NASA 5-YEAR PLANNING

FISCAL YEARS 1980 THROUGH 1984

MAN'S REACH SHOULD EXCEED HIS GRASP,
OR WHAT'S A HEAVEN FOR?

— ROBERT BROWNING IN
"ANDREA DEL SARTO"

(NASA-TM-80486) NASA 5-YEAR PLANNING: FISCAL YEARS 1980 THROUGH 1984 (National Aeronautics and Space Administration) N79-78912

Unclas
00/81 15397

Prepared as of January 31, 1979

CONTENTS

219

Tables

Figures

ERRATA

pp 2, 5, 209, and 216 - Initiation date for Large Advanced Antenna System (formerly Large-Aperture Antenna) should be 1981 instead of 1982.

p 33 second item in 1980 - Should read, in part, "Galileo Jupiter Orbit Insertion, Probe Entry, and ..."

INTRODUCTION

This report presents a 5-year program for NASA's aeronautics and space research and development for FY 1980 through 1984. It is the third such report NASA has published, but the first since the President issued his civil space policy and instituted 3-year budgeting. The latter added to the annual budgeting procedure a requirement for a budget estimate for the two years following the budget year.

The funding in the report is in dollars of the FY 1980 budget, and the program for FY 1980 is consistent with the FY 1980 budget the President submitted to Congress. The programs for the remaining two years of the 3-year budget (FY 1981 and 1982), although consistent with the President's civil space policy and the Administration's anti-inflation program, are larger than the programs in the 3-year budget. The programs for the remaining two years (FY 1983 and 1984) are also somewhat larger than future funding probably will support. We believe that the principal purpose of our 5-year plan is to outline a program that will ensure a sound, logical technological progression toward achievement of the Nation's goals in aeronautics and space. Consequently, our plan should include more work than we ultimately will undertake, so that the Administrator will have flexibility to modify the program as work under the program progresses and circumstances change.

CHANGES IN MAJOR INITIATIVES FROM FY 1979-1983 PLAN

Funding constraints precluded major new initiatives in NASA's FY 1980 program and limited the number of new initiatives in all the years of this plan. Table 1 shows the resulting major changes from our FY 1979-1983 plan. All changes are delays except that initiation of the Office of Space Science's program, Origins of Plasma in Earth's Neighborhood, has been advanced two years.

BASIS FOR THE FY 1980-1984 PROGRAM

The Space Act (National Aeronautics and Space Act of 1958, 72 Stat. 426, Amended (42 U.S.C. 2452) and the President's Civil Space Policy of October 1978 have defined the functions NASA is charged to perform. In order to carry out those functions, NASA has set goals and objectives to guide its activities. The most important of them are summarized below.

GOALS AND OBJECTIVES

To fill all the transportation and orbital operations needs of science and applications space missions and most transportation needs of national security space missions in an economical and effective manner. This goal will require:

1. Development and production of the Space Shuttle; participation with the Department of Defense in development and production of the Inertial Upper Stage (IUS), and with the European Space Agency in the Spacelab program; development of other auxiliary flight and

TABLE 1 - CHANGES IN MAJOR INITIATIVES FROM FY 1979-1983 PLAN

CHANGES IN INITIATION DATE

NEW INITIATIVE	INITIATION DATE 79-83 PLAN	80-84 PLAN
Shuttle Improvements	1980	1981
25-KW Power Module	1980	1981
Orbital Transfer Vehicle	1982	1983
Satellite Services	1980	1981
Tethered Satellite System	1980	1981
Space Power Systems Engineering	1981	1982
Seasat Follow-on (National Oceanic Satellite System)	1980	1981
Soil Moisture Mission	1980	1981
Advanced Geology Satellite	1981	1982
Spaceborne Geodynamics Ranging System	1980	1984
Molecular Shield (Space Vacuum Research Facility)	1982	1984
Efficient Sensing Systems	1980	1981
Automated Spacecraft Systems	1981	1982
Advanced Space Transportation Systems Technology	1980	1981
Gamma Ray Observatory	1980	1981
Advanced X-ray Astrophysics Facility	1982	1983
Venus Orbiting Imaging Radar	1980	1981
Comet Mission	1981	1982*
Upper Atmospheric Research Satellite	1981	1982**
Solar Probe	1983	1984
Origins of Plasma in Earth's Neighborhood	1983	1981
Special Computer (Numerical Aerodynamic Simulation Facility)	1981	1982
Large-Aperture Antenna	1981	1982

INITIATION DELAYED BEYOND 1984

Nonterrestrial Resources
Saturn Orbiter Dual Probe
Mars Program

INITIATIVES CANCELLED

Skylab Reboost and Rehabilitation
Public Services Communications ***

* Mission changed from Encke Rendezvous to Halley Flyby/Tempel 2 Rendezvous.

** Responsibility transferred from the Office of Space Science to the Office of Space and Terrestrial Applications.

***Responsibility for this area transferred to Department of Commerce in accordance with the President's October 1978 Civil Space Policy.

ground systems required for support of the Shuttle, IUS, and Spacelab; establishment of routine mission operations with those systems; and the carrying out of an effective transition from the use of expendable launch vehicles to full operation of the Space Transportation System (Shuttle, IUS, Spacelab, and Spinning Solid Upper Stages being developed by industry)

2. Development and operation of: orbit transfer vehicles for geostationary, earth departure, and other high energy orbits; services for maneuvering, servicing, and retrieving satellites both near to and far from the Shuttle; and free-flying platforms for hosting and supporting aggregated mission equipments and system tests.

To improve significantly our ability to apply space technology in three areas that promise immediate or potential benefits to humanity:

1. Remote Sensing. To establish a space system, integrated with ground components, that will make routine global observations from space of Earth's atmosphere and land and water surfaces with sufficient accuracy for predicting, in conjunction with information from other sources and within an established theoretical framework, the status of the environment and the productivity of Earth in terms that are economically and ecologically significant

2. Communications. To maintain U.S. leadership in satellite communications by developing and flight-proving wideband (20 to 30 GHz) and narrowband technology that industry will exploit to increase effective use of the frequency spectrum and of orbit space for the benefit particularly of major-trunk and thin-route users

3. Materials Processing. To develop a space laboratory capability routinely available to academic and commercial organizations for research on the processing in space of materials important for use on the ground, and to provide production technology when processing in space has been demonstrated to be technically or commercially advantageous.

To complete development of the technology for advanced high-aspect-ratio wings, composite structures, active controls, and fuel-economical turbofan engines that will permit long-range transport aircraft to consume on the order of 50 percent less fuel than current wide-body transports consume.

To improve, by a factor of 10 to 100, NASA's ability to acquire, transmit, and process data. Two activities are essential to meet this goal:

1. Development of technology for sensors, data transmission, and data processing

2. Completion of development of and attainment of full operational capability for the Tracking and Data Relay Satellite System.

To increase our knowledge about the history of the cosmos and expand our understanding of the evolutionary processes involved. This goal will require:

1. Study of high-energy nuclear and elementary particle processes in the universe and of X-ray sources -- quasars, galaxies, clusters of galaxies, and the intergalactic medium

2. Test and verification of the general theory of relativity

3. Detailed comparative planetology studies of the terrestrial planets, with next emphasis on obtaining for the entire surface of Venus a radar map providing resolution equivalent to or better than that Mariner 9 obtained at Mars

4. Initial reconnaissance of primordial bodies of the solar system, starting with a comet rendezvous.

To advance our fundamental knowledge of how energy is transported from the Sun and through the intergalactic medium, and what effects that energy has on Earth. This goal will require:

1. Analysis of spatial and temporal variations in the solar-terrestrial media to improve our understanding of the coupling between the magnetosphere, solar wind, ionosphere, and atmosphere

2. In situ measurement of the solar environment to determine the origin of energetic particles in the solar wind and the distribution of the Sun's mass.

