities of a space-based OTV that will provide lower cost routine transportation to geosychronous orbit and beyond.

Auxiliary propulsion technology efforts will focus on gaseous-oxygen/gaseous-hydrogen thruster development; long-life resistojets with multiple gas operating capability; and high-performance low-power arc jet thrusters. The technologies leading to very high-performance, durable, on-board propulsion systems will provide the basis for reducing propellant resupply, extending the useful lifetime of earth-orbiting satellites, and allowing more useful payloads to be carried on-board (science, transponders, etc.) because of reduced propellant requirements.

Advanced propulsion studies will continue with the objective of identifying promising concepts that offer performance capabilities far in excess of today's conventional propulsion systems. In addition, work will continue toward reducing cathode erosion of high-performance MPD thrusters and toward the design, fabrication, and test of a thruster designed to operate on laser-heated hydrogen.

	1985 Actual	1986 Budget Estimate	1986 Current Estimate	19137 Budget Estimate
		(Thousands of Dollars)		
Materials and structures research and technology.......	18,800	19,300	18,600	18,900

OBJECTIVES AND STATUS

The objectives of the materials and structures research and technology program are to provide for the construction, performance, efficiency, durability, and economy required for large-area space structures, antennas and space platforms, advanced space transportation systems, orbiting spacecraft, planetary probes, and shuttle payloads. Major technical areas of emphasis in materials include initiation and basic understanding of advanced materials; development of computational chemistry methodology; characterization of long-duration space environmental effects on materials; and the development of ceramic, metallic, and advanced carbon-carbon thermal protection systems. Structures technology is directed toward development of advanced truss structural concepts; reliable methods for deployment/erection and repair of space structures; new structural and tankage concepts for advanced earth-to-orbit rocket and airbreathing space transportation systems, and orbital transfer vehicles; and efficient analytical methods for design and evaluation of advanced space structures, including integrated structures/thermal controls analysis, optimization techniques, and structure/controls interaction methodology.

A key element for structural dynamics research during FY 1986 was the implementation of a focused program for the dynamic response and passive/active control of flexible space structures. This activity encompasses a variety of large space structures that include joint-dominated deployable beams, flexible platform structures, and antenna structures. The major program goal is to develop validated structures/controls analysis methods which will then allow detailed design studies that can assess technology merits between utilizing structural stiffness, passive damping techniques, and active control methods to attain specified system performance and accuracy requirements. As part of the ongoing space construction research activities, an in-space shuttle-bay structural assembly experiment was conducted in early FY 1986. This experiment involved the construction of a joint-dominated truss from the cargo bay of the space shuttle by two astronauts to obtain data to evaluate on-orbit assembly and repair techniques. Preliminary data show good agreement with ground-based studies in the neutral buoyancy facility. A data base of assembly and repair timelines is essential for space station and other large space construction in the future.

In FY 1986, ground testing of a 15-meter deployable hoop-column antenna to understand its modal vibration response will continue. The data obtained from this complex, cable-stiffened structure will serve as a basis for the development of future analytical dynamic models. Additionally, research in structural dynamic response is resulting in the completion of the nonlinear analysis of a generic, multibody, flexible, large space structure. This research is necessary to enhance understanding and lead to the development of suitable active and passive control technology for stable structures.

Materials research in FY 1986 focused on the effects of the space environment. Material behavior must be understood to ensure long-life survivability of space structures. The area of atomic oxygen interaction with materials received considerable attention. Ground-based facilities to simulate space effects were established in preparation for a December 1986 flight experiment to validate analytical models. Emphasis was placed on developing space-durable polymeric composite materials and protective coatings and the study of methods for nondestructive testing and evaluation. Supporting research was conducted to understand the mechanisms controlling surface properties of materials in a space environment.

Increased emphasis was placed on the technology requirements for an aeroassisted orbital transfer vehicle and an aerospace plane vehicle. Part of the assessment process for advanced thermal protection systems (TPS) concepts included exposure to an arc jet to simulate the reentry environment. Extensive research for advanced TPS will continue in FY 1986. The effort is focused on advanced silicon-carbide composite concepts and other ceramics in the form of tailorable advanced blanket insulation. Three-dimensional weaving procedures were developed, resulting in blankets of significantly greater durability.

CHANGES FROM FY 1986 BUDGET ESTIMATE.

The decrease of $0.7 million in materials and structures research and technology reflects the consolidation of base funding for control of flexible structures flight experiment into the space flight research and technology base program.

BASIS OF FY 1987 ESTIMATE

The effect of the space environment on structural materials for spacecraft, space station, and orbital transfer and transatmospheric vehicle applications will be a major program activity. Included in this activity will be research on the durability of polymeric materials, thermal control coatings, films, adhesives, and seals. The radiation damage mechanism in epoxy matrix composites tested in a ground-simulated space environment for geosynchronous earth orbit will be identified. This program continues the accelerated testing of these materials in the combined space radiation environment of electrons, protons, vacuum and ultraviolet. Analysis of both ground-based and flight data on atomic oxygen effects will be carried out to determine mechanisms involved. New protective coatings will be developed. Thermal control coatings research to allow full benefit of composite structures for large-area space application and the study of the dimensional stability of composite structures in the space cyclic-thermal environment will continue. Basic research on materials for space power systems, particularly in the area of fluid heat exchanger capability, will be increased to better understand material compatibility issues to ensure long-term system life.

Advanced carbon-carbon and ceramic composite concepts will remain a major focus in the thermal protection systems program. Activities in the ceramic thermal protection system area will continue to be directed toward the further development of flexible ceramic blanket-type insulation for application to advanced orbital transfer vehicles and for further upgrade of material currently used on the shuttle. The new system will cost less and will be more durable. Both rigid and flexible TPS will be evaluated for use on a rapid-response aerospace plane.

Research in advanced space structures will establish structural concepts, deployment schemes, and packaging techniques that will permit structures on the order of 100 to 200 meters in size to be carried into orbit in one shuttle flight and automatically deployed. Erectable concepts and assembly methods for structures between 100 and 1000 meters in size will be developed. Research on a multijointed flexible 20-meter beam will be performed to establish the technology base for the control of flexible structures dynamic response with the goal of conducting in-space structural dynamics flight experiments to validate the technology. This activity will require both analytical and experimental research to develop procedures to characterize structural configurations during ground tests, as well as during space tests. Active and passive damping techniques to reduce structural vibration will be aeveloped in parallel with the development of methods for predicting and reducing the dynamic response of structural configurations for large-area space platforms and antenna structures.

A coordinated program for research on advanced analytical methods will be conducted in FY 1987. This program is aimed at developing, testing, and verifying solution algorithms utilizing supercomputers. New, extremely fast and efficient structural analysis methods are essential to the design, analysis, and performance of large-area space structures, aerospace plane vehicles, and other space structures. Advanced analytical methods that include deployment dynamics and mechanisms simulation will be continued for analysis of large, flexible space structures and platforms. Additionally, research to develop improved integrated fluid-thermal-structural analysis capability will continue with focus on generic configurations to allow for the development of highly efficient, stable structures for high-speed flight. New innovative concepts and joining processes for fabricating lightweight high-temperature structures for advanced space transportation vehicles, including earth-to-orbit vehicles, will be developed.

	1985 Actual	1986 Budget Estimate	1986 Current Estimate	1987 Budget Estimate
		(Thousands of Dollars)		
Space data and communications research and technology........................	16,500	16,900	16,000	13,600

OBJECTIVES AND STATUS

The space data and communications research and technology program is directed toward controlling, processing, storing, and manipulating space-derived data and enabling new concepts in satellite communications.

The objectives of the data systems efforts are to proviae the technology to enable affordable utilization of space-derived information; to increase substantially the capability of on-board processing for future missions; and to provide computational systems anticipated for evolutionary space station. Development work is nearing completion on the massively parallel processor to be used in Landsat data reduction and the ten-terabit optical-disk juke-box system to be used to support a nationwide space science data base network. Development of the high-bandwidth terabit optical-disk buffer system intended for space station and other flight applications is underway. Individual elements of the technology needed to produce the buffer have been demonstrated and are now being assembled into a demonstration unit. Work is underway to obtain, evaluate, and assemble processors from the very advanced integrated circuits that are now becoming available for space applications. Advances in on-board processing and storage will allow the migration of ground-based data processing to the space station, thus enabling substantial savings in operations cost.

The communications technology effort provides the necessary research and technology required to maintain and ensure the U.S. preeminence in satellite communications. Fundamental research in microwave tubes has led to the development of a 100-watt, 60-GHz (gigahertz) traveling wave tube to provide high-bandwidth microwave communications capabilities for intersatellite links for the advanced tracking and data relay satellite systems. An eight-beam overlapping-cluster microwave feed has been developed to demonstrate that antennas with contiguous multiple beams can be designed with very low sidelobes for optimum ground cover and frequency. Also, a 15-meter hoop-column antenna was designed and successfully tested with the eight-beam feed. Large-aperature feed and antenna technology is aimed at opening new space communications markets for mobile applications and for the very large baseline interferometer (VLBI) science mission. Recent results from our large-aperature feed and antenna experiments provide the opportunity for on-orbit antenna shape adjustment capability which could significantly reduce the cost of assuring precision shape. An X-band dielectric resonator oscillator with excellent temperature stability and low-phase noise has been developed which replaces the more expensive and error-prone frequency multiplier chains previously employed in spacecraft transponders for application to the Mariner Mark II series of planetary exploration spacecraft. A 20-GHz monolithic microwave integrated-circuit transmit module has been successfully built and tested. This module consists of five-switched line phase shifter circuits with control logic, a buffer amplifier for phase compensation, and a power amplifier contained on a single chip. This technology is necessary for the development of low-weight and cost-effective phased array feeds for large antenna systems.

CHANGES FROM FY 1986 BUDGET ESTIMATE

The decrease of $0.9 million in space data and communications research and technology includes the transfer of $0.4 million of automation funding to the automation and robotics systems technology program; a decrease of $0.4 million to support the aerospace industry/university space flight experiments effort; and a decrease of $0.1 million in precision antenna research, which has been redirected to support transatmospheric technology efforts and other high priority requirements.

BASIS OF FY 1987 ESTIMATE

In data systems, the program provides computing technology for upcoming NASA missions with emphasis on the needs of space station and associated platforms. The data systems program takes substantial advantage of related development work done by DOD or other government agencies and is coordinated with those agencies. Very high-performance, high-speed processors will be assembled for NASA applications from modular components from the DOD very high-speed integrated circuits (VHSIC) program. A very highly reliable processor for use in high radiation environments will be assembled and tested to extend the life and performance capabilities of low-earth-orbit and planetary spacecraft. Spaceborne processors to meet very specific and demanding requirements of scientific instruments will be developed as special adaptations of processors for other government applications. The high-bandwidth terabit optical-disk buffer will be demonstrated for application to space station development. Work in developing high-speed fiber-optic modules for space applications in conjunction with the Air Force will continue. This technology is applicable to space station and the earth observing system for the distribution of high rate data between subsystems. Work will be initiated to investigate applications for very fast and high-capacity associative memory technology.

In FY 1987, the 60-GHz traveling wave tube (TWT) will be mated with a multiple-depressed collector with an expected twofold enhancement in efficiency. Also, a 60-GHz TWT will be specifically designed for power levels and bandwidths commensurate with a demonstration of communications between satellites at rates in excess of 300 million bits per second. A programmable adaptive phased array feed will be employed with the 15-meter hoop-column antenna to prove the theoretical concept of using phase and amplitude of the feed to compensate on-orbit for surface deformations of the antenna in order to provide the ideal far-field antenna pattern. Work will also be initiated on unique adaptive feed concepts with frequency reuse and contiguous multiple beams, a goal with revolutionary implications for large antenna systems technology. The major goal of the monolithic microwave integrated circuit research for FY 1987 will be to build a prototype 20-GHz feed, complete with the necessary phase and amplitude integrated circuits and control logic, and test this on an appropiate antenna in the Lewis Research Center's near-field facility. This work will ultimately enable the development of cost-effective, low-weight electronically steerable antennas, a technology that will dramatically increase the science returns of both low-earth-orbit and planetary missions. The X-band transponder demonstration technology will be completed and transitioned to the Office of Space Science and Applications for application to the Mariner Mark II series of missions. Included in this will be the successful design and demonstration of an engineering model of a 5-watt X-band solid-state power amplifier with record efficiencies of approximately 40 percent. Two-dimensional laser array technology for optical communications both in near-earth and planetary applications will continue. In particular, a new solid-state optical detector employing a superlattice-type construction will be built and tested. This device could allow operation of future optical communications systems at bandwidths in excess of one gigabit per second.

	1985 Actual	1986 Budget Estimate	1986 Current Estimate	1987 Budget Estimate
		(Thousands of Dollars)		
Information sciences research and technology	17,590	18,000	9,900	10,200

OBJECTIVES AND STATUS

The objective of the information sciences research and technology program is to provide advanced concepts, techniques, system architectures, hardware components, algorithms, and software for space information systems. The program contains disciplinary activities in computer science and sensor systems. The computer science program is improving the state of knowledge of fundamental aerospace computing principles and advancing computing technology in space applications such as spacecraft operations and information extraction from images. Advances in information science are necessary to cope with the explosive growth in the quantity and complexity of space-acquired data. Sensor research is focused on extending the capabilities of active and passive sensing systems in terms of NASA's unique requirements for spectral range, sensitivity, and resolution to enable future science and applications mission objectives.

In computer science, research in the fundamentals of data base logic have resulted in the development of a common user interface for accessing data from several data bases, even when the data bases being accessed have very different structures. This work provides the foundation that will enable NASA space data users access to multiple data bases independent of their physical distribution or structure. This research will reduce the cost of data base intensive research that would otherwise be unaffordable.

New approaches to software management will be evaluated in ongoing software production facilities. An experiment to test the validity of a simulation-based cost model for the software life cycle will be starting. Studies of parallel algorithms and principles of concurrency are underway and are yielding information on how to use the largely unexploited capabilities of parallel processors. The developmental work on the massively parallel processor is now concluding. That processor is now transitioning from its developmental role into an operational one to support research requiring very powerful computing capabilities. Researchers at 14 universities, 8 research laboratories, and 3 NASA centers are using this computer to evaluate its unique capabilities for image processing.

In the sensor technology program, a Raman-shifted, efficient, ultraviolet excimer laser under development will be used to demonstrate the feasibility of active remote monitoring of stratospheric ozone from the grouna-based light detection and ranging (LIDAR) facility for eventual space application for the earth observing system (EOS) mission. In the area of solid-state lasers, results of experimental measurements of potential laser materials and dopant ions indicate that materials which exhibit broad fluorescence emission will also be capable of tunable laser operation over broad wavelength regions, a feature of importance in active remote sensing. In addition, research is being done on two-dimensional arrays of semiconductor lasers with emission energy densities greater than a kilowatt per square centimeter to replace flashlamps for laser pumping for use in missions such as EOS.

In conjunction with the California Institute of Technology, a superlattice diode has been built which offers the potential of integrating the detector with the laser and other active devices on the same chip and having the device voltage-tune over wavelength regions of interest enabling wavelength adaptive space sensor capability. The development of an antimony doped silicon array has extended the capability of space infrared sensors to 30 micrometers with an order of magnitude lower readout noise. This device will find application on the large deployable reflector mission. An X-ray imaging spectrometer has been invented that will analyze X-rays in the 1- to 30-kiloelectron volt region which is an important science objective of the advanced X-ray astronomical facility.

CHANGES FROM FY 1986 BUDGET ESTIMATE

The decrease of $8.1 million in information sciences research and technology reflects the transfer of automation and robotics funding to systems technology and a reduction in information sciences of $0.3 million in order to support priority transatmospheric technology efforts.

BASIS OF FY 1987 ESTIMATE

In computer science, the knowledge-based techniques that have been demonstrated as applied to hyperspectral scene analysis for geologic remote sensing will be expanded and shared with other users to demonstrate the usefulness and portability of the approach to the analysis of space-acquired data. The distributed access and view integrated data base work will focus on applying this capability to selected pilot space data systems.

A major emphasis is being placed on the coordination of NASA and DOD software technology programs. ADA has already been selected as the language for space station, and efforts will be continued to maximize the benefits from use of that language. Special efforts will continue to coordinate NASA technology with the DOD software technology for adaptable reliable systems program and the DOD Software Engineering Institute. Software engineering research leading toward improved techniques and tools to produce and manage large and complex software development tasks will continue. Software engineering advances will be combined in a showcase aerospace software production environment which will reduce the cost of all future space software development efforts.

The Center for Aeronautics and Space Information Sciences at Stanford University will continue as a center of excellence in aerospace computing, conducting research and educating students in concurrent processing, networking, information management, and large-scale system architecture.

In the sensors program, work will continue on detector arrays for background-limited observations for space-based astronomical observations. Techniques such as impurity band photodetectors and stressed photodetectors will be investigated for extending the sensitivity out into the very far infrared and into the upper part of the submillimeter portion of the electromagnetic spectrum. Superconducting mixing devices with wide-band gap materials will be investigated for use at mid-submillimeter wavelengths. Research on arrays of mixers for simultaneous spatial and spectral imaging will be initiated. Submillimeter sensing technologies are targeted at atmospheric and astronomical sensing missions. These technology efforts are aimed at providing scientists with the remote sensing capability in the submillimeter region of the electromagnetic spectrum. Pumping of solid-state lasers with various geometrical arrays of semiconductor diodes will be pursued for active remote sensing. Also, new solid-state crystals with large degrees of tuning bandwidth, together with doubling crystals, will be investigated for reaching previously unattainable wavelengths. These laser sensing technologies will be evaluated on the lasers in space technology experiments and are targeted for application on EOS.