To ensure the good health and effective performance of humans in space, extend selection for space flight to a broader segment of the population, and develop an understanding of the role of gravity on living systems.

To understand the origin of life, the distribution of life in the universe, and the relationship between life and its habitat.

FY 1980-1984 PROGRAM

NEW INITIATIVES

Table 2 lists the major new initiatives in the FY 1980-1984 program, and Table 3 describes them. Major initiatives deferred beyond FY 1984 are listed in Table 4.

MISSION COVERAGES

Figures 1 through 5 show the coverage of important factors that NASA's past, current, planned, and projected space flight missions have provided and will continue to provide in the major program areas of astrophysics, solar terrestrial, environmental observation, resource observation, and tracking and data acquisition respectively.

TABLE 2 - MAJOR NEW INITIATIVES

PROGRAM	FIELD* CENTERS	DEVELOPMENT INITIATION DATE				FIRST LAUNCH
		1981	1982	1983	1984	
SPACE TRANSPORTATION SYSTEMS						
Shuttle Improvements	JSC	X				1984
Solar Electric Propulsion System	MSFC	X				1985
Satellite Services	MSFC, JSC	X				1983
Power Extension Package	JSC	X				1983
25-KW Power Module	MSFC	X				1984
Large Space Structures Systems Engineering	**	X				1983
Tethered Satellite System	MSFC	X				1983
Materials Experimentation Carrier	MSFC		X			1984
Large Geostationary Platform	MSFC		X			1988
Space Power Systems Engineering	**		X			1987
Orbital Transfer Vehicle	MSFC			X		1988
SPACE AND TERRESTRIAL APPLICATIONS						
National Oceanic Satellite System	GSFC	X				1985
System 85 (Follow-On Meteorological System)	GSFC	X				1985
Upper Atmospheric Research Satellite	GSFC	X				1984
Multispectral Resource Sampler	GSFC	X				1985
Stereosat	JPL	X				1984
Climate Research (Cryosphere)	GSFC		X			1985
Soil Moisture Mission	GSFC		X			1985
Advanced Geology Satellite	GSFC		X			1986
Operational Earth Resources System	GSFC		X			1985
Landsat-D Refurbishment	GSFC		X			**
Gravsat	GSFC		X			1985
Wideband Program (30/20 GHz)	GSFC		X			1985
Ocean Research	JPL			X		1985
Earth Resources Synthetic Aperture Radar	JPL			X		1987
Thermosat	GSFC			X		1986
Spaceborne Geodynamics Ranging System	GSFC				X	1987
Space Vacuum Research Facility	**				X	1984
Narrowband Program	LeRC				X	**
SPACE SCIENCE						
Gamma Ray Observatory	GSFC	X				1985
Venus Orbiting Imaging Radar	JPL	X				1984
Origins of Plasma in Earth's Neighborhood	GSFC	X				1984
Gravity Probe B	MSFC		X			1985
Halley Flyby/Tempel 2 Rendezvous	JPL, MSFC		X			1985
Advanced X-ray Astrophysics Facility	MSFC			X		1987
Solar Probe	JPL				X	1987
CONSTRUCTION OF FACILITIES						
Special Computer Facility	ARC		X			1985
Large Advanced Antenna System	JPL		X			1985

*ARC = Ames Research Center
GSFC = Goddard Space Flight Center
JPL = Jet Propulsion Laboratory
JSC = Johnson Space Center
LeRC = Lewis Research Center
MSFC = Marshall Space Flight Center

** To Be Determined

TABLE 3 - DESCRIPTION OF MAJOR NEW INITIATIVES

NEW INITIATIVE	OBJECTIVE	NEW TECHNOLOGY REQUIRED
SPACE TRANSPORTATION SYSTEMS		
Shuttle Improvements	To improve performance related to increased stay time in space, in-orbit power generation, orbit maneuvering, and rendezvous and docking	None; technology used as it becomes available
Solar Electric Propulsion System	To develop low-thrust ion propulsion system	Lightweight, high-specific-power solar arrays; long-life ion thrusters; power-processor thruster control
Satellite Services	To develop capabilities for placement, retrieval, and in-orbit maintenance and repair of satellites and debris	Teleoperator and robotic concepts and systems; regenerative, high-pressure suit and portable life-support systems for extravehicular activity; teleoperator and retrieval concepts
Power Extension Package	To develop Shuttle-borne system to provide 12 kilowatts (average) of solar electric power to Shuttle and its payloads	None
25-KW Power Module	To develop system to provide 25 kilowatts (average) of solar electric power to Shuttle and its payloads and to free-flying payloads in low Earth orbit	None

TABLE 3 - DESCRIPTION OF MAJOR NEW INITIATIVES (CONTINUED)

NEW INITIATIVE	OBJECTIVE	NEW TECHNOLOGY REQUIRED
Large Space Structures Systems Engineering	To conduct level-of-effort flight program to develop materials, tools, and techniques for assembling in orbit first generation of large space structures	Advanced composite materials; space fabrication machinery; techniques for testing large structures
Tethered Satellite System	To develop system allowing measurements in Earth's upper atmosphere by subsatellites suspended from Shuttle's cargo bay	None
Materials Experimentation Carrier	To develop pallet that will be carried to space on early Shuttle flights and docked with the 25-KW Power Module to provide, for 20 to 60 days, interface systems between the Module and the materials processing experiments mounted on the pallet	Advanced thermal energy dissipation systems; remote visual monitoring systems; low-g platform stability control; in-orbit servicing
Large Geostationary Platform	To develop general purpose platform to be used in lieu of numerous specialized satellites for communications, Earth observation, and space science payloads	Platform figure and attitude control; weight and size of beam switching systems; control of beam pointing; control of radio-frequency interference
Space Power Systems Engineering	To conduct engineering research for next-generation power system beyond 25-KW Power Module	High-capacity, low-cost power systems; large space structures; in-orbit servicing

TABLE 3 - DESCRIPTION OF MAJOR NEW INITIATIVES (CONTINUED)

NEW INITIATIVE	OBJECTIVE	NEW TECHNOLOGY REQUIRED
Orbital Transfer Vehicle	To develop vehicle to transport payloads from Shuttle to geosynchronous orbit	Advanced liquid oxygen-hydrogen engines, including high- and low-thrust throttling, long-life components, and human-related quality; in-orbit propellant transfer and propellant-system maintenance; insulation for high-performance cryogens; designs for lightweight structures
SPACE AND TERRESTRIAL APPLICATIONS		
National Oceanic Satellite System	To demonstrate limited operational capability for observing the oceans to describe ocean processes, ice dynamics, and coastal processes	Scanning multichannel radiometer with 4-meter antenna and ground resolution of 10 kilometers
System 85	To develop operational meteorological satellite system for studying severe storms and measuring surface temperatures, winds, clouds, and Earth's radiation budget in order to understand atmospheric processes and improve accuracy of mid-range (2- to 14-day) weather forecasts	Scanning multichannel radiometer with 4-meter antenna and ground resolution of 10 kilometers
Upper Atmospheric Research Satellite	To measure active constituents, temperatures, and other dynamic characteristics of stratosphere and mesosphere, and to observe interaction of stratosphere and mesosphere	Attitude determination with measuring accuracy of 0.003 degree; 18- to 24-month cryogens for instruments; advanced microwave limb sounder, far infrared spectrometer, and laser heterodyne radiometer; central data system with remote access

TABLE 3 - DESCRIPTION OF MAJOR NEW INITIATIVES (CONTINUED)

NEW INITIATIVE	OBJECTIVE	NEW TECHNOLOGY REQUIRED
Multispectral Resource Sampler	To observe agriculture, water resources, lithology, and botany with improved temporal resolution and providing discrimination and identification of types of vegetation and rocks, as well as measurement of areas covered by each	Extension of multilinear array to mid-infrared (1 to 4 microns)
Stereosat	To develop system for obtaining global stereo data to increase understanding of geomorphology and structural geology of Earth	None
Climate Research (Cryosphere)	To study Earth's ice and its interaction with the atmosphere, and therefore with climate	Imaging radar; radar and laser altimeters; multichannel microwave radiometer; data transmission and processing
Soil Moisture Mission	To measure amount of moisture in soil by use of passive and active microwave, visual, and infrared techniques	Solid state thermal infrared sensors; 18- to 20-meter, high-precision, parabolic antenna; low-noise, passive, microwave detectors
Advanced Geology Satellite	To determine surface composition using polar-orbiting satellite carrying imaging system with high spectral resolution, infrared laser reflectometer, and passive fluorescing device	Narrowband, near-infrared and infrared, multispectral linear array and scanner; Fraunhofer line discriminator
Operational Earth Resources System	To develop multidisciplinary satellite system to provide Landsat types of data after 1985	Data management system capable of processing 200 Thematic Mapper and 2,000 Multispectral Resources Sampler scenes daily on a continuous basis

TABLE 3 - DESCRIPTION OF MAJOR NEW INITIATIVES (CCONTINUED)

NEW INITIATIVE	OBJECTIVE	NEW TECHNOLOGY REQUIRED
Landsat-D Refurbishment	To initiate Operational Earth Resources System program by retrieving and refurbishing Landsat-D	None
Gravsat	To determine terrestrial gravitational anomalies precisely by means of satellite-to-satellite tracking	Radio-frequency or laser ranging to measure velocity increments of 0.03 millimeter per second
Wideband Program (30/20 GHz)	To establish conceptual designs, develop critical technology, and determine need for flight verification tests for K-band satellite communication system	Multibeam, spaceborne, 20-GHz antenna; high-sensitivity, 30-GHz receivers; onboard high-speed switching system for interconnecting beams
Ocean Research	To increase understanding of global circulation of oceans and demonstrate usefulness of remotely sensed data in studying oceans	Precise, high-resolution radar altimeter; advanced microwave radiometer; visible-infrared instruments; data transmission and processing
Earth Resources Synthetic Aperture Radar	To support applications research in mineral and petroleum exploration and water and vegetation monitoring by use of multidisciplinary radar research facility	Multifrequency, multipolarization, multiple-lock-angle antenna system
Thermosat	To develop satellites to collect narrowband thermal data with high spatial resolution	Narrowband, solid state, thermal-infrared detectors
Spaceborne Geodynamics Ranging System	To develop laser ranging system to make rapid, high-density, 3-dimensional measurements of relative positions with $\pm$1-centimeter accuracy to determine strain accumulation in seismically active zones	Long-life rods for solid state lasers; low-cost, ground-based, laser retro-reflectors

TABLE 3 - DESCRIPTION OF MAJOR NEW INITIATIVES (CONTINUED)

NEW INITIATIVE	OBJECTIVE	NEW TECHNOLOGY REQUIRED
Space Vacuum Research Facility	To determine utility of vacuum environment for materials processing	In-orbit degassing techniques; device for measuring vacuum of $\leq 10^{-14}$Torr; models for simulating outgassing from noncontaminating materials of construction of Shuttle and 25-KW Power Module; wideband ($\pm$ 4 degrees), noncontaminating attitude-control system; automatic management system for experimental samples; noncontact analysis equipment for surface chemistry and physics
Narrowband Program	To establish conceptual designs, develop critical technology, and determine need for flight verification tests for low-volume communications for emergencies, disasters and other such uses	Large, spaceborne, multibeam, 900-MHz antenna; low-cost ground terminals; onboard switching system to handle large number of interconnections
SPACE SCIENCE		
Gamma Ray Observatory	To study high-energy nuclear and elementary particle processes in universe by observing gamma-ray line and continuum emissions from celestial sources	None
Venus Orbiting Imaging Radar	To map with radar Venus' entire surface with resolution better than 1 kilometer and spot resolution of 100 meters to determine geological evolution of Venus; to study Venus' atmosphere	None

TABLE 3 - DESCRIPTION OF MAJOR NEW INITIATIVES (CONTINUED)

NEW INITIATIVE	OBJECTIVE	NEW TECHNOLOGY REQUIRED
Origins of Plasma in Earth's Neighborhood	To study region of Earth's atmosphere where plasma physics determines behavior of matter by investigating coupling between magnetosphere, solar wind, and ionosphere and energy and plasma transportation, storage, and dissipation or loss	Large changes in orbit
Gravity Probe B	To perform fundamental test of general relativity by measuring precession of gyroscope in Earth orbit	None
Halley Flyby/Tempel 2 Rendezvous	To obtain first reconnaissance data on small bodies of solar system and first look at nucleus of a comet	Rapid-response atmospheric sensors; dust analysis methods
Advanced X-ray Astrophysics Facility	To perform X-ray studies of quasars, galaxies, clusters of galaxies, and intergalactic medium with order-of-magnitude improvement in sensitivity and spectral and spatial resolution	Advanced X-ray detectors; high-precision X-ray mirror manufacturing techniques
Solar Probe	To make in situ measurements of interplanetary environment as close to Sun's surface as four solar radii to test general relativity and increase understanding of processes that heat and drive solar wind and accelerate solar energetic particles	Thermal control; telecommunications; advanced drag-free systems; advanced instrumentation

TABLE 3 - DESCRIPTION OF MAJOR NEW INITIATIVES (CONTINUED)

NEW INITIATIVE	OBJECTIVE	NEW TECHNOLOGY REQUIRED
CONSTRUCTION OF FACILITIES		
Special Computer Facility	To provide special computer facility for numerical simulation of complex flow of fluids in aerodynamics and Earth's atmosphere	Computation speed about forty times that of current supercomputers
Large Advanced Antenna System	To provide antenna having gain equivalent to that of 75-percent efficient, 100-meter dish at 8,450 MHz	None

TABLE 4 - MAJOR INITIATIVES DEFERRED BEYOND 1984

SPACE TRANSPORTATION SYSTEMS

Science and Applications Platforms
Space Power Technology Demonstration (Space Power for Use on Earth)
Manned Planetary Mission
Lunar Colonization
Space Station

SPACE AND TERRESTRIAL APPLICATIONS

Coastal Zone Observation
Severe Storms Observation System
Global and Regional Atmosphere Monitor
Nonterrestrial Resources