	1985 Actual	1986 Budget Estimate	1986 Current Estimate	1987 Budget Estimate
	(Thousands of Dollars)			
Controls and guidance research and technology..	8,600	8,900	7,500	7,500

OBJECTIVES AND STATUS

The space 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 on 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.

Recent program accomplishments include the successful demonstration of distributed active control in improving disturbance suppression damping by a factor of five or more, a result important to the NASA planned pinhole occulter project and planned mobile communication satellite ventures; the completion of the spacecraft control laboratory experiment test article for the testing of new spacecraft pointing control algorithms important to large flexible astrophysical reflector telescopes; system identification programs which can accurately determine, on orbit, the vibration modes in large space systems, such as growth space station; the successful breadboard test of a unique three-dimensional shape and motion sensor useful for determining the behavior of large flexible structures in space, such as will be tested in the control of flexible structures flight experiments; and the invention of a novel soft-mounting isolation device which uses a newly available piezoelectric polymer as the control actuator for supporting precisely pointed payloads on space station. Practical guidance laws were generated from optimal navigation control theory for a wide range of aeromaneuvering orbital transfer vehicles. Also, in the transportation system vehicles area, a very successful laboratory test was completed for the all solid-state fiber-optic rotation sensor, satisfying a wide spectrum of transportation vehicle requirements for a reliable, long-life, autonomous, precision navigation capability. A broad technology plan was completed to guide the overall transportation vehicle program's future activities.

CHANGES FROM FY 1986 BUDGET ESTIMATE

The decrease of $1.4 million in controls and guidance research and technology resulted from the following actions: realignment of $0.2 million for control of flexible structures to space flight research and technology; reduction of $0.7 million in space platform operations to support the aerospace industry/university flight experiments effort in the space flight research and technology budget line; transfer of $0.4 million in the teleoperations area to the automation and robotics systems technology program; and realignment of $0.1 million to support priority transatmospheric technology efforts.

BASIS OF FY 1987 ESTIMATE

Specific FY 1987 controls and guidance research activities will include further theoretical exploration of modern control theory methods associated with system identification, distributed control and adaptive control, and definitive testing of competing methods in ground test facilities. The goal is to identify and validate the most effective control concepts for in-space tests aboard the control of flexible structures flight experiment. The unique three-dimensional shape and motion sensor is being extended to a multitarget capability for a precise shape measurement of realistic three-dimensional large space structures such as the land mobile satellite and space station. The precision soft-mount elements, useful for space station mounted payloads, will be fabricated and breadboard tested under realistic space station disturbance environment.

In the advanced transportation systems area, the technical challenge will be met for solutions for aeromaneuvering vehicles undergoing skip trajectories, synergistic plane changes, and precise landings involving large downrange and crossrange capability. The advancement of the very promising all solid-state fiber-optic rotation sensor for navigation will be continued to provide transportation vehicle and interplanetary spacecraft requirements for long life and reliability. A substantial effort will be devoted to examining the concept of the control-configured space transportation vehicle, a vehicle which depends largely on the rapidly advancing areas of controls technology for its performance, stability, and economy of operation.

	1985 Actual	1986 Budget Estimate	1986 Current Estimate	1987 Budget Estimate
		(Thousands of Dollars)		
Human factors research and technology...	3,700	4,000	2,300	2,300

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 aerospace 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. For example, an expert system interface has been designed for an orbital refueling system with fault diagnosis and explanation strategies developed from simulated operational experience.

Effective information transfer between the system and the operator is fundamental to the operation of highly automated systems. Current research has guided development of a wide field-of-view stereo helmet- mounted display for remote manipulation, algorithms for machine vision, and guidelines for improved proximity operations displays.

One thrust of the crewstation design effort is to ensure that human/computer interaction technology developed outside the agency is adapted to NASA's unique aerospace needs. As part of this effort, a project is underway to develop comprehensive guidelines derived from research by industry, the military, and academia. An advisory group has been created and has formally reviewed initial sections of the guidelines. Formal publication is planned for FY 1987.

A second broad thrust is the development of rapid prototyping methodologies for crewstation design. The idea is to bring together very advanced research concepts in working aemonstrations and to obtain user evaluations early in the research and development process. This encourages focused research which addresses the needs of the user community. Rapid prototyping is being applied to a wide field-of-view stereo display for enhanced situational displays. The device is a major breakthrough in engineering design because it has achieved very high functionality at very low weight, power, and cost. It will sigificantly augment visual feedback in teleoperations tasks on space station. Currently, two versions of the display system have been built based on liquid crystal technology. Liquid crystal display technology allows low cost, high functionality, and ruggedness. An advanced version of the video processor has been built and holographic optics are being designed. Holographic optics will reduce the weight of the system and allow very compact packaging.

To encourage rapid prototyping at the systems level, a space station proximity operations workstation mockup is being built to bring together a wide array of advanced research concepts, including voice interaction automated systems, intelligent system interface software, three-dimensional perspective displays, spatial aural displays, and exterior window concepts. Currently, the display and control hardware is being assembled in a cylindrical module. Researchers in each of the above areas have projects which they are preparing for integration into the module. These include an expert system for human interface to the in-orbit refueling system, innovative display formats for space traffic control and EVA monitoring, and a working helmet-mounted display. The space station proximity operations workstation will be used to test advanced concepts for human/automation interface. Proximity operations scenarios will be utilized for these studies.

Interaction with automated (expert) systems is a third major thrust of the crewstation design effort. Effective coordination of automated and human-controlled functions is required for NASA's increasingly complex missions. Improved crew interface to automation will allow reduction of ground support requirements and greater crew productivity, even as operational demands increase. In particular, studies are underway to determine how best to interact with automation which shares system expertise, authority, and control with the human operator. One of these studies uses an orbital refueling system simulator and expert system for explanation of operator/automation interface experiments. This study has shown that operators require explanation of higher level situational implications of "out-of-tolerance" conditions.

A very successful research project in laser anthropometry supports both crewstation design and EVA performance. The system is installed and in full operation. This unique tool allows the three-dimensional position of an astronaut to be recorded rapidly and accurately; the data are then reconstructed into geometric form for analysis of astronaut activities. This allows automated tests of proposed workstation layouts, as well as determination of the feasibility of specific EVA tasks. The laser anthropometry system is being augmented by addition of a strength and motion data base. Experiments are underway to obtain data for the upper body.

Other support for EVA includes a space helmet-mounted display which can be used to display suit status and EVA task guidance information. This system has been prototyped and is currently undergoing integration tests and initial format development. The space human factors program is also contributing to the agency's development of a hard spacesuit. A hard spacesuit will allow astronauts to exit the spacecraft without several hours of prebreathing, because it operates at the same high atmospheric pressure as the spacecraft cabin. Two high-pressure demonstrator suits are being built and tested.

CHANGES FROM FY 1986 BUDGET ESTIMATE

The decrease of $1.7 million in human factors research and technology reflects the transfer of the teleoperations effort ($1.6 million) to the automation and robotics systems technology program and a realignment of $0.1 million to support transatmospheric technology efforts.

BASIS OF FY 1987 ESTIMATE

Research in FY *1987* will emphasize crew workstation design with a lesser effort in EVA aids. A comprehensive set of human factors guidelines which are specific to NASA's missions will be published ana distributed to space station contractors. The proximity operations mockup will be a mature facility for support of rapid prototyping, and advanced research concepts will be brought in for systems-level evaluation and comment by users. By FY 1987, research on the wide field-of-view stereo display will be ready to support an advanced virtual display capability. The virtual display is a major leap beyond current computer display technology. It allows computer-generated graphics and text to be displayed anywhere in the user's workspace, which greatly improves the information transfer capability of spatial information displays.

Expert system interface analyses will develop multilevel system models and other strategies to enable systems and users to communicate efficiently about system status and fault diagnosis. Laser anthropometry work will include the completion of efforts to model the strength and motion parameters of the upper body, and similar modeling work for the lower body will be initiated. Software enhancements will improve the user interface to the anthropometry data base. Efforts will begin to integrate the anthropometric data base with other human factors computer-aided design tools. Operational formats will be developed for the space helmet display and evaluated for application to EVA tasks. Research to support the high-pressure hard spacesuit effort will focus on new approaches to flexible but durable gloves that can be used comfortably at high internal pressures. Higher suit pressures cause gloves to be less flexible, which increases chaffing and other discomforts. High-pressure gloves have also suffered unacceptable fatigue failures.

	1985 Actual	1986 Budget Estimate	1986 Current Estimate	1987 Budget Estimate
		(Thousands of Dollars)		
Space flight research and technology........................	11,468	11,900	17,400	22,400

OBJECTIVES AND STATUS

The objective of this program is to provide a research-quality flight data base for the validation of ground-based research and technology efforts required for the development of future space systems and operations. This objective *is* accomplished through the utilization of the space shuttle as an in-space research laboratory. Flight data obtained from this effort provide a foundation for the development, refinement and verification of analytical theories and ground facility performance, test methods, and techniques. This program encompasses the design, development, and flight test of experiments and the development of special purpose, reusable, flight research facilities for use in space.

Under the orbiter experiments program (OEX), shuttle flights have included key aerodynamic and aerothermodynamic experiments on orbiter vehicle 102. These experiments included low- and high-altitude research-quality air data systems for the measurement of air density from the upper atmosphere to touchdown and an infrared scanner in the vertical stabilizer to measure entry heating on the shuttle upper wing and fuselage surfaces. Also, during FY 1986, the second flight of an adaptive autopilot will have demonstrated autonomous rendezvous with a real target. This experiment has demonstrated an automated rendezvous and docking capability that will provide significant benefits to future space operations and, in particular, to future space station operations. In late FY 1986, flight testing of advanced thermal protection system test panels will be initiated. These panels will provide actual flight data on durable, high-performance concepts which could become candidates for future aerospace vehicles. The orbiter acceleration research experiment will provide accurate aerodynamic acceleration measurements during orbit and reentry and will make significant contributions to the data base for the rarefied and transitional flow regimes. This data base will be used to predict drag forces more accurately on large space structures to enable accurate prediction of propellant usage for orbit maintenance and attitude control. This experiment has completed critical design review in preparation for hardware development and a planned flight in the 1988 time frame.

An aeroassist orbital transfer vehicle (AOTV) offers the potential of utilizing atmospheric forces rather than a propulsion system to achieve desired orbital changes. For some missions, the propellant savings of an AOTV, as compared to a conventional configuration, is estimated to be sufficient to allow nearly double the payload for the same size vehicle. The AOTV flight experiment will release a test vehicle from the orbiter payload bay to be raised in orbit, then accelerated into the atmosphere to simulate the aerobrake maneuver, and recovered into the payload bay. During the maneuver, data on aerodynamic, aerothermodynamic, and thermal protection system response will be achieved. Ground-based wind tunnels are not capable of simulating the aerobraking environment. This experiment is currently in concept definition in preparation for the Phase C/D (design, development, and flight test) initiation in FY 1988.

The cryogenic fluid management flight experiment, which provides basic understanding of the storage, acquisition, and transfer of cryogenic fluids in zero gravity, will complete systems level preliminary design efforts, the Phase I ground safety reviews, and the installation of the cryogenic systems analysis model on the Cray computer. 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 that it will provide the technology to design cryogenic systems to minimize propellant boiloff during storage and transfer and thus provide operating efficiencies that will significantly reduce the transportation costs associated with space-based OTV's.

The definition of a hypersonic technology flight experiment will be initiated in 1986 to provide experimental flight data applicable to high-speed aerospace vehicle performance in the high Mach number and altitude regimes to validate aerodynamic and aerothermodynamic computational capability and the behavior of advanced material components and actively cooled thermal structures components.

The development of a space technology experiments platform (STEP) was initiated in FY 1985 to provide a dedicated support system which will be used to conduct flight experiments to study the control of flexible structures in space. STEP is configured to accommodate a broad range of experimental objectives to study the effects of microgravity, wide thermal excursion, and absence of atmospheric damping which are characteristic of the space environment. STEP, as a reusable payload support system and standard orbiter interface, will provide a cost-effective means for routinely conducting a variety of experiments on-board the shuttle.

The long-duration exposure facility awaits retrieval by the shuttle and subsequent data analysis. The ion auxiliary propulsion system remains in flight-ready status for flight on an Air Force satellite. A conceptual design of a plume experiment was initiated, and two heat-pipe experiments, the capillary pump loop and the space station heat-pipe advanced radiator element, will complete flights in FY 1986.

CHANGES FROM FY 1986 BUDGET ESTIMATE

The increase of $5.5 million in space flight research and technology includes the consolidation of funding from other research and technology base programs for the following activities: control of flexible structures ($0.9 million), transatmospheric technology ($1.0 million), aerospace industry/university space flight experiments program ($2.0 million), and cryogenic fluid management technology ($0.1 million). In addition, the aeroassist portion of the OTV systems technology program ($1.5 million) was transferred to this research and technology base program from systems technology.

BASIS OF FY 1987 ESTIMATE

A new focus in FY 1987 is the expansion of the flight experiments program supporting base research and technology activities. This will be accomplished by a directed activity that will extend flight experiment opportunities to the aerospace and academic communities.

Significant activity will occur in the orbiter experiments program: the aerodynamic/aerothermodynamic instrumented flight initiated in FY 1986 will continue through a six-flight series concluding in approximately mid-1987; the thermal protection system panels, also installed on the orbiter in FY 1986, will continue flights on orbiter vehicle 102 through FY 1987 and conclude in FY 1988; and the hardware development for the orbital acceleration research experiment will be initiated.

The aeroassist flight experiment will continue through systems design definition. The hypersonic technology flight experiment will continue requirements definition and design activities leading to a potential flight in the 1988-1989 time frame.

The cryogenic fluid management flight experiment, the space technology experiments platform, and the solid-state laser light detection and ranging in-space technology experiment will initiate hardware development in FY 1987 to prepare for future flight dates. The plume survey experiment will complete preliminary design in preparation for hardware development leading to flight in 1990.

	1985 Actual	1986 Budget Estimate	1986 Current Estimate	1987 Budget Estimate
		(Thousands of Dollars)		
Systems analysis......	6,788	6,600	6,800	6,100

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 high-leverage technologies.

Spacecraft systems are subdivided into planetary systems, communications, earth sciences, and astronomy applications. In FY 1986, the planetary systems analysis has focused on technology needs for high priority missions, with continued emphasis on comet and planetary sample return missions. In communications, the emphasis is to identify, assess, and prioritize high-leverage enabling and enhancing technologies. These studies show that a concerted technology program could potentially double payload fractions, thereby increasing the spacecraft mission accomplishments and reducing costs. In earth sciences, the focus is on earth observing systems (EOS) where interactions between instruments and subsystems will be addressed on an interdisciplinary basis to achieve a total spacecraft system technology plan. In astrophysics, activities will include the design of a subscale large deployable reflector optics breadboard. This work will be supplemented by a pre-Phase A study with the Office of Space Science and Applications. The Office of Aeronautics and Space Technology capabilities in large space structures will be used to support missions and technology tradeoff studies in most of the spacecraft system areas under study.

The space transportation systems analyses are focused in three areas: advanced earth-to-orbit vehicles (ETO), aeroassist orbital transfer vehicles (AOTV), and advanced space transportation systems conceptual design and analysis methods. The ETO area includes the technology to support replacement shuttle (Shuttle II), the heavy-lift launch vehicle and very advanced (post-2010) future space transportation systems. The FY 1986 ETO studies/analyses are focused on Shuttle II and the impact of liquid-oxygen/hydrocarbon (LOX/HC) engines on reusable ETO configurations. The FY 1986 ETO studies also include the definition of nonintrusive 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. This vehicle will be consistent with the national space transportation architecture. The LOX/HC engines/vehicle integration and design studies are being used to assess 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 large reductions in cost per pound of payload to orbit. AOTV technology and environment studies are continuing in FY 1986 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 application of aeroassist braking to the OTV on return to LEO has the potential for a 50-percent reduction in propellant requirements and cost and a corresponding increase in payload to orbit. These studies are consistent with the renewed interest in lunar and planetary colonization and mining. Finally, conceptual design and analysis methods are needed 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 analysis program is undergoing a transition in focus from technology for IOC space station to technology for evolutionary growth configurations in the late *1990's* and beyond. Additionally, analysis activities have been started to identify in-space research and technology programs which would utilize the space station as a research facility in space, and to begin identifying technology requirements for a manned geosynchronous platform, a manned lunar base, and a manned Mars expedition.

In FY 1986, there are three specific activity areas in the large space systems analysis program: (1) systems analysis methods; (2) future space stations including the evolutionary growth space station in low earth orbit, a manned geosynchronous platform, a manned lunar base, and a manned Mars mission; and (3) in-space research, technology, and engineering program planning. The objective of the systems analysis methods is to maintain development of 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 stations, is to address mission and system requirements to identify associated technology needs and trends. Specifically, efforts will continue for developing generic space system models to permit the conduct of sensitivity trades for large in-space systems.

Additional tasks will investigate technology needs for such activities as construction of lunar structures, propellant and oxygen production from lunar oxides and Martian permafrost and atmosphere, food production for lunar and Martian missions, and in-flight training for long-duration interplanetary missions. The activities in the third area are associated with developing a technical basis for conducting in-space research, technology, and engineering experiments using the space station as a laboratory facility. Three areas are being investigated for potential in-space experiment programs: fluid behavior,, space environment, and structural dynamics and control.

CHANGES FRM FY 1986 BUDGET ESTIMATE

The increase of $0.2 million in systems analysis reflects an internal research and technology base realignment to provide for additional study efforts.

BASIS OF FY 1987 BUDGET ESTIMATE

In spacecraft systems, the analysis effort has identified technologies that will be needed to support the spacecraft technology driver missions. Efforts will continue to build upon these initial results by conducting detailed follow-up to the 1985 large deployable reflector (LOR) workshop; analyzing large space structures with focus on LDR and improving mobile communication satellite (termed MSAT) capability; assimilating the EOS technology workshop results and issuing a comprehensive technology plan; and conducting mission analysis and system technology studies on planetary and sample return missions.

The transportation systems analysis effort in FY 1987 will continue the definition of key areas for technology growth in orbital transfer vehicles and advanced systems for delivery of payloads to low earth orbit. The analyses will focus on concepts and technology requirements for a lunar orbital transfer vehicle, a heavy-lift launch vehicle, and the replacement shuttle. The continued development of design and analysis tools and the technology base for advanced transportation vehicles will enable the development of economical space systems in the future.

In large space systems, with the planning and definition activities associated with the early space station nearing a point in time when applicable technology will be baselined, the systems analysis program will be refocused to address the needs and opportunities of a broader menu of space systems including large antennas, unmanned platforms, and evolutionary space stations. The primary intent of the extended perspective is to ensure that the research and technology base program is structured to support the needs of these missions as they are being projected for the turn of the century. Additionally, the FY 1987 program will continue to expand the efforts started in FY 1986 to include planning for using the space station as a facility in space for technology development.

BASIS OF 1987 FUNDING REQUIREMENTS

SYSTEMS TECHNOLOGY PROGRAMS

	1985 Actual	1986 Budget Estimate	1986 Current Estimate	1987 Budget Estimate
		(Thousands of Dollars)		
Chemical propulsion systems technology	2,100	5,800	5,800	8,100
Space flight systems technology	6,642	6,200	6,200	---
Control of flexible structures flight experiment	---	5,000	5,000	11,300
Orbital transfer vehicle technologies	---	3,000	---	---
Automation and robotics technology	---	---	10,200	18,000
Total	8,742	20,000	27,200	37,400

	1985 Actual	1986 Budget Estimate	1986 Current Estimate	1987 Budget Estimate
	(Thousands of Dollars)			
Chemical propulsion systems technology				
Advanced earth-to-orbit systems technology...	2,100	5,800	5,800	8,100

OBJECTIVES AND STATUS

The objectives of the advanced earth-to-orbit systems technology program are to validate technologies being developed for advanced high-performance reusable engines by utilizing a testbed engine assembled from existing space shuttle main engine hardware for the purpose of providing experimental data to validate analytical models and to evaluate advanced component concepts emanating from the propulsion research and technology base program. Extensive instrumentation will be installed on the first engine assembly in order to experimentally establish a data base which characterizes the internal dynamic environment of these types of engines. Research quality instrumentation capable of accurately measuring both transient and steady-state pressures, temperatures, flow rates, stresses and strains is being provided as it becomes available from the research and technology base program. The data will be used to validate computer codes that have been developed to simulate these dynamic environments and their effect on operating components. In later engine assemblies, advanced technology components designed for extended life and/or higher performance will be evaluated under engine system operating conditions. Advanced turbine blade materials and coatings, damping seals, and advanced longer life bearing designs that have been evaluated initially in rig testing under the research and technology base program are examples of some of the earlier advanced component hardware that will be installed in the engine for testbed verification testing. In addition, advanced sensors being developed and evaluated in test rigs under the research and technology base program for monitoring the wear of high wear rate components will also be installed in engine components for system level test evaluation. These efforts will lead to the eventual assembly and test of a complete engine condition monitoring system.

The testbed engine provides the lowest risk path for verifying the behavior of improvements from the research and technology base program. Many promising products are emerging from the base program that will be ready for testbed engine testing in the FY 1988-1990 time frame. The testbed engine program will provide the experimental tools needed to evaluate longer term, higher risk technology items that will lay the foundation for advanced high-performance reusable engines essential for the support of national transportation needs being identified in current national security directive studies. The Office of Aeronautics and Space Technology portion of this program funds the analyses, design and fabrication of advanced technology components that have been iaentified as ready and needed for testbed evaluation. The Office of Space Flight funds are used to acquire engine component hardware, to install advanced technology items in the component hardware, to assemble the testbed, and to conduct test operations.

The design and fabrication of research instrumentation and advanced technology components are scheduled to be compatible with the availability of the SI-C test stand at the Marshall Space Flight Center and engine hardware being acquired by the Office of Space Flight for testing starting in FY 1988.

BASIS OF FY 1987 ESTIMATE

The design and fabrication of research instrumentation to be installed on the initial instrumented engine includes high-response pressure and temperature sensors and nonmoving parts cryogenic flow meters. Advanced technology items being designed and fabricated for installation in later engine builds include fiber-optic deflectometer bearing-wear sensors, turbine temperature sensors based on fiber-optic pyrometer concepts, advanced single-crystal turbine blades, thermal barrier coated turbine blades, advanced damping seal configurations, and longer life bearing designs.

	1985 Actual	1986 Budget Estimate	1986 Current Estimate	1987 Budget Estimate
		(Thousands of Dollars)		
Space flight systems technology				
Space flight experiments..	5,342	6,200	6,200	---
Long duration exposure facility....;	700	---	---	---
Ion auxiliary propulsion system	600	---	---	---
Total...............................	6,642	6,200	6,200	---

OBJECTIVES AND STATUS

The objective of the space flight systems technology program is to conduct research in space, capitalizing on the use of the space shuttle, spacelab, and free-flying vehicles where it is impossible or too costly to simulate the space environment in ground laboratories. The space environment uniquely provides long-term zero gravity and the combination of space vacuum and space radiation environments necessary to the development and characterization of many technologies important to future space systems. This program encompasses the design, development, and flight test of experiments and the development of special purpose, reusable, flight research facilities for use in space. Beginning in FY 1987, in-space experiments and the space technology experiments platform will be budgeted within the research and technology base. Also, beginning in FY 1987, flight experiments conducted for the control of flexible structures in space will be budgeted within the control of flexible structures flight experiment systems technology program.

	1985 Actual	1986 Budget Estimate	1986 Current Estimate	1987 Budget Estimate
		(Thousands of Dollars)		
Control of flexible structures flight experiment..........................	---	5,000	5,000	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. 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 a ground research program, including analysis and test methods, and a space-based experiment activity addressing the key technology unknowns through graduated testing of flexible elements of large space structures. This program will provide a validated technology data base that will enable these next generations of large flexible spacecraft to be developed. The research data base will allow the design and development of integrated complex control systems and structural configurations for difficult advanced mission goals to be achieved.

In order to meet the requirements of the control of flexible structures 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.

The space shuttle provides the opportunity to test and validate in space the dynamics, controls, structural concepts, theories, and system components required by future large space structures missions. 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, through the design of a generic flight test article that addresses fundamental large space systems (LSS) discipline issues. These critical issues will include flexible structural configurations that have fundamental frequencies below one hertz, complex nonlinear joint effects, structural dynamic/control systems interactions, and inherent low structural damping effects. This model can be tailored to validate discipline research objectives addressing the major concerns of LSS spacecraft, independent of any specific configurations ultimately chosen for new missions.

The first flight article, COFS I, is a large (60-meter) deployable/stowable truss-beam structure (termed mast) which will be flown in space cantilevered from the orbiter. Actuators and instrumentation necessary for excitation, measurement, and control of the low-frequency modes of mast are an integral part of the mast flight experiment. The mast test article will be mounted on the space technology experiments platform, integrated with the orbiter, and transported to space. Specific objectives of the COFS I flight experiment are to determine the degree to which analytical methodology and ground testing can predict flight performance of next-generation, low-frequency structures; evaluate mathematical modeling of large, lightweight, complex systems; evaluate control/structure interactions; evaluate sensor/measurement techniques applicable to low-frequency systems with low motion/deflection tolerances; evaluate deployment kinematics in zero gravity (g) versus one g; evaluate damping effects in zero g; and evaluate LSS control laws and control mechanizations.

The second flight article, COFS II, will incorporate gimbals and an antenna-like appenaage to the COFS I mast hardware and will provide the opportunity to study the more complex structural dynamics and control characteristics of large, flexible, three-dimensional spacecraft configurations. Technology needs that will be addressed by COFS II include maneuver control, articulation, printing, shape control, alignment, systems identification, deployment dynamics, and adaptive controls.

A third activity, COFS III, will be focused on the validation of control-structure interactive analysis and design methodologies for multibody spacecraft. Scale model investigations will be conducted on future large space platforms to determine modeling sensitivities, vibration suppression techniques, appropriate ground test methods, and capabilities.

In FY 1986, fabrication of the COFS I flight article will be initiated, and scale model "mini-mast" testing will begin. In FY 1986, a COFS II project plan will be developed, and the request for bids for the COFS II flight test article will be developed. Also in FY 1986; a COFS III project plan will be developed to support fundamental research and technology development in multibody dynamics and control.

BASIS OF FY 1987 ESTIHATE

Ground-based experiments initiated earlier will be continued in FY 1987 to accurately characterize/synthesize the dynamic behavior of the structure and to develop control laws and methods to control its configuration and motion. 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 preliminary design review and the critical design review of the mast flight test article will be completed in FY 1986. Flight test article delivery will occur at the end of FY 1988. The characteristics of the mast truss-beam flight test article will be defined through initiation of a mathematical model to be validated later in the ground-based and then space test program beginning in FY 1989. In FY 1987, a COFS II program plan will continue with flight article definition. Planning for COFS II will begin with definition of a generic configuration for an antenna-like structure and a related ground test program plan. In FY 1967, the fabrication and testing of scale models of large multibody spacecraft will be initiated.

	1985 Actual	1986 Budget Estimate	1986 Current Estimate	1987 Budget Estimate
		(Thousands of Dollars)		
Orbital transfer vehicle technologies				
Aeroassist technology................	---	1,500	---	---
Propulsion technology................	---	1,500	---	---
Total..............................	---	3,000	---	---

CHANGES FROM FY 1986 BUDGET ESTIMATE

The decrease of $3.0 million in OTV technologies reflects the transfer of the aeroassist portion of the program to space flight research and technology and the transfer of the propulsion technology portion to propulsion research and technology within the research and technology base.

	1985 Actual	1986 Budget Estimate	1986 Current Estimate	1987 Budget Estimate
	(Thousands of Dollars)			
Automation and robotics technology.. ..	(8,200)	(10,200)	10,200	18,000

OBJECTIVES AND STATUS

The objective of the automation and robotics technology program is to exploit the potential of artificial intelligence and of telerobotics to decrease the cost of ground control and to increase the capability and flexibility of space operations. Artificial intelligence will be used to reduce the size of ground control and operations, and telerobotics will be used to enable increased capability in space servicing, assembly, and repair. The goals of the program are to decrease mission operations manpower by 60 percent; replace 50 percent of extravehicular activity (EVA) with telerobotics; and enable remote servicing, assembly, and repair.

The program focuses on system autonomy and telerobotics. The objective of the systems autonomy effort is to develop a generic set of software tools for the design of expert systems for increasing automatic and intelligent control of complex dynamic space systems. The objectives of the telerobotics focus 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 capability for on-orbit assembly, servicing and repair, and for planetary exploration.

Integration of advancing technologies in each area, systems autonomy and telerobotics, is described by a sequence of evolutionary ground demonstrations scheduled from 1987 to 1996. In systems autonomy, 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. In telerobotics, the initial demonstration

(1987) 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.

Underlying both sequences of demonstrations 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 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 necesary to enable autonomous recognition of objects from a well defined data base, as well as autonomous capture and despin of tumbling satellites. In control execution, computer vision and force/torque feedback has 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. This capability is the basis for the systems autonomy focus. Ongoing and planned work is to evolve this initial autonomous planning capability to a wider set of applications with a reduced set of constraints. In system architecture and integration, a joint venture with DARPA has been initiated to develop a spaceborne symbolic processor to enable on-orbit execution of artificial intelligence software.

CHANGES FROM FY 1986 BUDGET ESTIMATE

The automation and robotics funding previously budgeted and managed in various programs within the space research and technology base ($10.2 million) has been consolidated into a systems technology program for management visibility.

BASIS OF FY 1987 ESTIMATE

The initial telerobot demonstration will take place in late FY 1987. It will comprise a two-arm telerobot which can perform simple servicing and assembly tasks on cooperative spacecraft using hand and power tools. It will include initial autonomous capability in terms of task primitives such as: open, close, screw in, etc. In FY 1987 the two-armed, fixed-base telerobot, as well as the operator control station and the spacecraft mockup, will be constructed, debugged, and demonstrated.

The initial systems autonomy demonstration will be in final preparation in FY 1987 and will take place early the next year. It will comprise automated control (i.e., an intelligent aide) for a single-mission operations subsystem integrated communications. An expert system for integrated communications control will be developed and debugged for use in the shuttle mission control center at Johnson Space Center. 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 will continue. In sensing and perception, the focus will be on multiple-class three-dimensional object recognition and tactile/proximity sensing in order to reduce reliance on the human operator's vision system. In task planning, the emphasis will be 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, predictive 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.

BASIS OF FY *1987* FUNDING REQUIRMENT

STANDARDS AND PRACTICES

	1985 Actual	1986 Budget Estimate	1986 Current Estimate	1987 Budget Estimate
		(Thousands of Dollars)		
Standards and Practices	4,900	8,000	8,000	9,200

OBJECTIVES AND STATUS

The objective of the Standards and Practices program is to support NASA's goals through activities in productivity; reliability and quality assurance; maintainability; safety; software assurance; systems engineering; and program practices which reduce program risk, improve product confidence, and encourage good program procedures in the technical execution of NASA programs.

During FY 1985, the Office of the Chief Engineer continued its efforts to improve NASA's software management, assurance, and productivity. Emphasis was directed toward developing validated procedures to ensure the integrity of the systems to be put into service. Non-destructive evaluation (NDE) testing techniques were extended to new materials such as composites. The results of this effort will ensure that material and fabrication specifications can be non-destructively verified and that degradation of materials in use can be quantitatively documented. In FY 1986, work continues on efforts with the NASA Centers and industry in the areas of Computer-Aided Design/Computer-Aided Manufacturing; materials, treatments and processes data bases; integrated circuit product assurance; microcircuit radiation effects evaluations; design and manufacturing standards; aerospace and systems safety related matters; and other activities which support NASA-wide program responsibilities.

BASIS OF FY 1987 ESTIMATE

In support of the goals of NASA, the FY 1987 Standards and Practices program will continue to conduct activities related to its objectives. The increase in funding from the FY 1986 level reflects a broadened NDE program, and an expansion of NASA's Software Management and Assurance Program (SMAP).

The efforts of the SMAP are critical to NASA's ability to economically develop and acquire reliable software to support the more complex, computer driven systems required by its future missions. The objectives of the SMAP are to adapt industry and DOD software solutions to the NASA environment, and to create more effective implementation schemes which take advantage of NASA's existing expertise, communications media, and recent lessons learned. Software standards, specialized software training, distributed software corporate memory data bases, and software guidebooks will be the primary products that will facilitate improved software business practices and software resources sharing by NASA projects. Industry, DOD and NASA achievements in the areas of software acquisition management, reliability engineering, and quality assurance will be monitored and assessed on a continuing basis to ensure that NASA's state of software practices is as close as practical to the emerging state of the art.

The NDE Measurement Assurance Program, currently focused on metals and composites, will be expanded to include electronics and will explore and develop qualitative and quantitative inspection and quality control techniques for microcircuits and semiconductors. New microcircuit technology is approaching one micron-line width and, based on past experience, contamination and particulates will have a major impact on microcircuit reliability. Existing quality control practices, especially process control and screening techniques, are inadequate and too time consuming for new-generation microcircuits, making parts availability a major concern for NASA. Some of the current screening methods, such as Particle Impact Noise Detection (PIND) tests and x-rays, are not effective NDE techniques. This program will develop techniques to accompany the advances in microcircuits, and to replace the outdated process and quality control practices and screening techniques. The program will concentrate on the chip level, but will explore the assemblies as well.

The FY 1987 funds will also continue to provide for special efforts focused on finding solutions to specific technical problems arising from programmatic activities. In addition, overall support is required to continue to ensure that advances in technology, such as microelectronics, robotics, computer automation, and composite fibers, can confidently be qualified for use in NASA programs within a timeframe that is consistent with project needs.

TRACKING AND
DATA ADVANCED
SYSTEMS

RESEARCH AND DEVELOPMENT

FISCAL YEAR 1987 ESTIMATES

BUDGET SUMMARY

OFFICE OF SPACE TRACKING AND DATA SYSTMS | TRACKING AND DATA ADVANCED SYSTEMS

SUMMARY OF S REQUIREMENTS

	1985 Actual	1986 Budget Estimate	1986 Current Estimate	1987 Budget Estimate	Page Number
		(Thousands of Dollars)			
Advanced systems............	14,800	16,200	16,200	17,100	RD 16-2
TOTAL............................	14,800	16,200	16,200	17,100	
Distribution of Program Amounts by Installation					
Goddard Space Flight Center...........	4,400	5,100	4,700	5,000	
Jet Propulsion Laboratory.............	16,228	11,100	11,500	12,100	
Ames Research Center	24	--	--	--	
Headquarters.........	148	--	--	--	
TOTAL............................	14,800	16,200	16, Z00	17,100	

BASIS OF FY 1987 FUNDING REQUIREMENTS

ADVANCED SYSTEMS

	1985 Actual	1986 Budget Estimate	1986 Current Estimate	1987 Budget Estimate	Page Number
		(Thousands of Dollars)			
Advanced systems....	14,800	16,200	16,200	17,100	

OBJECTIVES AND STATUS

The objective of the Advanced Systems Program is to perform studies and provide for the development of tracking and data systems and techniques required to: (1) obtain new and improved tracking and data handling capabilities that will meet the needs of approved missions and near-term new starts; and (2) improve the cost effectiveness and reliability needed for overall support of the total mix of spaceflight missions.