AERONAUTICS

Enabling Technology for a Pre-mid 1990s Commercial Supersonic Transport

SPACE SCIENCE

Large-Area Moderate Angular Resolution (X-ray Telescope)
X-ray Observatory
Cosmic Ray Observatory
Very Long Baseline Interferometer
Mars Sample Return Mission
Saturn Orbiter Dual Probe
Asteroid Multiple Rendezvous
Mercury Orbiter and Lander
Neptune and Pluto Reconnaissance
Comet Sample Return
Near-Earth Asteroid Sample Return
Venus Lander
Solar Cycle and Dynamics Mission
Pinhole Satellite
Solar Terrestrial Observatory

FIGURE 1—MAJOR ENVIRONMENTAL OBSERVATION MISSIONS

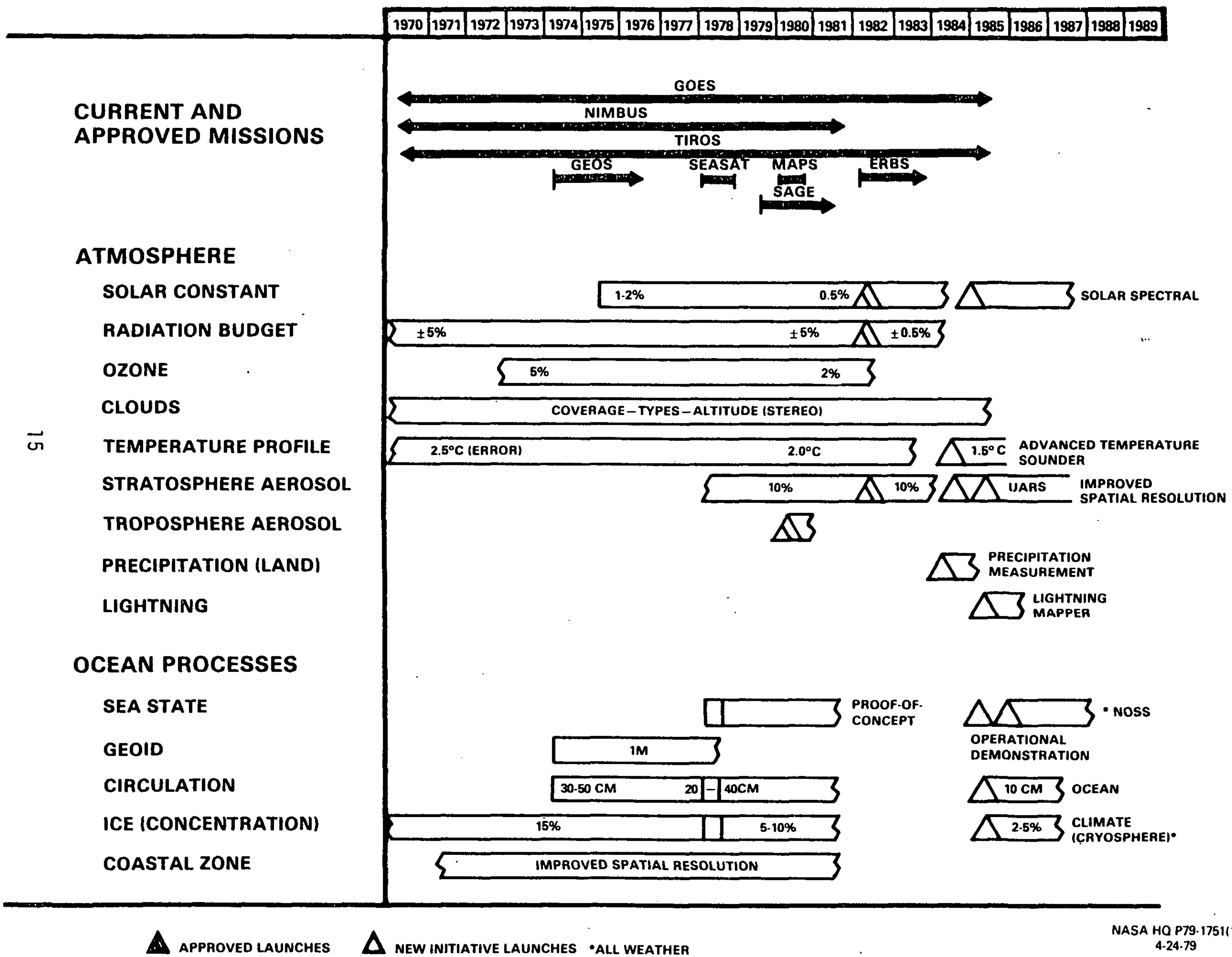


FIGURE 2—MAJOR RESOURCE OBSERVATION MISSIONS

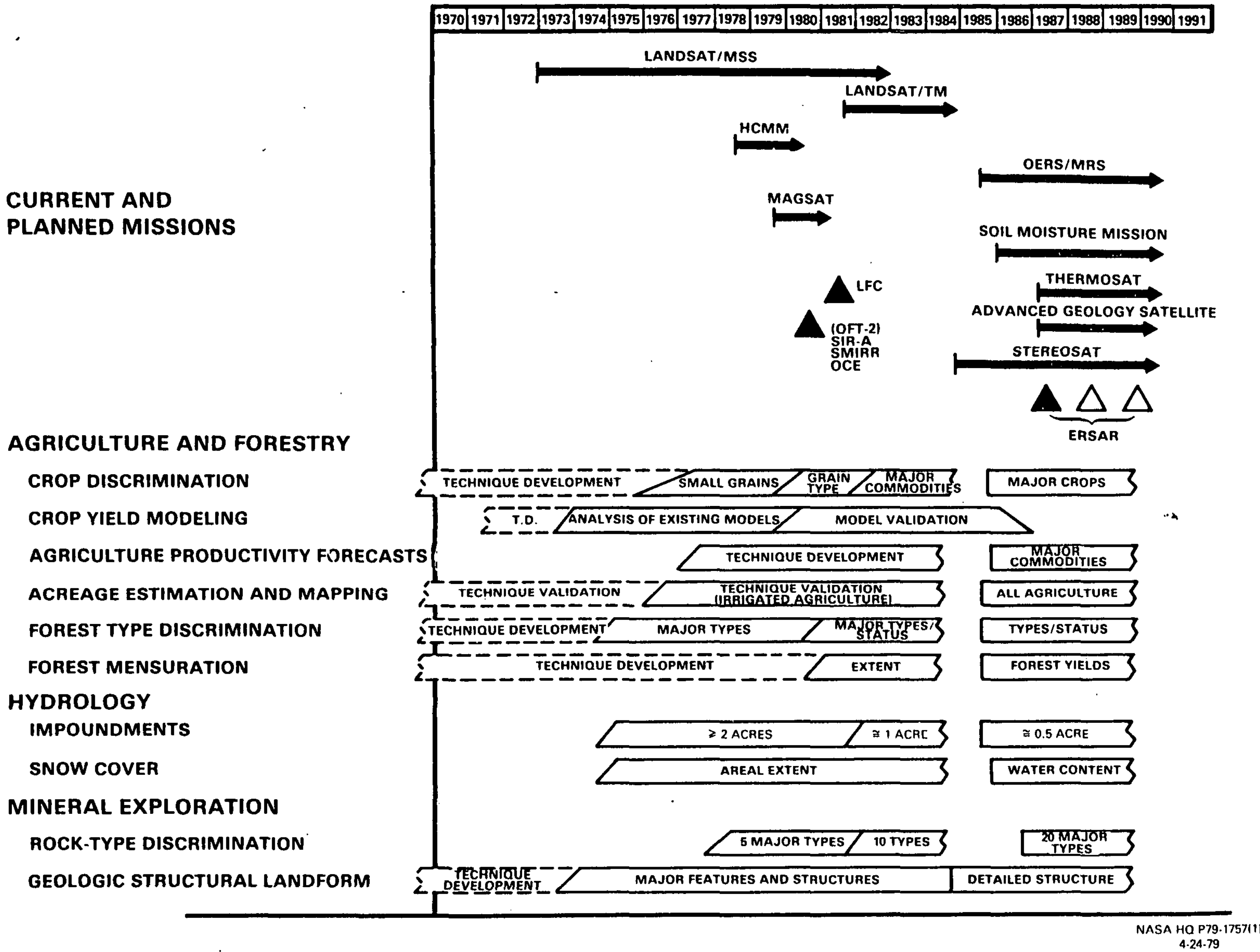
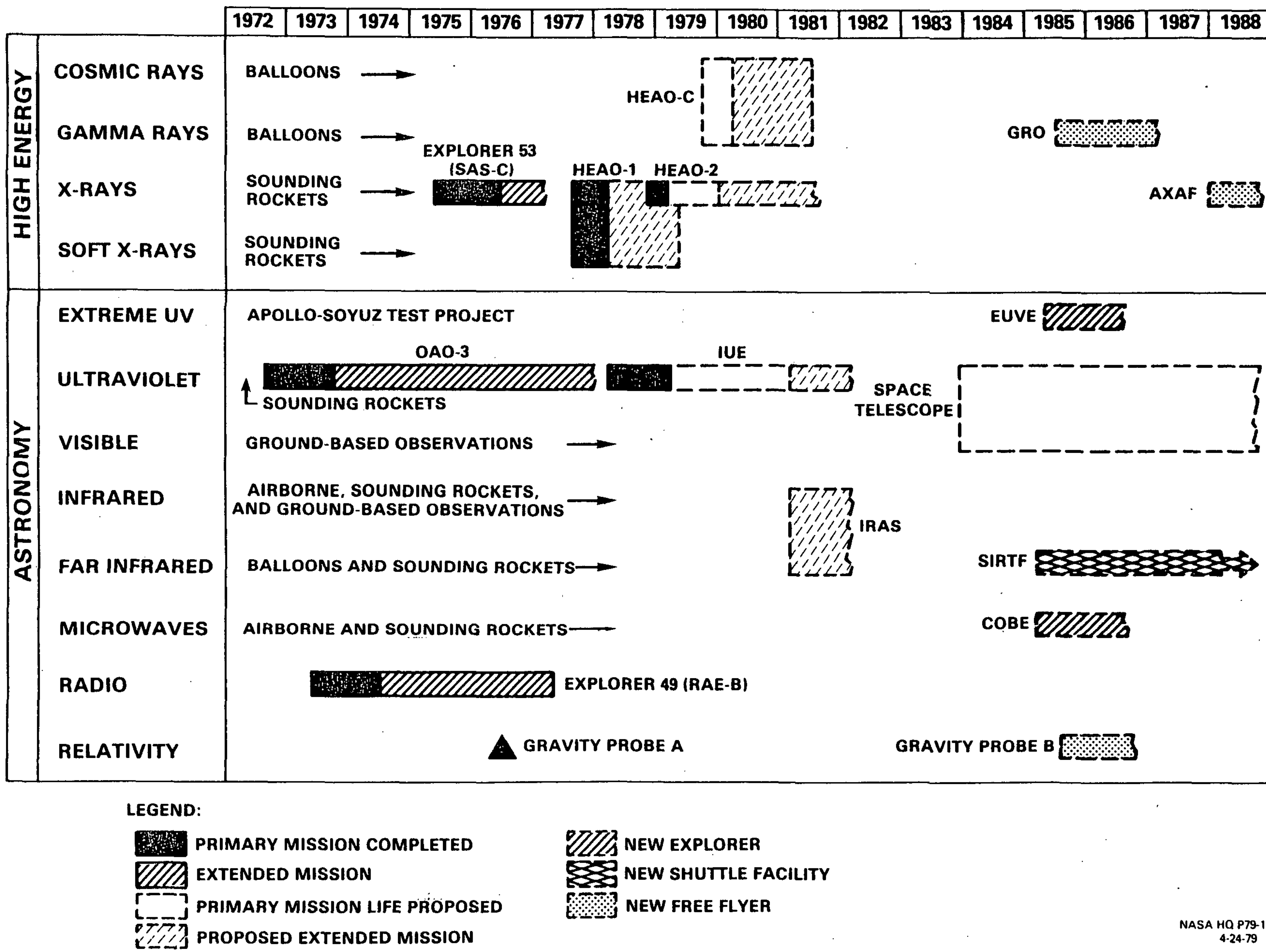