As a small but vital portion of the total Space Tracking and Data Systems Program, this activity continues to be focused on assessing and making use of the dramatic changes taking place in the state of the art in telecommunications, electronic micro-circuitry and computer technology. Such effort is critical for proper planning and for the application of cost effective and reliable new technology to future support capabilities. Ongoing work includes the investigation of upcoming missions and studies of ground systems and telecommunication links to determine design approaches and overall tradeoffs for the lowest life cycle costs to support future space missions.

BASIS OF FY 1987 ESTIMATE

Activities planned for FY 1987 include efforts aimed at obtaining location accuracies to the one meter level for Earth-orbiting spacecraft which would make possible a new class of high precision Earth observatory missions on the Shuttle, Space Station and on free-flying spacecraft. The techniques to be studied include a specialized use of the Department of Defense's Global Positioning System and Very Long Baseline Interferometry. Work will also continue on the development of extremely precise radiometric techniques for determining angular direction of future planetary missions to an accuracy of five nano-radians. Such improvements typically lead to improved spacecraft navigation and the conduct of science experiments not previously possible.

New methods for improving communications with spacecraft will continue in such areas as signal coding; use of millimeter wave frequencies on large diameter antennas; the development of more efficient transmitters; highly reliable, low noise telemetry receivers; and, antenna feed systems capable of multiple frequency operation, i.e., K, X, and S-band. Improving space-to-ground link performance can benefit many future missions by reducing mission costs through reduced spacecraft weight and power requirements or increasing the amount or quality of the data returned. Optical communications technology to meet telecommunications needs beyond the 1990's will also be investigated both for its cost-performance advantages over microwave technology and for its potential in space data relay applications.

Use of high density tape and optical disk storage with automated quality control of data is being investigated to meet future image data processing requirements because the data handled from Earth-orbital missions is expected to increase 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 a K-band terminal for TDRSS user spacecraft, computer assisted operations, digital processing of high volume data, improved man-machine interfaces, and wide band satellite communications to distribute data to processing centers and users.

Investigations will continue on methods for reducing projected manpower requirements for operating the mission control facilities and for providing the necessary real time interaction between the spacecraft experimenters and their experiments. Other investigations are being carried out in the areas of automated mission control, 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 1987 ESTIMATES

GENERAL STATEMENT

The objective of the National Aeronautics and Space Administration 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 cost effective shuttle system with a minimum flight rate capability of 24 per year in *1989* by providing the national fleet of Space Shuttle orbiters, main engines, launch site and mission operations control requirements, 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 AND DATA SYSTEMS: A program to provide vital tracking, telemetry, command, and data acquisition support to meet the requirements 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. In 1986, the Tracking and Data Relay Satellite Systems (TDRSS) will become the primary system for supporting upcoming Earth orbiting missions.

NATIONAL AERONAUTICS AND SPACE ADMININSTRATION

SPACE FLIGHT, CONTROL AND DATA COMMUNICATIONS
FY 1987 BUDGET ESTIMATES

	1985 Actual	1986 Budget Estimate	1986 Current Estimate	1987 Budget Estimate
	(Thousands of Dollars)			
SHUTTLE PRODUCTION AND OPERATIONAL CAPABILITY......	1,484,500	976,500	971,600	745,400
SPACE TRANSPORTATION OPERATIONS.	1,314,1300	1,725,100	1,725,000	1,524,700
SPACE AND GROUND NETWORKS, COMMUNICATION AND DATA SYSTEMS	795,700	808,300	701,300	798,900
TOTAL	3,594,200	3,509,900	3,397,900	3,069,000

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; [$3,397,900,000] *$3,069,000,000*, to remain available until September 30, [1987] *1988*. *(Department of Housing and Urban Development-Independent Agencies Appropriations Act. 1986; additional authorizing legislation to be proposed.)*

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 1985	Budget Plan FY 1986	Budget Plan FY 1987
Shuttle Production and Capability Development	319,185	317,992	230,000
Space Transportation Operations	480,600	300,000	704,000
Expendable Launch Vehicles...........	129,582	271,679	77,300
Tracking and Data Acquisition	46,833	45,329	33,000
Total..	976,200	935,000	1,044,300

NATIONAL AERONAUTICS AND SPACE ADMINISTRATION

SPACE FLIGHT, CONTROL AND DATA COMMUNICATIONS

FISCAL YEAR 1987 ESTIMATES

SUMMARY OF BUDGET PLAN BY SUBFUNCTION
(In thousands of dollars)

Code		FY 1985	FY 1986	FY 1967
253	Space Fligh..	2,798,500	2,696,600	2,270,100
255	Supporting Space Activities................	795,700	701,300	798,900
	Total, General Science, Space and Technology......	3,594,200	3,397,900	3,069,000

NATIONAL AERONAUTICS AND SPACE ADMINISTRATION

FISCAL YEAR 1987 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	1985	2,798,500	1,159,500	383,100	1,205,800	6,300	1,700	2,600	3,800	100	3,400	32,200
	1986	2,696,600	918,900	407,200	1,229,000	8,300	1,400	300	4,900	100	3,000	123,500
	1987	2,270,100	560,500	485,800	1,058,400	8,600	1,200	1,500	2,800	100	500	150,700
Shuttle Production and Capability Development	1985	1,484,500	763,800	105,200	581,300	6,300	500	2,600	—	—	3,400	21,400
	1986	971,600	379,100	64,000	416,000	7,500	—	300	—	—	3,000	101,700
	1987	745,400	210,500	105,500	318,500	7,900	—	1,500	—	—	500	101,000
Space Transportation Operations	1985	1,314,000	395,700	277,900	624,,500	—	1,200	—	3,800	100	—	10,800
	1986	1,725,000	539,800	343,200	813,000	800	1,400	—	4,900	100	—	21,800
	1987	1,524,700	350,000	380,300	739,900	700	1,200	—	2,800	100	—	49,700
Tracking and Data Acquisition	1985	795,700	150	—	17,687	—	429,446	108,402	8,545	—	—	231,470
	1986	701,300	—	—	29,200	—	365,200	122,200	10,900	—	—	173,800
	1987	798,900	—	—	29,300	—	377,200	128,200	12,000	—	—	252,200
Total	1985	3,594,200	1,159,650	383,100	1,223,487	6,300	431,146	111,002	12,345	100	3,400	263,670
	1986	3,397,900	918,900	407,200	1,258,200	8,300	366,600	122,500	15,800	100	3,000	297,300
	1987	3,069,000	560,500	485,800	1,087,700	8,600	378,400	129,700	14,800	100	500	402,900

SPACE
TRANSPORTATION
SYSTEMS

FISCAL YEAR 1987 ESTIMATES

BUDGET SUMMARY

OFFICE OF SPACE FLIGHT | **SPACE TRANSPORTATION SYSTEM PROGRAM**

SUMMARY OF RESOURCES REQUIREMENTS

	1985 Actual	1986 Budget Estimate	1986 Current Estimate	1987 Budget Estimate	Page Number
		(Thousands of Dollars)			
Shuttle production and operational capability	1,484,500	976,500	971,600	745,400	SF 1-1
Space transportation operations	1,314,000	1,725,100	1,725,000	1,524,700	SF 2-1
Total	2,798,500	2,701,600	2,695,600	2,270,100	
Distribution of Program Amounts By Installation					
Johnson Space Center	1,159,500	910,100	918,900	560,500	
Kennedy Space Center	383,100	375,500	407,200	485,800	
Marshall Space Flight Center	1,205,800	1,245,900	1,229,000	1,058,400	
National Space Technology Lab	6,300	7,200	8,300	8,600	
Goddard Space Flight Center	1,700	1,100	1,400	1,200	
Jet Propulsion Laboratory	2,600	---	300	1,500	
Lewis Research Center	3,400	---	3,000	500	
Langley Research Center	100	100	100	100	
Ames Research Center	3,800	3,100	4,900	2,800	
Headquarters	32,200	158,600	123,500	150,700	
Total	2,798,500	2,701,600	2,696,600	2,270,100	

OFFICE OF SPACE FLIGHT | SPACE TRANSPORTATION SYSTEM PROGRAM

PROGRAM OBJECTIVES

The Space Shuttle is the key element of a versatile Space Transportation System (STS) that is available to a wide variety of national and international users. The Space Shuttle is the first reusable space vehicle and is configured to carry many different types of space apparatus, scientific experiments, and national security payloads. In addition to transporting materials, equipment 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 Capability provides for the national fleet of four Shuttle orbiters, including main engines, and provides for the launch site facilities, initial spares, production tooling, and related supporting activities to meet the needs of NASA, the Department of Defense (DOD), and other domestic and international users of space. This line item contains orbiter production for flight hardware improvements and mission kits; the procurement of a spares inventory for the operational orbiter fleet, including major structural orbiter components; the residual devslopment tasks for the orbiter, Space Shuttle main engine (SSME), external tank (ET), and solid rocket booster (SRB); Johnson Space Center (JSC) mission operations capability development; the equipment provisioning of the facilities for launch and landing at the Kennedy Space Center (KSC); the development of the filament wound case (FWC) solid rocket booster; the initial lay-in of spares and ground support equipment; and the rate tooling for the ET and SRB. Modification of two orbiters, two mobile launch platforms (MLP) and both launch pads for the conduct of the planetary missions (Galileo and Ulysses) in 1986, using the Centaur as an STS upper stage, are also funded under this budget item.

Shuttle Operations provides the standard operational support services for Shuttle, the primary U.S. launch system. Within Shuttle Operations, flight hardware is produced, refurbished and repaired; and manpower, propellants, and other materials are furnished to conduct and support both flight and ground operations. The Shuttle Operations program provides for the launch of NASA missions and on a reimbursable basis DOD, other U.S. Government, commercial, and international missions. The launch schedule calls for 14 flights, including the first launch from the west coast, in FY 1986, 17 flights in FY 1387, and 18 flights in FY 1988. The flight rate is planned to reach *24* launches per year by 1989.

The Shuttle provides launch services to non-NASA users on a reimbursable basis as determined by the greater of each payload's length or weight. Launches occcurring in the current pricing phase (FY 1986 through FY 1988) are priced at $71.0 million (1982 dollars) for commercial launches and $55.5 million (1982 dollars) for DOD launches. Commercial launches occurring subsequent to FY 1988 are to be priced through auction procedures at a minimum of $74.0 million (FY 1982 dollars) in accordance with National Security Decision Directive 181 of July 30, 1985. DOD launches in the FY 1989 through FY 1991 period are priced at $60.0 million (FY 1982 dollars).

The ELV program is now totally funded through reimbursements from users. Privatization of these systems continues to be actively pursued.

STATUS

In orbiter production, the delivery of Atlantis (OV-104) in April 1985 and Columbia's (OV-102) completion of modification and delivery in July 1985 brings to four the number of vehicles available for flight. The emphasis on the orbiter logistics program is ongoing with analysis and procurement activity for the provisioning of orbiter spares for the initial lay-in at the launch site. The procurement of structural spares is also progressing. This program will provide major structural spares for the four orbiter fleet and includes elements such as wings, mid-fuselage, and payload bay doors. Operations spares support the flight program with repairs, procurement of consumables, and replenishment of inventory. Orbiter flight anomalies are resolved under the sustaining engineering effort and support to the launch site contractor is provided through the launch support services contract.

At KSC, activation and equipping of facilities is provided under the launch site equipment budget to support simultaneous processing of Shuttle vehicles to meet the increasing flight rate. Simultaneous processing of flight hardware is currently underway with two mobile launch platforms, two orbiter processing facilities, and parallel processing bays in the vehicle assembly building. The second launch pad, which will also support simultaneous processing and checkout of mated launch vehicles has met its operational readiness date of January 1986 in order to support the two planetary missions, Galileo and Ulysses, in May 1986. In addition, the third mobile launch platform is on schedule for a September 1986 operational readiness date and work continues on outfitting the Orbiter Maintenance and Refurbishment Facility (OMRF) to come on line late in 1986.

At JSC, the third Shuttle training aircraft (STA) has been put into service, while training capacity is being expanded by modification of the simulators and the mission control center. Contingency abort sites will be brought to full operational capability during FY 1986 and FY 1987. Initial efforts are underway on the replacement and refurbishment of JSC mission support equipment.

Development and life certification of the 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 a continuation of work begun in FY 1983, and are directed at reducing the SSME operating costs, increasing the SSME operating margins, and determining the hardware life and replacement requirements through a certification extension test program. The operating cost reduction activities are concentrated on the high pressure oxygen and hydrogen pumps. The testing of design modifications to the two pumps is well underway and has shown good progress toward improving pump life. These modified design pumps are expected to complete certification testing in March 1986, and will be phased into the flight program beginning in mid FY-1986. Redesign of the hot gas manifold is continuing with the design goal of improving flow conditions which will extend engine life by decreasing systems resistance and reducing pump loads. These manifold changes will be introduced into the fleet beginning in FY 1990. The SSME program also includes an advanced engine development effort which will provide alternate sources for SSME-class hardware, will improve the operating margins on selected critical components, and will evaluate technical advances arising from the OAST technology program.

The experience with the solid rocket boosters during early flights indicated the need for design improvements to reduce the damage incurred during booster water impact. Improvements implemented to date have proven to be successful in reducing structural damage although problems remain with water intrusion damage to the thrust vector control (TVC) servo actuators. Design modifications already underway will continue this year to eliminate this problem. Development of a sensor unit to separate the main parachutes at water impact for added diver safety during recovery operations was completed.

The SRB assembly contractor, USBI, started construction of a refurbishment and subassembly facility in FY 1985, with completion scheduled during the last quarter of FY 1986. During FY 1987, assembly operations will be transferred from the vehicle assembly building and Hanger N facilities to the new facility. Procurement of tooling to support a 24 per year flight rate capability will continue through 1987.

Performance of the external tank on all Shuttle flights to date has been excellent. Emphasis continues on sustaining the rate of cost-reduction and achieving increased production capability efforts as the flight rate increases. Manufacturing flow design and processing improvements necessary to achieve reductions in the tank operational costs have been identified and are being implemented. Efforts are also continuing in the ET as in the SRB programs to provide tooling to support a flight rate of 24 flights per year by FY 1989.

The filament wound case is continuing development and qualification testing for flight use for missions requiring increase payload lift capability. The lighter graphite-epoxy filament wound motor cases will provide an additional 4600 pounds of payload capability to the Shuttle. The first launch of the FWC is scheduled from Vandenberg in mid-1986. The development of the FWC was proceeding on schedule until the recent structural test article (STA) failure. This will require repeating the test to demonstrate adequate margin of safety at engine ignition. The test is scheduled for February 1986 and will support the first Vandenberg launch in mid-1986.

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 systems analytical integration, mission analysis, post-flight anomaly resolution, sustaining engineering and launch support services. A consolidated operations contract covering most of the flight operation functions performed at JSC has been awarded, and the contractor will begin early in 1986.

Flight hardware includes the procurement of orbiter flight spares, SRB rate gyros, 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 equipment. A consolidated operations contract covering most of the crew equipment support at JSC will begin transitioning functions during 1986. The funding requested for the ET and solid rocket motors and boosters (including production of filament wound cases) includes long lead time raw materials, subassemblies, and subsystems required to sustain production.

The launch and landing operations budget provides funding for processing of the elements of flight hardware that comprise the Shuttle launch vehicles as they flow through the ground processing stations at KSC. The Shuttle processing contractor (SPC), in conjunction with the base operations contactor (BOC), successfully processed and launched eight operational flights and their associated payloads with two orbiters, Discovery and Challenger, during FY 1985. In addition, Atlantis was delivered to KSC and processed for its first launch, which occurred on October 3, 1985 (FY 1986). Columbia, which had been undergoing structural and thermal protection system modifications at Palmdale, California, was also delivered to KSC in FY 1985 and completed its seventh mission in January 1986. Discovery is scheduled for the first launch from the Vandenberg launch site in 1986. A significant portion of the pre-launch processing will be accomplished at KSC facilities prior to being delivered to Vandenberg, where mating and final pre-launch checkout will be conducted. KSC planning includes launch of 13 flights in FY 1986 which includes back-to-back launches of two planetary missions involving the Centaur upper stage and also the processing of Discovery again for its second launch from Vandenberg.

PRODUCTION AND
OPERATIONAL
CAPABILITY

BASIS OF FY 1987 FUNDING REQUIREMENT

SHUTTLE PRODUCTION AND OPERATIONAL CAPABILITY

	1985 Actual	1386 Budget Estimate	1386 Current Estimate	1987 Budget Estimate	Page Number
	(Thousands of Dollars)				
Orbiter..............................	674,200	333,600	333,600	211,000	SF 1-4
Launch and mission support.............	218,100	163,900	169,000	161,000	SF 1-6
Propulsion systems....................	592,200	454,000	454, 000	338,400	SF 1-9
Changes and system upgrading...........	---	25,000	15,000	35.000	SF 1-12
Total..............................	1,484,500	976,500	971,600	745,400	

Distribution of Program Amounts by Installation

	1985 Actual	1386 Budget Estimate	1386 Current Estimate	1987 Budget Estimate
Johnson Space Center.................	763,800	371,400	379,100	210,500
Kennedy Space Center..................	105,200	56,700	64,000	105,500
Marshall Space Flight Center..........	581,300	449,800	416,000	318,500
National Space Technology Laboratories	6,300	7,200	7,500	7,900
Lewis Research Center.................	3,400	---	3,000	500
Goddard Space Flight Center...........	500	---	---	---
Jet Propulsion Laboratory.............	2,600	---	300	1,500
Headquarters..........................	21,400	91,400	101,700	101,000
Total..............................	1,464,500	976,500	971,600	745,400

OBJECTIVES AND STATUS

The objectives of this program are to provide for the completion of a fully capable national fleet of Shuttle orbiters; the development of the propulsion systems; preparation of launch site capabilities; and, the potential changes and upgrading of the Space Transportation System (STS).