FIGURE 3—MAJOR ASTROPHYSICS MISSIONS



NASA HQ P79-1756(1)
4-24-79

FIGURE 4—MAJOR SOLAR TERRESTRIAL MISSIONS

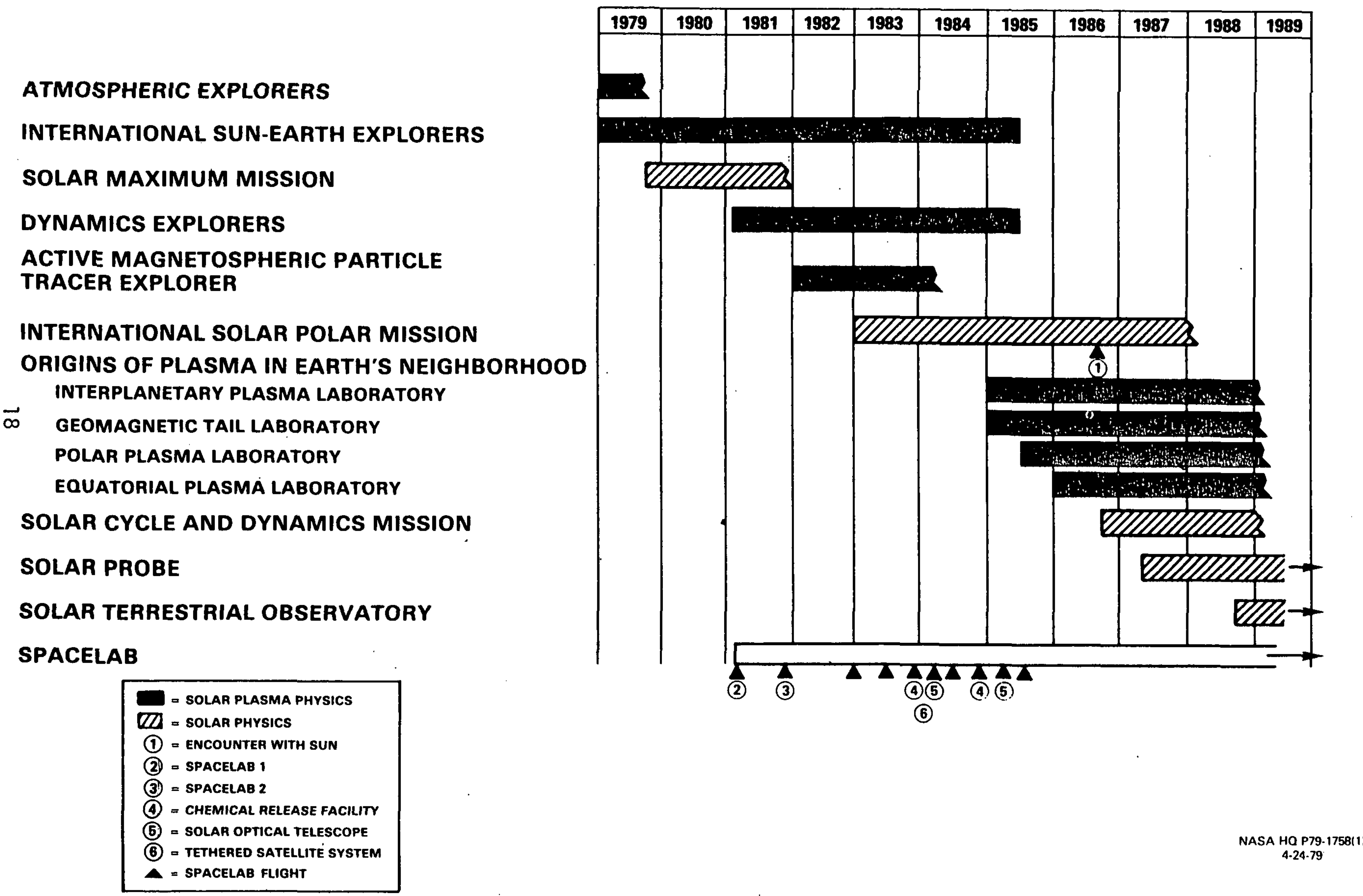
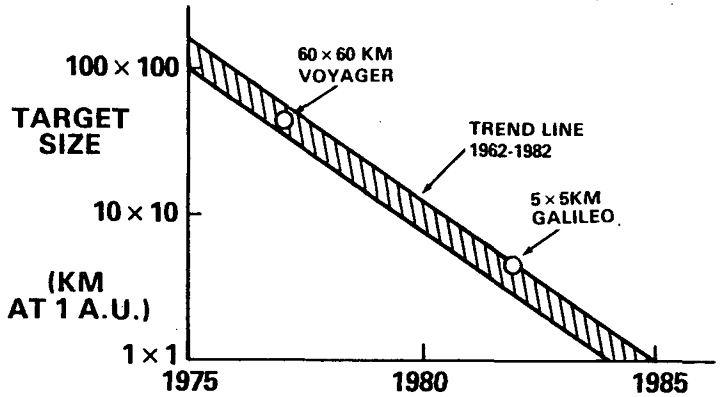
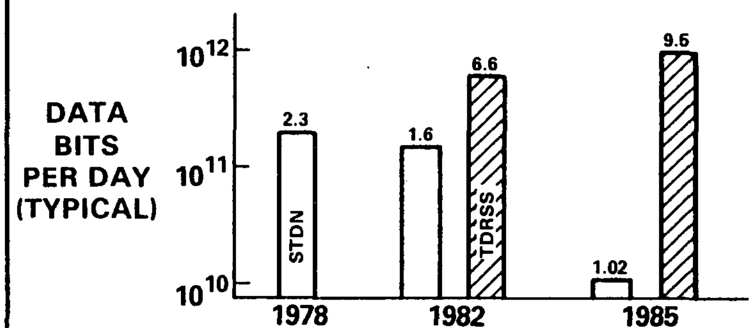


FIGURE 5—GROWTH IN TRACKING AND DATA SYSTEMS CAPABILITIES

DSN NAVIGATION ACCURACY



EARTH SATELLITE DATA ACQUISITION



DSN TELEMETRY DATA RATES

- 1964 MARINER IV .... 8⅓ b/s FROM MARS
- 1977-79 VOYAGER ...... 115 kb/s FROM JUPITER
- 1985 VOIR .... 8.0 Mb/s FROM VENUS
- FACTOR OF 4 IMPROVEMENT WITH LAAS (LARGE ADVANCED ANTENNA SYSTEM) ABOUT 1985

MENSURATION ACCURACIES (IN FIELD)

		1979	1982	1985
• LASER RANGING		10 cm	2-5cm	1-2 cm
• FREQUENCY STANDARDS..		10^{-14}	5×10^{-15}	10^{-15}
• TIME SYN-CHRONI-ZATION	AMONG STATIONS	1 μs	50 ns	5 ns
	TO TDRSS USERS	—	50 ns	5 ns
	INSTITUTIONAL	—	—	5 ns
• VLBI BASELINE 1 σ MEASURING ACCURACY	300 km	4-10 cm	2 cm	2 cm
	1,000 km	16 cm	5 cm	5 cm
	5,000 km	—	12 cm	12 cm

NASA HQ P79-1761(1)
4-24-79

SUPPORTING RESEARCH AND TECHNOLOGY

Development of a technology is part of a continuous process beginning with mostly basic research and ending with operational use. The Office of Aeronautics and Space Technology (OAST) conducts NASA's aeronautics technology work. In addition, OAST conducts the bulk of the technology work in NASA's space program -- in accordance with the expected requirements of that program. In the space program, however, as a technology matures, the center of activity shifts from OAST to one or more of the other program offices. Most of the technology work of those other program offices is related to their flight programs, but they also perform some non-project technology work. The major areas in which that non-project work is in process, as well as the major areas in which OAST is performing technology work, are described in Table 5 (see page 24).

To be able to assess more accurately the anticipated requirements for and status of technology and to coordinate the efforts of the program offices, the NASA Council created in 1978 the mechanism of "cross-cutting technology teams." The teams consist of representatives from all involved program offices and report to the NASA Council. Cross-cutting technology teams participating in the FY 1980-1984 planning process focused on large space systems, information systems, space power, and chemical propulsion.

The large space systems team includes the Office of Space and Terrestrial Applications (OSTA), the Office of Space Science (OSS), and the Office of Space Tracking and Data Systems (OSTDS) as potential users of future large spacecraft and OAST and the Office of Space Transportation Systems (OSTS) as suppliers of the required technology and in-space engineering demonstrations and services respectively. The team helped OAST focus its systems-technology program for space structures into the two principal areas of platform and antenna systems. The team is now conducting an intensive study of the future requirements for, and cost advantages of, integrated space platforms.

The information systems team identified the future requirements of OSTA and OSS for data acquisition and data management and proposed a phasing of the OAST programs for efficient sensing systems and the NASA End-to-End Data System that was compatible with those requirements. The team's activity resulted in the development of an OAST-OSTA joint program starting in 1980 to develop technology for satellite communications systems.

The power systems team involves OSTS as the developer of space power systems and OAST as the supplier of needed technology for the systems. The team's program calls for OSTS to develop power systems capable of delivering tens of kilowatts of power to support near-term Shuttle and other space operations, and for OAST to extend current technology to permit development of systems capable of delivering hundreds of kilowatts of power.

The chemical propulsion team involves OSTS as the developer and operator of space transportation systems and OAST as the supplier of propulsion technology. The team evaluated requirements for space transportation and related those requirements to propulsion needs. The team then organized an intercenter working group to translate those needs into a technology plan. The team is now assessing the U.S. industrial base to determine whether it will be adequate to develop required future systems.

INTERNATIONAL PROGRAMS

From its early years, NASA has conducted cooperative programs with agencies in other countries. Indeed, it is charged to do so by the Space Act. Mutual interest and no exchange of funds form the basis for the programs. During the five years of this plan, the number of cooperative programs could well continue to grow, and the resulting benefits to NASA's programmatic objectives increase. However, growing independent capabilities abroad could offset this in some measure. Both the cooperative trends and the independent trends reflect: foreign recognition of the utility of space technology for basic research and applications; rapid growth in foreign investment in government space programs and related commercial activities; and growing recognition in the United States that carefully structured cooperation with other countries can both complement and supplement NASA's program activities. Areas in which growth in NASA cooperation with other countries may be most significant during the next five years are discussed below.