The four-orbiter fleet includes Columbia (OV-102), the orbiter vehicle developed and flown on the four test and evaluation flights; Challenger (OV-099), the second flight orbiter, which was fabricated using elements of the structural test article; and, two orbiters - Discovery (OV-103) and Atlantis (OV-104) of a lighter-weight configuration. Modifications to orbiters and the related systems integration analyses for the use of the Centaur and its payloads will be completed during 1986. The budget provides necessary improvements, hardware fixes and mission kits for the orbiter fleet to satisfy flight requirements. The provisioning of orbiter spares is an on-going activity to support the requirements for the initial lay-in of line replaceable units of equipment at the launch site. In addition, the budget provides for the extensive acquisition of orbiter structural spares to support the four-orbiter fleet.

Launch and Mission Support provides for capability to support simultaneous processing of launch vehicles at the Kennedy Space Center (KSC); the additional astronaut training, mission preparation and mission operation capabilities required for higher flight rates; the modifications to the launch site facilities to accommodate the new Centaur upper stage; and, studies and analyses of program level improvements for the operations and management of the STS. The first line of KSC facilities supported the launch processing and checkout of one launch vehicle at a time from landing through launch. The additional processing stations allow for simultaneous processing of orbiters and assorted flight hardware to meet the East Coast launch rate of up to 20 flights per year. A Gulfstream II aircraft has been modified into a third Shuttle training aircraft (STA) to support increased training requirements and to permit the existing two aircraft to be overhauled when structural fatigue considerations make this necessary. The upgrading of the mission control center (MCC), the Shuttle Mission Simulator (SMS) complex, the flight planning and preparation facilities and other data handling systems are necessary to provide a full rate capability for flight operations. Support for the Vandenberg launch site, including provisioning of abort landing facilities, is proceeding.

Propulsion Systems provide for the production of the Space Shuttle main engine (SSME) and the development 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 development, and an anomaly resolution capability. The SRB production and capability development activities include: the procurement of tooling and equipment to support a flight rate of

24 flights per year; a minimal level of selected studies to continue investigative, analytical and problem-solving activities; and, the development and initial flight hardware for the filament wound case. In the ET program, the objectives are to improve the manufacturing process and provide manufacturing tooling and equipment to support the 24 per year flight rate. Systems engineering support and SSME testing in the main propulsion test article configuration are both provided in systems support.

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 1987 FUNDING REQUIREMENT

ORBITER

	1985 Actual	1986 Budget Estimate	1986 Current Estimate	1987 Budget Estimate
	(Thousands of Dollars)			
Orbiter production....................	318,500	117,000	150,800	82,400
Systems integration....................	50,Z00	---	---	---
Orbiter spares........................	305,500	216,600	182,800	128,600
Total...............................	674,Z00	333,600	333,600	211,000

OBJECTIVES AND STATUS

With the delivery of OV-104 (Atlantis) in April 1985 and OV-102 (Columbia) in its operational configuration in July 1985, the number of orbiters available for flight has been increased to four. Orbiter production activities include development and installation of hardware improvements necessary to achieve operational capabilities, reduce operational costs, and meet system requirements including improved on board general purpose computers (GPC), inertial measurement units (IMU) and auxiliary propulsion units (APU). Hardware fixes are being made to the brakes and nose wheel steering to improve landing performance. In addition, necessary mission and modification kits requested for specific flights and payloads are included. Other activities cover flight software development to accommodate hardware changes and mission requirements. The structural spares program initiated in FY 1983 maintains a continued production capability and improves the ability to repair structural elements in the event of damage to one of the four orbiters. Fabrication of these major elements is underway and will continue throughout the year. Structural assemblies include the wings, aft thrust structure, engine compartment, crew module (including the nose and cockpit), mid and aft fuselage sections, payload bay doors, vertical tail, and the orbital maneuvering system pods.

The procurement and fabrication of the orbiter spares inventory to support 24 flights per year is ongoing. A concerted effort has been made to better define the spares requirements and production capability at various vendors. A study is underway to determine logistics depot and maintenance 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 1986 BUDGET ESTIMATE

Funding for orbiter production and support activities increased $33.8 million. Additional funding was required for operational improvements including brake fixes, nose wheel steering improvements, improved general purpose computer, auxiliary propulsion unit design fixes, and improvement to the orbiter waste collection systems. Additional increases were the result of software upgrades and the deferral of remote manipulator system work from FY 1985 to FY 1986. Funding for spares decreased $33.8 million, including a $35.0 million reduction in structural spares as the result of a cancellation of the augmentation and restructuring of the basic program implemented during 1985.

BASIS OF FY 1987 ESTIHATE

FY 1987 funding provides for completion of major structural components as spares for the orbiter fleet. These structural components include elements such as wings, vertical stabilizer, crew module, payload bay doors, and aft thrust structure. These items are being assembled into varying stages of completion. Ground support equipment and test hardware are also being provided to support KSC systems. Development efforts will continue on the orbiter system improvements begun in FY 1985 and FY 1986. FY 1987 funding will also be utilized for the continuation and improvement of flight software, the acquisition of navigational aids for the trans-Atlantic abort sites, refurbishment of the remote manipulator system qualification hardware and the development of the upgraded general purpose computer, and the improved inertial measurement unit.

Logistics support to the Shuttle program requires the lay-in of orbiter initial spares and rate spares to meet the buildup to a 24 per year flight rate and for support to ground processing operations as the fleet size and flight rate increase. The funding for orbiter spares covers not only the cost of establishing an inventory of orbiter flight spares and ground support equipment spares, but also the logistics support to analyze requirements and procure these spares. In addition, maintenance test equipment will be designed and procured to support establishment of depot maintenance capabilities.

BASIS OF FY 1987 FUNDING REQUIREMENT

LAUNCH AND MISSION SUPPORT

	1905 Actual	1986 Budget Estimate	1986 Current Estimate	1986 Budget Estimate
	(Thousands of Dollars)			
Launch site equipment..................	104,300	56,700	59,700	44,500
Mission support capability.............	64,700	64,300	72,800	72,600
Mission operations capability..........	49,100	42,900	36,500	43,900
Total............................	218,100	163,900	169,000	161,000

OBJECTIVES AND STATUS

The first line of facilities at KSC activated during DDT&E supports the launch processing and checkout of an orbiter from landing through launch. A second line of processing stations is being phased in to support parallel launch processing of more than one orbiter through the various work areas. The second high bay of the Orbiter Processing Facility (OPF) and the second mobile launch Platform (MLP) were activated in late FY 1982 to support parallel processing of two orbiters. The second set of high bays in the vehicle assembly building, the software production facility, and the second control room were activated in FY 1983 to enable parallel processing through orbiter - ET mate. An SRB processing and storage facility was activated in FY 1984 to facilitate SRB handling including off-loading of segments from rail cars, segment rotation capability, storage capability for two flight sets (16 segments) and the assembly of SRB aft segments. As a result of the second launch pad's recent activation, parallel processing is possible from the start of OPF flow through launch. A third MLP will be activated in late FY 1986 to help meet the flight rate scheduled in 1987 and beyond. Facility modifications supporting the FY 1986 Centaur launches are nearing completion.

Also under Launch and Mission Support are the necessary investments at JSC to support 24 flights per year. Among these capabilities are the ability to rapidly configure the ground data handling system, encompassing mission planning, simulations, and flight design. This is accomplished through the acquisition of an electronic data network, additional hardware, and refined and expanded software.

Other investments necessary to meet STS program objectives include uprating the Shuttle carrier aircraft (SCA) engines to increase load/ferry range capability and improve the long term supportability. The uprated engines should eliminate the need for an in-flight refueling capability from contingency landing sites. It also includes the hardware deliveries for the extravehicular mobility units (spacesuits), other government furnished crew-related equipment, the upgrade/capability expansion of the mission control center, the service life extension to refurbish all T-38 aircraft, and the ongoing program to replace and refurbish aging and obsolete equipment. The latter incorporates technology advances to solve maintenance and operating problems stemming from outdated hardware and software subsystems that manufacturers can no longer support with spares and viable operating systems. At the same time, the use of this advanced technology will permit more rapid reconfiguration from flight to flight, with considerable improvement in responsiveness to manifest and requirements changes.

CHANGES FROM FY 1986 BUDGET ESTIMATE

The Launch and Mission Support total has increased by $5.1 million since the FY 1986 budget. The launch site equipment increase of $3.0 million is due, in part, to increased costs to complete Pad B and MLP-3 and the addition of a flight readiness firing to support the first launch from Vandenberg in 1986. Also, a safing and deservicing capability has been added to the Orbiter Maintenance and Refurbishment Facility (OMRF) in order to allow orbiter vehicles to proceed directly from landing to the OMRF for modifications and repair as well as the initial post flight checkout. Mission operations capability decreased by $6.4 million primarily due to the slower start up of the JSC equipment replacement and upgrading program. Mission support capability increased $8.5 million due to increased post flight analysis.

BASIS OF FY 1987 ESTIMATE

In FY 1987, the launch site equipment activity includes continued upgrade of the operational intercommunications system connecting all major Shuttle facilities at KSC. The current system, installed for the Apollo program, falls short in reliability and capability to support the planned flight rate and is becoming increasingly difficult to maintain. The new system will use state-of-the-art, digital equipment and will interconnect the facilities with a network of fiber optic cabling. Also, during FY 1987, major components of the launch processing systems will undergo initial stages of replacement. The central data subsystem and the checkout, control and monitoring subsystem currently require high levels of maintenance, computer memory is nearing limits, and some major components of these subsystems are no longer commercially available at reasonable costs. In addition, the OMRF will be completed which will provide the capability for orbiters to undergo initial post-flight checkout immediately after landing without having to interrupt the pre-launch processing underway in the Orbiter Processing Facility. The OMRF is also planned as a dedicated area where orbiter modifications and needed repairs can be conducted outside the normal launch-to-launch processing flow since the Palmdale facility will no longer be equipped for this purpose. Equipment from the orbiter assembly facility at Palmdale compatible with this new facility will be moved to KSC for use in the OMRF. Other efforts contained in the launch site equipment budget include addition of structural modifications to both launch pads to protect the orbiters from rain damage while they are awaiting launch, continued support to contingency landing sites, and completion of the Shuttle inventory management system upgrade (SIMS II).

Mission support capability requirements continue establishing an inventory of crew equipment (principally extravehicular mobility units) to support the 24 per year flight rate capability and post-orbital flight (OFT) testing. STS operations effectiveness work and other support functions continue to support the STS achievement of program-wide requirements including the 24 per year flight rate capability.

Mission operations capability funding in FY 1987 provides for completion of modifications to the fixed and motion base simulators at JSC, initiation of the project to re-engine the SCA, and continuation of the service life extension program of the T-38 training aircraft. FY 1987 funding also provides for replacement of obsolete and inefficient equipment in the mission control center and the Shuttle mission simulator.

BASIS OF FY 1987 FUNDING REQUIREMENT

PROPULSION SYSTEMS

	1985 Actual	1986 Budget Estimate	1986 Current Estimate	1987 Budget Estimate
		(Thousands of Dollars)		
Main engine	419,000	357,500	336,200	293,200
Solid rocket booster	105,100	43,000	51,700	17,600
External tank	60,500	53,300	63,800	27,600
Systems support	7,600	100	2,300	---
Total	592,200	454,000	454,000	338,400

OBJECTIVES AND STATUS

Propulsion Systems provides for the production of the Space Shuttle main engines (SSME) and the implementation of the capability to support operational requirements established for the SSME, solid rocket booster (SRB), and external tank (ET). The SSME program includes the production of the main engines required for the orbiter fleet, the procurement of spares, ground testing operations development and certification activities to improve operating margins, reliability and durability, and anomaly resolution capability. The SRB program includes the development and qualification of the filament wound case (FWC) solid rocket motors, redesign of the hardware for reusability and operational cost reductions, and procurement of manufacturing tooling and equipment to support fabrication and transportation at the 24 per year flight rate. In the ET program, the objective is establishing the manufacturing capability, primarily tooling equipment and process improvements, to support the 24 per year flight rate. Systems support primarily provides for the testing of the SSME in the main propulsion test article configuration in addition to providing systems integration engineering support.

The main engines continued their record of excellent flight performance during the eight 1985 flights of the Shuttle. Engine performance was nominal during all flights except for a premature engine shutdown on STS-51F resulting from instrumentation failure. The total SSME ground test experience now exceeds 1,264 tests, totaling approximately 258,000 seconds of test time. This experience includes 240 tests, exceeding 51,000 seconds of operation, at the full power level (FPL).

During the course of FPL testing over the past several years, it became apparent that design margins were inadequate for routine FPL flight operation and that the current SSME configuration required an unacceptable amount of maintenance at that power level. Consequently, the SSME program was restructured into three areas: (1) flight support, (2) product improvement and (3) advanced development.

The flight support element, involving both production and operations, is charged with producing all engine hardware, conducting the acceptance and flight anomaly resolution tests which are directly related to the flight program, providing all logistics support (including engine/component overhauls), and conducting the flight readiness assessments.

The product improvement element continues the work begun in FY 1983 to reduce the SSME operating costs and increase the SSME operating margins. Work to reduce the operating costs is concentrated in design modifications to the high pressure oxygen and hydrogen pumps. The testing of the modifications to the two pumps is well underway and has shown good progress toward achisving better pump life. Modified design pumps are expected to complete certification testing in March 1986 and will be phased into the fleet beginning in mid FY 1986. A redesign of the hot gas manifold is underway to provide better flow conditions, and hence lower resistance and lower pump loads. These manifold changes will be available for test in FY 1986 and for subsequent introduction into the fleet beginning in FY 1990 during routine engine overhauls.

The objective of the advanced development element is to assure a viable technology program for the development of SSME class rocket engines, (i.e., high thrust, high performance, cryogenic fuels) and components; to provide an independent means to evaluate the technical advances arising from the supporting research and technology program by means of a technology testbed; and to provide an alternative source for SSME hardware. Contractor selection for the alternative SSME hardware is scheduled to be completed during FY 1986.

The SRM FWC second development motor (DM-7) static test firing was successfully tested in April 1985, and the qualification motor has been processed and is being prepared for static test in mid FY 1986. The structural test article (STA-2A) successfully passed all but the final load test cycles. The test article failed at 118.5% of engine ignition limit loads. Replacement test articles are being prepared for repeating this load cycle in February 1986. The first flight articles delivery to Vandenberg was completed by July 1, 1985 in support of the mid 1986 launch and the Air Force need date.

Transition to the production mode in the ET program is well underway. Production readiness activities continue to smooth this transition and favorably improve production capability. Rearrangement of existing tools and new tools to eliminate manufacturing "choke points" and smooth the production flow for the buildup to 24 tanks per year has been emphasized and is nearing completion.

In systems support, preparations are underway for the test of three clustered engines at full power level in the main propulsion test stand at NSTL in early 1986. This test will provide for a verification of the main propulsion system operations at full power level using the main propulsion system test hardware mounted in the aft end of the simulated orbiter.

CHANGES FROM FY 1986 BUDGET ESTIMATE

The decrease in funding requirements within Propulsion Systems for the main engine project of $21.4 million includes a rephasing of the two elements of the SSME advanced development effort. The start of the competitive program for alternative SSME hardware has been delayed to allow for the contractor selection process which is scheduled for completion in FY 1986. To maintain program balance, the technology test bed has also been rephased. In addition, the decrease in capability development reflects the restructuring of the main engine contract consistent with actual use of spares and flight support. This resulted in the transfer of some flight support and flight hardware to operations. The life improvement program increased in FY 1986 due to increased test requirements.

These decreases were partially offset by the increase of $8.7 million for the SRM project due to development problems experienced on the FWC program and additional residual development tasks on the SRB. ET funding requirements increased $10.5 million as a result of the rephasing from prior years of the rate tooling requirements in accordance with the slower flight rate buildup. The increase in systems support of $2.2 million is attributed to the extension to FY 1936 of the main propulsion test for full power level testing. Following completion of these tests, the main propulsion test stand will be converted to a single engine capability to support the SSME development/production program.

BASIS OF FY 1987 ESTIMATE

In FY 1987, funding for the SSME provides for those activities necessary to support the engine production, flight schedules, and ground testing. Product improvement testing will continue as will certification of new SSME component design modifications. Other on-going activities also provided for within the SSME budget estimates include development and production of the Block II controller, anomaly resolution testing, updating of the SSME hardware to the improved component configuration, and advanced development effort.

In the SRB, efforts will continue on the improvements to the thrust vector control system to prevent salt water intrusion and to provide rate tooling to support the 24 per year flight rate in FY 1989. The construction of the new assembly and refurbishment facility will be completed, and efforts will start on the installation of equipment. Producibility improvements will also continue in order to reduce the turnaround time required for assembly and refurbishment of boosters.

In the ET program, enhancement of manufacturing processes will continue through production readiness efforts. The major thrust for FY 1987 will be continuing procurement and installation of tools and equipment to support the build-up to a production rate of 24 per year.

BASIS OF FY 1987 FINDING REQUIREMENT

CHANGES AND SYSTEMS UPGRADING

	1985 Actual	1986 Budget Estimate	1986 Current Estimate	1987 Budget Estimate
		(Thousands of Dollars)		
Changes and systems upgrading	---	25,000	15,000	35,000

OBJECTIVES AND STATUS

Management, technical flight experience, and cost reviews of the Shuttle program have stressed the need for providing an adequate 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 systems modifications and unanticipated developments which are not included in the program element budget estimates. Such funds are necessary to provide for programmatic and technical changes, such as modifications to the orbiters to improve flight performance and system reliability, changes and upgrading of ground systems 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 1986 funds will be allocated to the appropriate budget activity.

CHANGES FROM FY 1986 BUDGET ESTIMATE

The FY 1986 operating plan has allocated $10 million of Changes and Systems Upgrading. Within this total, $5 million was allocated to support increased requirements in Launch and Mission Support and $5 million was deleted as an application of the HUD-Independent Agencies Appropriation Act, 1986. General reduction for Space Flight, Control and Data Communications is consistent with direction in the FY 1986 Authorization Act.

BASIS OF FY 1987 ESTIMATE

The funding requested for FY 1987 will provide for those changes which are considered to have the highest priority. The objectives are to improve reliability, increase operating efficiency, and reduce costs. Changes and upgrading areas of interest include modifications to flight and ground systems; design and development of hardware/software systems which meet 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. Change requirements are expected to increase in FY 1987 as operational experience is gained with the doubling of the FY 1985 flight rate to 17 in FY 1987, with the initial experience of utilizing capabilities such as the Centaur upper stage, with initial operations at the Vandenberg launch site, and as the demands of supporting four orbiters in parallel processing are realized.

OPERATIONS

BASIS OF FY 1987 FUNDING REQUIREMENT

SPACE TRANSPORTATION OPERATIONS

	1985 Actual	1986 Budget Estimate	1986 Current Estimate	1987 Budget Estimate	Page Number
		(Thousands of Dollars)			
Flight operations....................	315,600	425,200	435,000	360,600	SF 2-3
Flight hardware....................	[redacted]	964,000	957,600	879,100	SF 2-7
Launch and landing operations........	275 500	335,900	332,400	285,000	SF 2-9
Total..............................	1,314,000	1,725,100	1,725,000	1,524,700	

Distribution of Program Amounts by Installation

	1985 Actual	1986 Budget Estimate	1986 Current Estimate	1987 Budget Estimate
Johnson Space Center..................	395,700	538,700	539,800	350,000
Kennedy Space Center..................	277,900	313,800	343,200	380,300
Marshall Space Flight Center........	624,500	796,100	813,000	739,900
National Space Technology Laboratories	---	---	800	700
Goddard Space Flight Center...........	1,200	1,100	1,400	1,200
Langley Research Center...............	100	100	100	100
Ames Research Center..................	3,800	3,100	4,900	2,800
Headquarters..........................	10,800	67,200	21,800	49,700
Total..............................	1,314,000	1,725,100	1,725,000	1,524,700

OBJECTIVES AND STATUS

Shuttle Operations direct appropriated funding is combined with the reimbursements for standard service received from other U.S. Government, commercial, and international users to support the launch and flight operations requirements of the Space Shuttle. Through 1985, 19 operational Shuttle missions were successfully flown. These missions demonstrated many of the Shuttle's capabilities including deployments of spacecraft and their upper stages, satellite repairs, satellite retrieval and operations using the remote manipulator, a dedicated Spacelab, extravehicular activity operations, a night landing, and a widening of the Shuttle's performance envelope. In FY 1386, 14 missions are scheduled to be flown, 17 are scheduled for FY 1987, and 18 flights are planned for FY 1988.

The Flight Operations activity is divided into three major elements: mission support, integration, and support. Mission support includes a wide variety of planning activities ranging from operational concepts and techniques to detailed systems operational procedures and checklists. Integration includes launch support services and sustaining engineering for orbiter systems, cargo analytical integration, and systems integration. The support element includes base operational support at JSC and systems 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 disconnect and SHB rate gyros, 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 manner consistent with the increasing flight rate.

Launch and Landing Operations provides for the pre-launch preparation, launch, and landing operations of the Shuttle and its cargo.

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 reimbursable basis. There are no direct appropriated fund requirements for the Expendable Launch Vehicles program. The privatization of these systems continues to be actively pursued.

BASIS OF FY 1987 FUNDING REQUIREMENT

FLIGHT OPERATIONS

	1985 Actual	1986 Budget Estimate	1986 Current Estimate	1987 Budget Estimate
		(Thousands of Dollars)		
Mission support........................	155,5013	182,900	197,600	117,003
Integration............................	86,900	126,300	125,300	115,600
Support................................	73,200	116,000	112,100	128,000
Total............,..................	315,600	425,200	435,000	360,600

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 from 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. The software activities include the development, formulation, and verification support of the guidance, targeting, and navigation systems software requirements in the orbiter and MCC. 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 vehicle, payload and system integration and launch support services. Support includes base operations support to Shuttle operations at JSC and systems level support at JSC, Headquarters, and Goddard. The Space Transportation System operations contract (STSOC), a consolidation of work currently being performed by 16 firms under 22 separate contracts, has been awarded. This contract is an incentive fee contract similar to the SPC at KSC as it is mission oriented with fee determination based on cost management as well as performance. The STSOC contractor will be responsible for major functions of such facilities as the MCC, Shuttle Misssion Simulator (SMS), Shuttle Avionics Integration Laboratory (SAIL), Software Production Facility (SPF), and the Mockup and Integration Laboratory (MAIL).

CHANGES FROM FY 1986 BUDGET ESTIMATE

The Flight Operations direct budget requirement increase of $9.8 million reflects the impact of a three equivalent flight reduction for commercial customers in the FY 1985 through FY 1988 timeframe. As a result, the allocation of reimbursements for Flight Operations was reduced $21.9 million. This increase was partially offset by a $12.1 million reduction in total funding requirements including sustaining engineering and the application of program reserve.

BASIS OF FY 1987 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. Included in this activity is the pre-flight planning and mission design necessary to conduct and control a successful mission; maintenance and operation of onboard avionics software and mission control systems; maintenance and operation of the training and flight proficiency aircraft and facilities for crew training; integration of the orbiter, payload, and STS; sustaining engineering for the orbiter and flight operations systems; post flight data analysis and anomaly resolution; and systems-wide management activities required for mature STS operations. During FY 1987, 17 flights will be supported. As a result of the pre-flight planning and integration cycle, FY 1987 activities will include the planning and training for the 18 flights in FY 1988 and the initial phases of the flight design process for the 24 flights in FY 1989.

With implementation of the consolidated STS operations contract (STSOC), there has been a realignment of work among three Flight Operations categories--mission support, integration, and support as described below:

Mission support encompasses all of the STSOC effort funded in Flight Operations, performing the functions directly related to flight preparation and execution. Major items no longer included are spacecraft software (except flight-to-flight reconfiguration), aircraft operations, and the non-STSOC portion of engineering support, notably engineering analyses, materials and subsystem testing, and payload/orbiter operations safety reliability and quality assurance.

The tasks performed by the STSOC contractor include project management, maintenance and operations, sustaining engineering, flight preparation requirements and analysis, flight preparation production, and direct mission operations and training support.

Project management includes the overall management functions of project, resource, configuration, information, and logistics management; plus contract administration, procurement, personnel, security, safety, reliability, and quality assurance.

Maintenance and operations includes contractor maintenance and operations services for the STS major facilities and assets; i.e., mission control center, Software Production Facility, flight operations trainers and crew simulators, Shuttle Avionics Integration Laboratory, and the flight and training planning facilities.

Sustaining engineering includes anomaly investigation, requirements analysis, planning, and feasibility studies, leading to design, development, integration, and testing of improved hardware and software systems. The objectives are to correct system deficiencies, decrease operating/security costs, implement new NASA requirements, and maintain reconfiguration production tools consistent with the flight software for the same systems and facilities for which the contractor has maintenance and operations responsibilies.

Flight preparation requirements and analysis includes engineering and analysis support for the preparation of each STS flight, including flight profile design and analysis; navigation flight preparations; crew activity planning training preparation; systems support analysis; and STS program, payload vehicle and scheduling support,

Flight preparation production includes generating the products required of STS flights as well as postflight products. The work stations included in this process are flight design, flight data file, MCC, Software Production Facility, Trend Monitoring System, Shuttle Mission Simulator, Mockup and Integration Laboratory, and Shuttle Avionics Integration Laboratory. Postflight reconstruction, including the Shuttle Telemetry Conversion Facility and distribution of postflight products, is generated to serve engineering and management needs.

Direct mission operations and training support includes the support to and conduct of all mission training, the flight in real time, and the selected testing related to mission control and supporting operations, SAIL operations support, navigation system quality assessment, and Manipulator Development Facility and 1-G trainer and mockup operations.

Integration now includes spacecraft creation in addition to retaining payload analytical integration, systems integration, orbiter sustaining design engineering, and launch support services, which provides development contractor expertise on-site at the launch site for pre-launch processing. Payload and systems integration assures compatability, safety, and integrity aaong all flight elements, including the verification of interfaces. Orbiter sustaining design engineering ensures vehicle maintainability, reliability, and provides for anomaly resolution during operations, as well as identification of operational requirements and their design solutions for improved flight systems.

Support continues to include: base operations activities related to Shuttle Operations; the "Getaway Special" payload canister project managed by the Goddard Space Flight Center; Headquarters programs assessments for agency-wide activities; and efforts of the STS Program Office associated achieving program objectives such as the planned flight rate, schedule reliability, and management efficiencies. The major additions to this category are aircraft operations and the non-STSOC portion of engineering support such as engineering systems support furnished by Draper Labs, crew and bio-systems laboratories, and the White Sands Test Facility.

BASIS OF FY 1987 FUNDING REQUIREMENT

FLIGHT HARDWARE

	1985 Actual	1986 Budget Estimate	1986 Current Estimate	1987 Budget Estimate
		(Thousands of Dollars)		
Orbiter..............................	157,300	238,400	257,600	232,700
Solid rocket booster..................	298,600	401,500	392,700	357,900
External tank.........................	267,000	324,100	307,300	288,500
Total..............................	722,900	964,000	957,600	879,100

OBJECTIVES AND STATUS

The Flight Hardware program element provides for the procurement of external tank (ET) and solid rocket booster (SRB) hardware, and propellants; spare components for the main engine (SSME); orbiter spares including ET disconnects and SRB rate gyros; sustaining engineering and logistics support for ET/SRB/main engine flight hardware elements; and maintenance and operation 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 these elements in a manner consistent with the increasing flight rate. Production phasing of these elements is based on the current flight traffic model and is structured to maintain a smooth and efficient buildup of the production capability. In the ET, an efficient and non-disruptive production process continues to be implemented which enables manufacturing, assembly, and checkout operations to proceed on a basis that provides for timely delivery of flight hardware to the launch site. The orbiter line element includes: orbiter spares for replenishment of line and shop replaceable units, the manpower for supporting this logistics operation and the repair capability for flight hardware; SSME overhauls, flight support, and procurement of replacement spare parts; provision for the fixed level of annual support for the liquid hydrogen plant; and, replaceable spares, field support, and maintenance of crew-related equipment. Some 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 maneuvering 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 have been consolidated contractually into the Flight Equipment Processing Contract (FEPC). Boeing has been selected as the FEPC contractor and will consolidate the functions previously performed by 16 contractors. Transition *to* the FEPC will begin during FY 1966.

CHANGES FROM FY 1986 BUDGET ESTIMATE

Direct funding requirements for Flight Hardware show a net decrease of $6.4 million. This includes a $58.6 million decrease in total requirements offset by a $52.2 million increase resulting from reduced commerical reimbursements. The change in total requirements includes decreases in the SRB and ET projects reflecting savings being achieved under current incentive contracts and rephased hardware deliveries for the three flight reduction through FY 1988. The orbiter funding is increased to reflect the restructuring of the main engine contract. This resulted in a transfer from the Shuttle Production and Operational Capability propulsion budget to be consistent with the actual use of spares and flight support.

BASIS OF FY 1967 ESTIMATE

Requirements for orbiter flight spares, crew equipment spares, and logistics are based on calculations involving flight rates, maintenance schedules, operational hours, turnaround times, and lead times to procure or repair flight harware. The budget provides replenishment line and shop replaceable units, as well as the manpower to support the overhaul and repair activity to support the projected and flight rate. Main engine hardware provides for manufacturing and delivery of overhauled engines, engine component spares and flight support. Flight hardware requirements activity for the SRB and ET include the procurement of the materials and labor required for refurbishment and fabrication of units which will be flown after FY 1987, as well as the support of the production of units which will be flown in that year.

BASIS OF FY 1987 FUNDING REQUIREMENT

LAUNCH AND LANDING OPERATIONS

	1985 Actual	1986 Budget Estimate	1986 Current Estimate	1987 Budget Estimate
		(Thousands of Dollars)		
Launch operations	247,300	294,200	292,800	245,800
Payload and launch support	28,200	41,700	39,600	39,200
Total	275,500	335,900	332,400	285,000

OBJECTIVES AND STATUS

Launch and Landing Operations provides for the launch preparations and the launch and landing operations of the Shuttle and its cargo. The orbiter, ET, SRB, SSME, and payloads are checked out, integrated, and launched from KSC at Cape Canaveral, Florida. The SRB's are retrieved from the Atlantic Ocean after separation from the Shuttle. Shuttle landing support is furnished at KSC and contingency landing sites as required. The major facilities used for launch and landing operations include: the launch control center, Orbiter Processing Facility, vehicle assembly building, mobile launch platforms, SRB processing and storage facility, payload processing facilities, launch pads, and the Shuttle landing facility.

Funding for Launch and Landing Operations provides the propellants (excluding SRB propellants), manpower and support services required to accomplish the integration and processing of the Shuttle and its payloads. Under launch operations, manpower is provided to process, integrate, and check out the orbiter, ET, solid rocket motors and boosters, and the SSME into the proper launch configuration preparatory to each flight. Support manpower is also included to conduct the SRB retrieval operations, engineering support, logistics, central data system support, facility and equipment modifications, spares procurement and the maintenance and operation of the ground systems, structures and equipment. Funding for payload and launch support provides for the processing and integration of the payloads, propellants for launch operations and base support, and Shuttle landing operations at the Dryden Flight Research Facility.

Contractual arrangements at KSC which consolidate responsiblity and incentives based on performance have provided the framework for achieving a truly operational STS with improved productivity and increased reliability. The KSC base operations contractor has successfully completed its second full year of providing support to Shuttle programs as well as institutional organizations at KSC. The Shuttle processing contract (SPC) is an incentive fee, mission-oriented contract for processing the STS both at KSC and at the Vandenberg launch site (VLS) in California. (The VLS activities are funded by the DOD.) The SPC has completed its second year of operations at KSC and has successfully processed and launched 10 missions, 8 of which were launched in FY 1985. In addition, the SPC initiated processing of the orbiter Discovery in late FY 1985 for its first launch from the VLS in 1986.

CHANGES FROM FY 1986 BUDGET ESTIMATE

The Launch and Landing Operations direct budget requirement decrease of $3.5 million reflects an $18.4 million increase as the result of reduced reimbursement offset by a $21.9 million reduction in total funding requirements. The reduction to total funding includes reduced propellants replenishment from the reduced FY 1985 flights and operational effeciencies.

BASIS OF FY 1987 ESTIMATE

Launch operations funding in FY 1987 provides for manpower and support services necessary for processing the 15 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 maintenance, 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 1987 ESTIMATES

BUDGET SUMMARY

OFFICE Of SPACE TRACKING AND DATA SYSTEMS SPACE AND GROUND NETWORKS, COMMUNICATIONS AND DATA SYSTEMS

SUMMARY OF RESOURCES

	1985 Actual	1986 Budget Estimate	1986 Current Estimate	1987 Budget Estimate	Page Number
		(Thousands of Dollars)			
Space network........................	378,300	400,800	286,300	374,300	SF 3-4
Ground networks......................	233,200	219,300	223,000	222,000	SF 3-9
Communications and data systems..... ..	184,200	188,200	192,000	202,600	SF 3-18
TOTAL...........................	795,700	808,300	701,300	798,900	

Distribution of Program Amounts by Installation

	1985 Actual	1986 Budget Estimate	1986 Current Estimate	1987 Budget Estimate
Marshall Space Flight Center..........	17,687	27,900	29,200	29,300
Goddard Space Flight Center...........	429,446	365,000	365,200	377,200
Jet Propulsion Laboratory.............	108,402	124,800	122,200	128,200
Ames Research Center..................	8,545	11,000	10,900	12,000
Headquarters.....	231,470	279,600	173,800	252,200
Johnson Space Center..................	150	---	---	---
TOTAL.............................	795,700	808,300	701,300	798,900

SPACE FLIGHT, CONTROL AND DATA COMMUNICATIONS

FISCAL YEAR 1987 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, Spacelab flight missions, and Hubble Space Telescope. 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 from on-board experiments and sensors; (c) acquisition of engineering aata on the performance of spacecraft and launch vehicle systems; (d) reception of television transmissions from space vehicles; *(e)* transmission of commands from ground stations to the spacecraft; (f) communication with astronauts; (g) transfer of information between the various ground facilities and control centers; and (h) processing of data acquired from the launch vehicles and spacecraft. Such support is essential for achieving the scientific objectives of all flight missions, for executing the critical decisions which must be made to assure the success of these flight missions, and in the case of Shuttle missions, to ensure safety of the crew.

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 communications satellite circuits which are leased from communications carriers, both domestic and foreign. This interconnection provides the communications capability needed between spacecraft and the control centers from which the flights are directed.