Cooperative Activities

Space Shuttle and Spacelab

International interest in using the Shuttle and Spacelab could continue to grow during the early 1980s. Reimbursable (as distinguished from cooperative) use for scientific and applications purposes could be supplemented later with a second cooperative development and use of Shuttle-based multiuser instruments for such activities as infrared telescope observations and materials processing research.

Space Applications

Remote Sensing - Current widespread interest and participation in NASA's experimental Landsat program will continue to grow to the point where, by the mid-1980s, some fifteen foreign countries will be funding and operating stations to receive, process, and distribute Landsat satellite data. Foreign participation in other NASA experimental remote-sensing missions, such as atmospheric and ocean observations programs, could also expand during the years ahead.

Geodynamics - NASA plans to conduct, in cooperation with the U.S. Geological Survey, a geodynamics research program involving laser ranging and very long baseline interferometry from space to study movements in

Earth's crust so as to better understand earthquake phenomena. The program will include data exchanges in the early 1980s with foreign research organizations, particularly ones in Asia, Australia, Latin America, and Europe.

Materials Processing - Discussions are under way with West Europe, particularly Germany, on research projects in materials processing. Possible areas for cooperation are the sharing of flight opportunities and the development of facilities such as furnaces that are useful for a variety of experiments. Continued U.S. and foreign investments in materials processing research may lead to a variety of cooperative projects in areas where the proprietary and commercial interests of both sides can be adequately protected.

Communications - Arrangements are moving forward for Canadian, French and Soviet participation in NASA's satellite-aided search and rescue demonstration project. Several other countries, including Japan and Norway, are also considering participation. This project should be operational in 1982.

Space Science

Astronomy - For the Space Telescope, ESA is providing solar arrays and the faint-object camera in return for a portion of the observing time on the Telescope after its launch in 1983. NASA is also cooperating with the Netherlands and the United Kingdom in developing and launching the Infrared Astronomy Satellite in 1981. Possibilities for additional cooperative programs, particularly in the Explorer class of satellites, are being actively pursued.

Planetary Research - The German Ministry for Research and Technology is providing the retropropulsion module and some scientific investigations for the Galileo mission scheduled to be launched to Jupiter in 1982. In addition, NASA and the European Space Agency are studying possible cooperation on a mission that would fly by Halley's comet in 1985 and rendezvous with the Tempel-2 comet in 1988.

Solar Terrestrial - This year, NASA and ESA are starting to develop the International Solar Polar Mission, which will provide the first opportunity to explore solar and interplanetary phenomena from spacecraft traveling over the poles of the Sun. NASA also has the cooperation of Canadian and European scientists in planning the Origins of Plasma in Earth's Neighborhood program. One or more international cooperative projects in the early 1980s are likely to result.

Solar Energy

Photovoltaic cell arrays show promise as a source of electrical power to provide essential services, such as pumping water and grinding grain, to remote communities that have no other sources of power readily available.

NASA, in cooperation with the Department of Energy and the Agency for International Development, is developing demonstration projects to be evaluated for such applications.

Soviet Union

Cooperative exchanges between a Soviet Venus mission in 1983 and the planned U.S. 1984 Venus Orbiting Imaging Radar mission are likely. The United States will continue to fly experiments on the next series of Soviet biological satellites (with primates) in 1981, 1983, and 1985. In exchange, Soviet life sciences experiments are expected to fly on a Shuttle-Spacelab mission planned for 1982-1983. As noted above, the Soviets will begin in 1982 to participate with the United States, Canada, and France in a demonstration of a satellite-aided search and rescue system for ships and aircraft in distress. Further U.S.-Soviet discussions about starting a study of a possible joint Shuttle-Salyut mission have been postponed pending a U.S. interagency review of the subject.

China

Space cooperation with China became a possibility with the recent "understanding" according to which China will, under suitable conditions, purchase a civil-broadcast and communications satellite system and a Landsat ground station.

Reimbursable Launchings

A combination of firm orders and serious inquiries suggests that foreign countries will want to launch 12 to 18 geostationary communications satellites during the 1980-1984 period. Assuming 2 or 3 payloads per Shuttle launching, 5 to 9 Shuttle launchings total, or 1 or 2 per year, would be required. Similarly, 3 to 5 predominantly foreign Spacelab payloads in 1983 and 1984 appear likely, but some could be delayed to 1985.

Competition and Cooperation

During the period of this plan, foreign competition is likely to grow, especially in remote sensing and communications. France and Japan are already developing remote sensing satellites, and Western Europe and Japan are developing satellites and ground systems for communications. France's Ariane booster may compete in some respects with the Shuttle as a launcher. As in other fields, however, competition and cooperation could proceed in parallel.

TABLE 5 - MAJOR NON-PROJECT RESEARCH AND TECHNOLOGY

PROGRAM AREA	FUNDING IN FY 80 ($M)*	FIELD CENTERS INVOLVED	OBJECTIVES
SPACE AND TERRESTRIAL APPLICATIONS (OSTA)			
Global Weather (Including GARP)	11	GSFC, JPL, LaRC, MSFC, WFC	Define, develop, and demonstrate concepts for new and improved sensors; study atmosphere behavior and modeling; study and demonstrate space data for improving forecasts
Climate	9	GSFC, ARC, JPL, LaRC, WFC	Develop data base; study climate variables, modeling, and analysis; define climate observing system requirements
Severe Storms	5	MSFC, GSFC, KSC	Provide theoretical studies and research for basic understanding; develop and demonstrate techniques for interpreting remotely sensed data; define and develop concepts for instruments; develop forecasting models
Environmental Quality	11	LaRC, JPL, GSFC	Study and demonstrate use of remotely sensed data for monitoring atmospheric and water pollution; conduct studies to define sensors and systems for monitoring pollution
Ocean Processes	11	GSFC, JPL, LaRC, LeRC, WFC, NSTL	Develop data base; demonstrate use of remotely sensed data to solve oceans and ice research and operational problems; study ocean and coastal behavior; define and demonstrate concepts for advanced sensors

*Includes funding for work by universities, industry, and the listed NASA field centers.

TABLE 5 - MAJOR NON-PROJECT RESEARCH AND TECHNOLOGY (CONTINUED)

PROGRAM AREA	FUNDING IN FY 80 ($M)*	FIELD CENTERS INVOLVED	OBJECTIVES
OSTA (CONTINUED)			
Upper Atmosphere	13	ARC, GSFC, JPL, LaRC, LeRC	Conduct field measurements, laboratory studies, theoretical studies, and data analysis to expand scientific knowledge of Earth's stratosphere and mesosphere and to develop ability to assess threats to upper atmosphere
Agriculture and Resource Inventory Surveys through Aerospace Remote Sensing (AGRISTARS)	16	JSC, ARC, LaRC, GSFC, NSTL	Develop remote sensing techniques to augment or replace existing sources of information or provide new information for agriculture commodity forecasts and early warning and assessment of commodity condition
Renewable Resources Applied Research and Data Analysis (AR&DA)	7	JSC, ARC, LaRC, GSFC, NSTL	Research quantitative estimating techniques for assessing crop, range land, and forest conditions
Non-Renewable Resources AR&DA	4	JPL, GSFC	Conduct studies to improve capability to interpret Earth's geologic structure and chemical composition from space using visual, infrared, thermal, and active and passive microwave techniques; interpret magnetic and gravitational anomalies; research vegetative anomalies as indicators of underlying mineralization
Application Pilot Tests	3	NSTL, JSC, GSFC, ARC	Test techniques to detect land cover changes, inventory Navajo resources, delineate urban areas, inventory wildlife vegetation, inventory forest resources, assess irrigated lands, measure cotton crops, demonstrate land productivity, and map channel contours

*Includes funding for work by universities, industry, and the listed NASA field centers.