To meet the support requirements levied by the wide variety and large number of flight projects, NASA has established 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 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 six ground stations. This is presently planned for mid-1986 and is based upon the successful launch and checkout of the second TDRSS spacecraft in January, 1986. Two STDN stations (Merritt Island and Bermuda) will be retained to provide prelaunch, launch and Shuttle landing support.

The DSN, under the management of the Set Propulsion Laboratory (JPL), provides a single network to support geosynchronous, highly elliptical, and planetary and solar system exploration missions, as well as supporting those spacecraft, now in low-Earth orbit, which are not compatible with TDRSS.

Computation facilities are maintained to provide real-time information for mission control and to 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 Network, and Data Processing and Communications elements of the program, and provides funds for: (a) the cost of TORSS 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.

CHANGES FROM FY 1986 BUDGET ESTIMATES

The current estimate for FY 1986 is $701,300 which is $107 million below the budget estimate and represents a reduction in the payment to the Federal Financing Bank (FFB) for the TDRSS consistent with Congressional direction. Within the $701.3 million level, adjustments have been made to provide for the operation of the STDN stations into mid 1986. These and other adjustments are addressed in subsequent sections of the program justification.

BASIS OF FY 1987 FUNDING REQUIREMENTS

SPACE NETWORK

	1985 Actual	1986 Budget Estimate	1986 Current Estimate	1987 Budget Estimate
		(Thousands of Dollars)		
Tracking and data relay satellite system (TDRSS)	316,600	335,600	218,100	301,500
Space network operations	36,151	37,100	40,500	43,700
Systems engineering and support	25,549	28,100	27,700	29,100
TOTAL	378,300	400,800	286,300	374,300

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 communication services to low Earth orbital spacecraft. The TDRSS itself will consist of a three-satellite system, including an on-orbit spare, all in geosynchronous orbit and a single ground terminal located at White Sands, New Mexico. The satellites communicate with the user spacecraft in space and relay information to and from the ground terminal. From the ground terminal, satellite and ground communication links interconnect the NASA' elements of the network and any remotely located user facilities.

The FY 1987 request includes funding for: repayment of the loans extended by the Federal Financing Bank (FFB) for TDRSS development; payments to the TDRSS contractor for TORSS services and for maintenance and operation of the White Sands complex; manpower and services necessary to operate and maintain the other NASA elements of the network; and systems engineering, equipment replacement, engineering analyses and other support activities such as mission planning and documentation.

Funding is also included to continue studies and analyses for assuring the availability of TDRSS support beyond the current TDRSS contract period which ends in 1993. By that time, given the projected TDRS spacecraft lifetimes, the existing TDRS replacement spacecraft will have been launched. In addition, limitations on the present system associated with the ground station at White Sands, New Mexico dictate that a backup capability is urgently needed for that portion of the system. Three additional spacecraft and a second ground terminal will be required to provide TDRSS services through the *1990's.*

	1985 Actual	1986 Budget Estimate	1986 Current Estimate	1987 Budget Estimate
		(Thousands of Dollars)		
Tracking and data relay satellite system	316,611	335,600	218,100	301,500

OBJECTIVES AND STATUS

The Tracking and Data Relay Satellite System (TDRSS) objective is to provide communication services between the user spacecraft and ground facilities. The Tracking and Data Relay Satellites (TORS) provide space-to-space communications to and from the user satellites and relay these communications to the ground via a single ground terminal which is interconnected with the other elements of the Space Network. From their position in geosynchronous orbit, the TDRS can provide nearly a six-fold increase in the orbital coverage provided by the existing complex of ground stations and can accommodate extremely high user data rates ranging up to 300 megabits per second.

The TDRS-1 was launched in April 1983, but due to an upper stage failure was delivered to an incorrect orbit. Subsequently, through a sequence of complex maneuvers, the spacecraft was placed into its nominal orbit. Since that time, it has supported Shuttle missions, including Spacelabs, and free flyer missions including Solar Maximum Mission (SMM), Earth Radiation Budget Satellite (ERBS), Landsat, and Solar Mesopheric Explorer (SME). Problems with the spacecraft timing circuitry led to cancellation of the second TDRS launch that was scheduled for early 1985. Modifications have been made to all remaining spacecraft to correct the problem, and the launches of the second and third spacecraft are currently scheduled for January and July 1986, respectively. TDRS-1 will become the on-orbit spare when the two newly launched spacecraft achieve operational status.

CHANGES FROM FY 1986 BUDGET ESTIMATE

The net decrease of $117.5 million includes a $107 million reduction in the payment of principal on the TDRSS loans to the FFB consistent with Congressional direction. The balance of the reduction resulted from adjustments in launch and production schedules due to the delay in the launch of the second and third spacecraft.

BASIS OF FY 1987 ESTIMATE

Under the terms of the TDRSS service contract, loans were extended by the Federal Financing Bank (FFB) to the Space Communication Company (SCC), the owner-operator of the TORSS, 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 TDRSS services for maintenance and operation of the White Sands Ground Terminal and other support to be provided during the year. Current planning provides for launch of the initial four spacecraft using the IUS and the launches of the two subsequent spacecraft using an upper stage to be competitively procured. Activities associated with integrating the fourth TDRS with an upper stage are planned for initiation in FY 1986 and will continue in FY 1987.

Of the amount requested in FY 1987, approximately $227 million is for loan repayments to the FFB for TDRSS development. Approximately $50 million of the request provides for TDRSS service payments, TDRSS integration with an upper stage and other changes and support activities. Another $24 million is included in the request for the maintenance and operation of the White Sands Ground Terminal. These estimates are predicated upon the successful launch and checkout of a second and third spacecraft in 1986.

	1985 Actual	1986 Budget Estimate	1986 Current Estimate	1987 Budget Estimate
	(Thousands of Dollars)			
Space network operations...............	36,151	37,100	40,500	43,700

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 communication services to user spacecraft in low-Earth orbit. Each of these NASA elements perform 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 TDHSS 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 DSN. The Bilateration Ranging Transponder System (BRTS) provides precision position location and orbit determination information for the TDRS. The Simulation 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 elements are designed to function as an integrated operational system. Currently, the overall system is providing service to a variety of missions, including Shuttle and Spacelab, as previously noted. Effort is also continuing on achieving an operational configuration that will be capable of supporting an expanded workload in the late 1980's.

CHANGES FRM FY 1986 ESTIMATE

The increase of $3.4 million is necessary to continue to meet the operational support requirements in the Space Network due to the delay of the TDRSS program.

BASIS OF FY 1987 ESTIMATE

The funding request provides for contractor personnel to operate the network systems 24 hours per day, seven days per week, and for the related hardware and software maintenance. Funding also provides for a variety of support activities such as operational analyses, mission planning and documentation. In addition to the missions currently being supported by the Space Network, the support workload will increase significantly in FY 1987 with the launch of the Hubble Space Telescope.

	1985 Actual	1986 Budget Estimate	1986 Current Estimate	1987 Budget Estimate
	(Thousands of Dollars)			
Systems engineering and support.......	25,549	28,100	27,700	29,100

OBJECTIVES AND STATUS

The objective of Systems Engineering and Support is to provide the engineering services and hardware required to sustain and modify the NASA elements of the Space Network. Engineering services are supplied through both the maintenance and operations contract and a number of small, highly specialized engineering service contracts.

Preparations are underway to assure ground system readiness for the two upcoming launches and for full network operation once the total complement of three TDRS's, including the on-orbit spare, are operational. There is also continuing activity to sustain system reliability for current users as well as preparations to meet upcoming support requirements. In the Network Control Center (NCC) display, processing and communication equipment is being replaced and software development is underway to improve TDRSS user access and operational reliability. At the Network Ground Terminal (NGT), there is a continuing effort to automate functions to improve operational reliability and to achieve operating efficiencies. Preliminary effort, associated with the implementation of a second ground terminal for the TDRSS, is also underway.

CHANGES FROM FY 1986 ESTIMATE

The decrease of $.4 million reflects minor reductions in contractor support related to NCC systems engineering.

BASIS OF FY 1987 ESTIMATE

Funds requested will provide for engineering support in the areas of systems engineering, performance and operations analyses, minor facility modifications, network integration testing and interface verification, sustaining engineering support, test equipment, and vendor maintenance for specialized equipment and subsystems within the Space Network. Design and analytical studies will be conducted on a wide array of items ranging from subsystem modifications to meet new mission requirements or to correct system deficiencies to the analysis of the radio frequency environment for potential impact on TDRSS and other network systems. Funds are also requested for continued software development for the NCC and ongoing hardware implementation, replacement and modification.

The FY 1987 funding request will support definition activities which will lead to implementation of a second ground terminal to be located in the vicinity of White Sands, New Mexico. Construction of a second ground terminal will be initiated in 1987 from the CofF appropriation. Experience to date with the existing terminal indicates that to maintain continuity of service over an extended period of time, a backup to the existing White Sands Ground Terminal (WSGT) is essential to eliminate a critical single point of failure in the control and support of space programs.

BASIS FOR FY 1987 FUNDING REQUIREMENTS

GROUND NETWORKS

	1985 Actual	1986 Budget Estimate	1986 Current Estimate	1987 Budget Estimate
		(Thousands of Dollars)		
Spaceflight tracking and data network systems implementation.......	6,400	2,700	3,000	3,400
Spaceflight tracking and data network operations.......	91,447	58,700	60,400	53,000
Deep space network systems implementation.......	37,100	44,400	44,400	44,000
Deep space network operations.........	77,661	88,9U0	88,900	94,100
Aeronautics, balloons, and sounding rocket support systems implementation	8,965	11,400	11,400	11,200
Aeronautics, balloons, and sounding rocket support operations............	11,627	13,200	14,900	16,300
Total...............................	233,200	219,300	223,000	222,000

OBJECTIVES AND STATUS

As of January 1, 1986, the Ground Networks included the Spaceflight Tracking and Data Network (STDN), consisting of nine geographically dispersed ground stations which support Earth orbital missions; the Deep Space Network (DSN) consisting of three stations approximately 120 degrees apart in longitude, which support planetary and solar system flight missions and some Earth orbital missions; and instrumentation facilities, both fixed and mobile, which support the Aeronautics, Balloon and Sounding Rocket (AB&SR) programs. In addition, sounding rocket and balloon launches are conducted at selected worldwide locations.

Funding for the ground networks provides for operation and maintenance of the worldwide facilities, as well as engineering and procurement of equipment to sustain and modify network systems. The workload in FY 1987 includes ongoing support *to* the Space Shuttle, and spacecraft including Voyager, Galileo, Ulysses, Pioneers, Dynamic Explorer, International Ultraviolet Explorer (IUE), Nimbus and the International Sun-Earth Explorers, as well as preparation for support of such upcoming missions as the planned Voyager-Neptune encounter, Magellan (formerly Venus Radar Mapper), and the Mars Observer. Support will also be provided to aircraft programs such as the F-16 and F-111 and the X-29A forward swept wing.

	1985 Actual	1986 Budget Estimate	1986 Current Estimate	1987 Budget Estimate
		(Thousands of Dollars)		
Spaceflight tracking and data network systems implementation......	6,400	2,700	3,000	3,400

OBJECTIVES AND STATUS

The Spaceflight Tracking and Data Network (STDN) systems implementation program encompasses the procurement and implementation of services and hardware to sustain network facilities and equipment to ensure reliable tracking, command, and data acquisition support to ongoing scientific and applications satellite missions and the Space Shuttle. The network is currently supporting many missions with highly complex requirements for tracking, data acquisition, command and control including Shuttle and Spacelab missions. With the closure of six STDN ground stations planned for mid-1986, this program will be limited to sustaining capabilities at Bermuda, Merritt Island, Florida and the Wallops Flight Facility.

CHANGES FROM FY 1986 ESTIMATE

The increase of $0.3 million is for sustaining STDN systems and facilities into late FY 1986 due to the delay in the station closure dates.

BASIS OF FY 1987 ESTIMATE

The FY 1987 request includes funds for the replacement of obsolete and difficult-to-maintain equipment at those facilities that remain open after the TDRSS is operational. These facilities will be used for prelaunch, launch and landing support at Bermuda and Merritt Island, Florida, and for limited orbital support from the Wallops Flight Facility for the Space Shuttle. The requirements for support from these sites will continue for the foreseeable future. Equipment replacements and modifications are required in FY 1987 to maintain a level of proficiency to support the continuing workload and to assure the reliability of the major systems. Accordingly, funds are required to replace obsolete equipment, for reliability modifications and to achieve operating efficiencies in the network. The funds requested also provide for procurement of major subsystem spares, for the provision and modification of test equipment, and for minor equipment modifications resulting from changes in support requirements.

	1985 Actual	1986 Budget Estimate	1986 Current Estimate	1987 Budget Estimate
		(Thousands of Dollars)		
Spaceflight tracking and data network operations........	91,447	58,700	60,400	53,000

OBJECTIVES AND STATUS

The primary function of the Spaceflight Tracking and Data Network (STDN) system is to support NASA Earth-orbital 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.

As of January 1, 1986, the STDN consisted of nine geographically dispersed ground stations. Eight of these stations are located at: Greenbelt, Maryland; Merritt Island, Florida; Kauai, Hawaii; Guam; Ascension Island; Dakar, Senegal; Bermuda; and Santiago, Chile. These global facilities have the capability to electronically track the 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 maintain voice communications for crew operations and safety and other project-related purposes. The ninth station, located at Yarragadee, Australia, provides only air-to-ground voice communication with. the astronauts.

During FY 1986, the tracking and data acquisition support function will be transferred from the station at Greenbelt, Maryland to the Wallops Flight Facility in Virginia. When the second TDRS satellite is operational, the following STDN stations will cease operations and be closed: Ascension Island, Guam, Hawaii, Santiago and Yarragadee. Dakar will close about three months later when the third TDRS satellite is on station to support the ascent phase of STS missions. The two remaining stations at Merritt Island and Bermuda will provide prelaunch, launch and STS landing support.

CHANGES FRM FY 1986 BUDGET ESTIMATE

The net increase of $1.7 million results from requirements to operate the STDN stations for nine months in FY 1986 for Shuttle and other support brought about by the delay in the Tracking and Data Relay Satellite launches. The STDN will be required to provide Shuttle and other spacecraft support until the second TDRS is successfully launched and checked out, with the Dakar station being required until the third TDRS is capable of supporting the Shuttle ascent mission phase. An adjustment has been made in this program for the transfer of operations from the Greenbelt, Maryland tracking station to the Wallops Flight Facility in April, 1986.

BASIS OF FY 1987 ESTIMATE

The FY 1987 funding requirements provide for the maintenance and operation of the remaining STDN stations. These estimates are based upon the successful launch and checkout of the second and third TDRS's as currently planned. Included in the funding request are the related logistics support, network planning, scheduling, engineering, documentation and software programming costs associated with the operation of the network stations. Logistics support in the form of spare parts and some equipment repairs is provided to a variety of OSTDS users including the Deep Space Network (DSN), NASA Communications Network (NASCOM), Space Network, Wallops Flight Facility, and project control centers.

	1985 Actual	1986 Budget Estimate	1986 Current Estimate	1987 Budget Estimate
		(Thousands of Dollars)		
Deep space network (DSN) systems implementation...............	37,100	44,400	44,400	44,0013

OBJECTIVES AND STATUS

The role of the Deep Space Network (DSN) is to provide the communication link between each of NASA's distant 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 low earth orbit to over 5.3 billion kilometers from Earth. When the three STDN stations were consolidated with the DSN stations in Australia, California and Spain in February 1985, the DSN also assumed support responsibility for several spacecraft already in Earth orbit and for any spacecraft not supportable by the TDRSS. Several of these support requirements include missions in low-Earth, highly-elliptical and synchronous Earth orbits.

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 a phased 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 (NOCC).

Since the Galileo spacecraft is the first to utilize a receiver in the X-band frequency spectrum, the ground network must be implemented to transmit commands in this frequency range. By mid-1987, a 34-meter antenna at Spain and Australia will be implemented with 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. As all new deep space missions will 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 highly elliptical Earth orbiters and synchronous Earth orbital missions (both types will be in orbits at altitudes that are beyond the support area of TDRSS); and (4) to provide the improved navigation capabilities required for precise spacecraft targeting and probe delivery.

These objectives represent a significant challenge to the DSN, as it will be supporting many more spacecraft than in the past, many of which will be at extremely great distances. The most distant planetary encounter will be of Neptune by Voyager-2 in 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. An expansion of the 64-meter antennas to 70 meters which is underway, along with multiple antenna arraying of radiotelescopes in New Mexico, Japan and Australia, will provide the increased signal capturing capability for the first look at Neptune.

Upcoming missions which will be supported by the network include Galileo, Ulysses, Magellan and Mars Observer.

BASIS OF FY 1987 BUDGET REQUEST

Funding in the FY 1987 request provides for continuing the evolution of the DSN, taking advantage of the latest technologies to meet the increasingly complex support requirements. Included are new capabilities needed to meet the more stringent navigation and spacecraft-ground telecommunications requirements while reducing overall maintenance and operations costs.

Funds are included in the 1987 budget to implement the new capabilities required for the mission. These are: (1) high telemetry data rates which will require telemetry system modifications and (2) spacecraft signal dynamics which will require extensive changes to the receiver system.

The X-band transmission capability required for Galileo will require extensive additions to the new 34-meter antenna feed systems at Spain and Australia and the addition of a transmitter to these antennas which are currently in a "listen only" configuration. Extensive improvements to the ground tracking systems are required in 1987 to provide the navigation accuracy required for the Galileo probe release. This mission event requires that the position of the spacecraft be precisely known in order that the probe, when released, will follow the correct ballistic trajectory into the Jovian atmosphere.

Work will continue in 1987 in preparation for the Voyager 2 spacecraft encounter of the planet Neptune which will occur in 1989. This activity consists of implementation of an X-band receive capability for the Very Large Array at Socorro, New Mexico (which will be arrayed with the Goldstone, California antennas) ana the 64-meter antennas at Parkes, Australia and Usuda, Japan (which will be arrayed with the DSN antennas at Canberra, Australia).

To improve the operability, maintainability and reliability of the DSN, significant modifications, including replacement of obsolete equipment, will be made during 1987 at the signal processing centers at the three DSN complexes and at the Network Control Center at Pasadena, California.

	1985 Actual	1986 Budset Estimate	1986 Current Estimate	1987 Budget Estimate
		(Thousands of Dollars)		
Deep space network operations.........	77,661	88,900	88,900	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. Each complex has one 64-meter and two 34-meter diameter antennas including one 34-meter antenna under construction at Madrid. A centralized control center for the network is located at the Jet Propulsion Laboratory (JPL) in Pasadena, California. The DSN also operates 26-meter antennas at all three stations having completed the consolidation of STDN station resources under the network consolidation program. These 26-meter antennas are used to track spacecraft in the vicinity of the Earth which cannot utilize TDRSS.

The Voyager-2 spacecraft encounter with Uranus in January 1986 should provide the first detailed information on that distant planet. Voyager-1 is now about 3.8 billion kilometers from Earth on a trajectory that will take it out of the solar system. The Pioneer-10 Spacecraft is now 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 2.9 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 noninterference 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.

Additional 34-meter antennas have been completed at both Goldstone and Canberra. These antennas have been electronically combined with the other antenna facilities at their respective complex to increase the receiver gain available at these two stations. Both of these stations are crucial to capturing imaging and science data from the Voyager-2 encounter with Uranus. The DSN complex at Canberra, because of its southern hemisphere location, has the best view of Voyager-2 at Uranus. At that location, an additional facility will be used at the time of encounter the additional facility is the Australian 64-meter Radio Observatory at Parkes, which will be electronically combined with an array of DSN antennas. The European Space Agency (ESA) will use this same Radio Observatory facility in support of their Giotto mission to Halley's Comet in March 1986. The arrival of Giotto at Halley's Comet at a time close to the Voyager-2 Uranus encounter requires close coordination between NASA, the Commonwealth Scientific and Industrial Research Organization (CSIRO) in Australia, and ESA in order to assure mission success.

BASIS OF FY 1987 ESTIMATE

The DSN operations fundiny provides for the maintenance and operation of the consolidated network facilities, control center, and the support and engineering effort associated with both implementation activities and continuing operation of the network. The expected workload in 1987 on the DSN 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, Galileo, the Ulysses encounter with the planet Jupiter, 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.

	1985 Actual	1986 Budget Estimate	1986 Current Estimate	1987 Budget Estimate
		(Thousands of Dollars)		
Aeronautics, balloons and sounding rocket support systems implementation	8,965	11,400	11,400	11,200

OBJECTIVES AND STATUS

The objectives of the Aeronautics, Balloons, and Sounding Rocket (AB&SR) Systems Implementation program are two fold. First, fixed and mobile instrumentation systems are provided to meet the tracking, data acquisition, and range safety requirements of the aeronautics research conducted at the Wallops Flight Facility (WFF) in Virginia, the Dryden Flight Research Facility (DFRF) and Moffett Field Flight Complex (MFFC) in California, and the scientific investigations conducted with balloons and sounding rockets at Wallops, the White Sands Missile Range, New Mexico; Poker Flats, Alaska; Palestine, Texas; and other selected sites around the world. Second, tracking and data acquisition support will be provided at Wallops to selected near-Earth orbiting satellites which cannot be supported by TDRSS. This function is being moved from Greenbelt, Maryland, to Wallops in April 1986 and will permit the closedown of that type of operations at Greenbelt.

BASIS OF FY 1987 ESTIMATE

The aeronautical research efforts and scientific experiments using sounding rockets and balloons are programs of a continuing nature which generally require about the same level of support from year to year. 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 and test and calibration equipment routinely replaced. Due to the age of some of the radar, telemetry, and impact prediction equipment, a phased replacement and refurbishment program is underway to assure reliable real-time data collection and handling support to meet current and future requirements.

	1985 Actual	1986 Budget Estimate	1986 Current Estimate	1987 Budget Estimate
		'(Thousands of Dollars)		
Aeronautics, balloons and sounding rocket support operations...........	11,627	13,200	14,900	16,300

OBJECTIVES AND STATUS

Fixed and mobile instrumentation systems are maintained and operated to support sounding rocket, balloon, spacecraft, and aeronautics programs conducted by the Wallops Flight Facility (WFF), the Ames Research Center (ARC) at its Dryden Flight Research Facility (DFRF), and Moffett Field Flight Complex (MFFC). These instrumentation systems include radar, telemetry, data processing, data handling, and communications systems, as well as special purpose optical equipment.

The Sounding Rocket program continues to be an active program with approximately 110 launches in FY 1985, most of which were conducted at WFF. In addition, there were approximately 190 balloon flights during the same period. At WFF, the aeronautics programs are primarily related to investigation of aircraft handling characteristics, advanced control and display concepts, spin and stall tests, terminal area guidance and traffic control systems, and storm dynamics studies. During 1985, approximately 275 research missions were conducted. In addition to support of sounding rocket, balloon, and aeronautics programs, instrumentation at WFF will continue to be utilized to support the shuttle orbital flights with C-band radar support.

ARC operates aeronautical test ranges at DFRF and MFFC which provide radar, telemetry, optical, and communications support for the performance of aircraft research and development programs. A variety of programs are conducted at these facilities involving high performance aircraft such as the F-111, F-18A, F-16, F-104, F-8, X-29A, and unique research vehicles such as the tilt-rotor research aircraft, composite rotorcraft, and the X-wing aircraft. Nearly 500 aeronautical research missions were supported at DFRF and approximately 275 at MFFC during FY 1985. DFRF continues to serve as an alternative lanaing site for the Space Shuttle.

CHANGES FRM THE FY 1986 BUDGET ESTIMATE

The increase of $1.7 million reflects the decision to transfer operations from the Greenbelt, Maryland tracking station to the Wallops Flight Facility in April 1986.

BASIS OF FY 1987 ESTIMATE

The FY 1987 funding requirements provide engineering and technical services for maintenance and operation of fixed and mobile radar, telemetry, optical, communications, and data handling and processing equipment and facilities to support the ongoing sounding rocket, balloon, orbiting satellites, and aeronautical research activities. It includes the first full year of funding for the transfer of operations from Greenbelt, Maryland to the Wallops Flight Facility.

BASIS OF FY 1987 FUNDING REQUIREMENT

COMMUNICATIONS AND DATA SYSTEMS

	1985 Actual	1986 Budget Estimate	1986 Current Estimate	1987 Budget Estimate
	(Thousands of Dollars)			
Communications systems implementation	6,500	6,500	5,000	6,200
Communications operations.	73,000	75,700	83,200	82,000
Mission facilities	12,675	13,300	13,300	6,900
Mission operations.	21,200	27,100	24,000	29,300
Data processing systems implementation	25,016	24,100	25,000	25,100
Data processing operations	45,809	41,500	41,500	53,100
Total	184,200	188,200	192,000	202,600

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) the Program Support Communications Network (PSCN) which provides for the day-to-day communications among NASA field centers and Headquarters; 2) a mission control and data capture system for Hubble Space Telescope and 3) 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, preliminary studies have been initiated to evaluate Space Station support requirements.

	1985 Actual	1986 Budget Estimate	1986 Current Estimate	1987 Budget Estimate
	(Thousands of Dollars)			
Communications systems implementation......................	6,500	6,500	5,000	6,200

OBJECTIVES AND STATUS

The objective of the Communications Systems Implementation Program is to provide the necessary capability in NASA's Global Communications Network 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 underway in NASCOM is the phased replacement of the digital voice and data message switching system at the Goddard Space Flight Center (GSFC).

CHANGES FROM FY 1986 BUDGET ESTIMATE

The decrease of $1.5 million results from rephasing of the funding for the operational network digital voice and data message switching system to coincide with the availability of other communications equipment at the Goddard Space Flight Center (GSFC).

BASIS OF 1987 ESTIMATE

The FY 1987 funding requirements will provide the sustaining equipment and modifications to support the NASCOM network and continue implementation of the replacement digital voice and data message switching system at GSFC. Effort will continue on the use of advanced digital techniques for Time-Division-Multiple-Access (TDMA) via satellite. With the completion of the 15 MBS system at 14 locations in FY 1986, implementation and augmentation for a 60 MBS capability at selected NASA Centers will be initiated in FY 1987 to meet growing requirements.

On-line operation of the Control and Status System (CSS) is scheduled for mid-1987. This system will provide real-time performance information and automate the manual switching function for the baseline Tracking and Data Relay Satellite (TDRS) communication system. The baseline TDRS communications system ties together the Goddard Space Flight Center (GSFC), Johnson Space Center (JSC), Marshall Space Flight Center (MSFC), and the TDRSS ground terminal in New Mexico.

	1985 Actual	1986 Budget Estimate	1986 Current Estimate	1987 Budget Estimate
	(Thousands of Dollars)			
Communications operations............	73,000	75,700	**83,200**	82,000

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. NASCOM also 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.

CHANGES FRM FY 1986 BUDGET ESTIMATE

The increase of $7.5 million is attributable to the need to provide communications with the STDN tracking sites for Shuttle support longer than planned due to the delay in the Tracking and Data Relay Satellite launches.

BASIS OF FY 1987 ESTIMATE

The FY 1987 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 cable systems 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. The initiation and transfer of selected domestic satellite services to the TDRSS C-Band transponders will be undertaken with other government users reimbursing NASA for their portion of the service. It is anticipated that NASCOM's TDMA based network and the PSCN backbone network will also utilize the TDRS satellite C-Band capability.

In addition, funds are included for the Program Support Communications Network (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 1987 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 Space Transportation System, Hubble Space Telescope, and Space Station management information system. In addition, the network will support administrative and institutional information systems.

	1985 Actual	1986 Budget Estimate	1986 Current Estimate	1987 Budget Estimate
	(Thousands of Dollars)			
Mission facilities....................	12,675	13,300	13,300	6,900

OBJECTIVES AN) STATUS

The Mis'sion Facilities Implementation Program provides the systems capability for the command and control of NASA's unmanned scientific and applications satellite programs. Command and control of the spacecraft and on-board experiments are carried out via Payload Operations Control Centers (POCC's) and related Mission Support Systems (MSS).

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 will be operational in FY 1986 to control the Hubble Space Telescope scheduled for launch in late 1986. 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 1987 ESTIMATE

The FY 1987 funding requirements will provide for Hubble Space Telescope post launch software enhancements based upon on-orbit performance of the spacecraft and science instruments. Certain control center parameters related to focusing of the telescope and calibration of the optics can only be determined and implemented after the Hubble Space Telescope is in orbit.

In addition, FY 1987 funds will provide for modifications to the existing Multisatellite Operations Control Center (MSOCC) for control of the Gamma Ray Observatory (GRO), Cosmic

Background Explorer (COBE), Upper Atmosphere Research Satellite (UARS), and various Shuttle attached payloads. In FY 1967 control center developments to permit spacecraft payload operations from user facilities will also be initiated. This new concept which is planned for use with Space Station will provide operational efficiencies for experimenters.

	1985 Actual	1986 Budget Estimate	1986 Current Estimate	1987 Budget Estimate
	(Thousands of Dollars)			
Mission operations..	21,200	27,100	24,000	29,300

OBJECTIVES AND STATUS

The Mission Operations Program in FY 1987 will provide for the operation of five Payload Operations Control Centers (POCC's) and the related software and support services necessary for the monitoring and control of ten in-orbit spacecraft.

These POCC's, which are the control facilities for spacecraft/payload operations, have the capability for receiving, processing, and displaying spacecraft engineering and telemetry data for sending commands to the spacecraft. Commands transmitted to the spacecraft include both emergency commands resulting from decisions made by the spacecraft analysts as well as preplanned command sequences generated in advance to carry out the mission objectives. Each POCC is operated 24 hours per day, 7 days per week. 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.

CHANGES FROM FY 1986 BUDGET ESTIMATE

The decrease of $3.1 million is due to reduced and rephased software requirements in the POCC and Command Management facilities.

BASIS OF FY 1987 ESTIMATE

The FY 1987 budget request includes funds to operate POCC's and supporting facilities for control of on-orbit missions and control center software development for supporting upcoming missions. In FY 1987 the new Hubble Space Telescope POCC will be operational and a major activity that will be conducted in this facility after launch is the operational checkout and calibration of the spacecraft and scientific instruments. Also in FY 1987, software development activities will continue to increase for the COBE and UARS missions. Software to enable POCC control of the GRO will continue along with SPIF software development.

Also included in the FY 1987 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.

	1905 Actual	1906 Budget Estimate	1906 Current Estimate	1907 Budget Estimate
		(Thousands of Dollars)		
Data processing systems implementation	25,016	24,100	25,000	25,100

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. There are three major systems for processing data: 1) the Telemetry On-Line Processing System (TELOPS) which routinely supports a number of Earth-orbiting spacecraft; 2) The Image Processing Facility which generates products for Landsat and Nimbus 7 and, 3) The Spacelab Data Processing Facility (SLDPF) which supported the Spacelab 1, 2, 3 and D1 missions and the Shuttle Imaging Radar-B experiment.

Significant activities in this program continue at the Goddard Space Flight Center to keep the large systems viable and responsive to project support requirements. Implementation continues on a new system to process data from numerous and varied experiments which comprise the payloads of early Spacelab missions and new payloads associated with later missions. The early Spacelab missions may be described generally as multi-discipline missions consisting of a mixture of experiments in areas such as life science, microgravity, space plasma, etc., whereas the later Spacelab missions place emphasis on a single discipline and are called Dedicated Discipline Laboratory (DDL) missions. Examples of DDL missions are the Attached Shuttle Astronomy Payload (ASTRO 1, 2, & 3), the Earth Observation Missions (EOM) 1 and 2, and the Shuttle High Energy Astrophysics Laboratory (SHEAL).

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 advanced data base management systems.

CHANGES FROM FY 1986 BUDGET ESTIMATE

The increase of $.9 million is due to revised data processing requirements including studies and analyses of support for upcoming missions.

BASIS OF FY 1987 ESTIMATE

The FY 1987 budget request will provide funding for continuing the phased replacement of the existing computation systems at the Goddard Space Flight Center which provide real-time support to NASA spacecraft. Included in the support are such critical activities as real-time attitude and orbit determination, memory management for on-board computers, and flight maneuver control.

The funding request provides for continuing the phased replacement program for the Command Management System (CMS) and the Orbit Computation System (OCS) at GSFC. The initial phase for replacing the CMS system has been completed and this funding provides for initiating the final phase of the replacement plan. Also, funding is included for replacing custom displays and large application software programs for the OCS. In addition, the request provides for the improvement/upgrade of the Flight Dynamics Facility (FDF) and for systems studies in autonomous navigation as part of the test bed/prototyping activity.

Funds are required in FY 1987 to continue the implementation of an institutional packet telemetry processing system with the Gamma Ray Observatory (GRO) as its first user. This facility will capture, error check, and ship real-time, quick-look and production scientific data to various users. The system is necessary to handle the "packet" telemetry and to assure support over the long mission lifetime of GRO and other spacecraft. 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.

Funds are also required in FY 1987 to continue the augmentation of the SLDPF to support missions such as International Microgravity Laboratory (IML), ASTRO -2 and -3, EOM-3, SHEAL, Sunlab 1 and the Shuttle Radar Lab (SRL-2). The Dedicated Discipline Laboratory (DDL) missions will be flown more frequently than the earlier Spacelab missions, and will require more concurrent support and quicker release of experiment data to the scientific community.

The FY 1987 budget request includes funds to continue the upgrade of the existing TELOPS in order to develop a generic time division multiplexed (TDM) system of which the Upper Atmosphere Research Satellite (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.

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 also included in the request for continuing the evaluation of Space Station support requirements and the capabilities needed to provide such support.

	1985 Actual	1986 Budget Estimate	1986 Current Estimate	1987 Budget Estimate
		(Thousands of Dollars)		
Data processing operations............	45,809	41,500	41,500	53,100

OBJECTIVES 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 Landsat and Nimbus.

In addition to the actual processing of the 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. Three facilities, the Image Processing Facility (IPF), the Telemetry On-Line Processing System (TELOPS), and the Spacelab Data Processing Facility (SLDPF), 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 residual data from these spacecraft as well as current data from the Nimbus mission. These spacecraft are being supported with an all-digital system using high density recorders and computer compatible tapes. This equipment is being used currently to process archived Landsat data now required for climatic and meteorological studies. This data was processed initially into film and picture products; however, the scientific community requires the data to be reprocessed with the output in the form of digital tapes. 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 Telemetry On-Line Processing System (TELOPS) handles the non-image data. TELOPS receives satellite data in a digital form from the tracking stations via the NASA global communications network lines and is able to electronically store 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 Spacelab Data Processing Facility is included along with software development and maintenance required for attitude determination, flight maneuvers, and mission simulations.

BASIS OF FY 1987 ESTIMATE

FY 1987 budget request includes funds to operate the Image Processing Facility (IPF), the Hubble Space Telescope Data Capture Facility (HSTDCF), and the Telemetry On-Line Processing System (TELOPS). Also, funds are necessary for operation of the SLDPF which includes maintenance of unique hardware and software for Spacelab and Dedicated Discipline Laboratory (DDL) missions.

Application software development, prototyping, and system testing activities are continuing or will be 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 attitude control maneuvers and for data processing activities.

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