TABLE 5 - MAJOR NON-PROJECT RESEARCH AND TECHNOLOGY (CONTINUED)

PROGRAM AREA	FUNDING IN FY 80 ($M)*	FIELD CENTERS INVOLVED	OBJECTIVES
OSTA (CONTINUED)			
Mission Definition and Advanced Studies	3	JPL, JSC, GSFC	Study feasibility and identify options for future resource observation missions: conduct Phase B studies on Operational Earth Resources System, Stereosat, Earth Gravity Survey Satellite, Multispectral Resource Sampler
Materials and Process Research	4	MSFC, LaRC, JPL	Conduct ground-based research on material processes and properties to develop science and technology and advanced concepts for space experiments
Advanced Technology Development	1	MSFC, LaRC, LeRC, JPL	Provide technology for basic equipment and instrumentation for ground and space investigations
Equipment Definition Studies	2	MSFC, JPL	Evaluate system approaches to design and integrate STS payload equipment, select optimum approaches, and evaluate costs
Advanced Communications Research	5	LeRC	Explore technical feasibility and cost of key subsystems at 20 and 30 GHz such as multibeam antennas, onboard switching systems, low-noise and high-power amplifiers
Wideband 20/30 GHz Definition	1	LeRC	Review alternatives to flight testing key 20 and 30 GHz subsystems to ensure their transition to private sector and to minimize NASA's flight-test costs

*Includes funding for work by universities, industry, and the listed NASA field centers.

TABLE 5 - MAJOR NON-PROJECT RESEARCH AND TECHNOLOGY (CONTINUED)

PROGRAM AREA	FUNDING IN FY 80 ($M)*	FIELD CENTERS INVOLVED	OBJECTIVES
AERONAUTICS			
Generic Research	60	ARC, DFRC, LaRC, LeRC	Conduct continuous fundamental research in individual technical disciplines that are broadly applicable to many, frequently all, classes of aircraft
Conventional Takeoff and Landing (CTOL) Aircraft	157	ARC, DFRC, LaRC, LeRC	Improve operational efficiency and safety; reduce environmental effects
Rotorcraft	26	ARC, LaRC, LeRC	Increase technology base in aerodynamics and propulsion; evaluate, in flight, composite materials components, avionic components, and flying qualities
Supersonic Cruise	18	LaRC, LeRC	Study and understand major technical problems related to military and civilian supersonic cruise aircraft
General Aviation	9	LaRC, LeRC	Provide efficient aerodynamics; reduce drag; determine avionics and systems requirements; develop efficient low-noise propulsion systems; improve stall-spin characteristics and structural crashworthiness
Vertical or Short Takeoff and Landing (V/STOL) Aircraft	12	ARC, LeRC,	Develop data base and prediction methods for establishing design criteria for military and civilian V/STOL aircraft; complete flight experiments in STOL part of program
High-Performance Aircraft and Missiles	19	DFRC, LaRC, LeRC	Improve performance and effectiveness; conduct flight-research experiments stressing technology integration

*Includes funding for work by universities, industry, and the listed NASA field centers.

TABLE 5 - MAJOR NON-PROJECT RESEARCH AND TECHNOLOGY (CONTINUED)

PROGRAM AREA	FUNDING IN FY 80 ($M)*	FIELD CENTERS INVOLVED	OBJECTIVES
SPACE TECHNOLOGY			
Information Systems	26	ARC, GSFC, JPL, JSC, KSC, LaRC, LeRC, MSFC	Develop capabilities for acquiring, processing, and disseminating data in form responsive to user needs
Spacecraft Systems	37	GSFC, JPL, JSC, KSC, LaRC, LeRC, MSFC	Develop technology for space structures requiring new techniques and components for their in-orbit construction, deployment, and operation
Transportation Systems	36	ARC, JSC, LaRC, LeRC, MSFC	Develop technology for more fully reusable space transportation system with substantially lower operating costs
ENERGY SYSTEMS	5	JPL, LeRC, MSFC	Use NASA's aeronautics and space technologies, experience, and facilities to support needs of Department of Energy and other government organizations in implementing national energy policy
SPACE SCIENCE (OSS)			
Theory and Laboratory Work	25	GSFC, JPL	Evaluate interactions of Mars' soil and atmosphere; develop theory in astronomy, solar physics, and related areas of physics such as atomic parameters; analyze upper atmospheric processes; interpret and combine results
Ground-Based Observations	11	ARC, GSFC, JPL, JSC	Complement space measurements; provide basic data for space missions; supplement space data; maintain facilities

*Includes funding for work by universities, industry, and the listed NASA field centers.

TABLE 5 - MAJOR NON-PROJECT RESEARCH AND TECHNOLOGY (CONTINUED)

PROGRAM AREA	FUNDING IN FY 80 ($M)*	FIELD CENTERS INVOLVED	OBJECTIVES
OSS (CONTINUED)			
Instrument Development	17	GSFC, JPL	Develop detectors and experimental techniques in all areas, including manned support systems
Data Analysis	23	GSFC, JPL, JSC	Provide methods for interpreting data; extend use of data; make comparative studies of data; enable planetary cartography
Suborbital Programs	8	GSFC, JPL, JSC	Test concepts for advanced instruments; determine special opportunities for solar physics experimentation; obtain supporting data for atmospheric studies
Space Medicine	14	JSC	Provide medical services to Shuttle crews; develop requirements for future work; determine cause of and methods for preventing observed changes; maintain medical standards
Planetary and Space Biology	9	ARC, JPL	Conduct biomedical research related to stresses on humans in space flight; study life-support requirements for long-term space flight, including control of ecological environment; study biological evolution in planetary context and distribution of life in the universe

*Includes funding for work by universities, industry, and the listed NASA field centers.

TABLE 5 - *MAJOR NON-PROJECT RESEARCH AND TECHNOLOGY (CONTINUED)*

PROGRAM AREA	FUNDING IN FY 80 ($M)*	FIELD CENTERS INVOLVED	OBJECTIVES
OSS (CONTINUED)			
Advanced Development	15	ARC, GSFC, JPL, MSFC	Perform definition studies for future missions on explorer class of satellites, Spacelab, and major free-flying satellites; participate in development of ion drive (SEPS); define planetary flight program
SPACE TRACKING AND DATA SYSTEMS			
Tracking, Orbit Determination, and Ground-Based Navigation	3	GSFC, JPL	Develop ground-based technology for cost-effective support of more accurate planetary targeting requirements, missions with high velocities and accelerations, very long baseline interferometer, planetary radar, navigational accuracy analysis, experiments, and demonstrations
Spacecraft to Ground Communications Telemetry and Command	3	GSFC, JPL	Develop ground-based technology for missions requiring higher and more variable data rates, higher frequencies, data acquisition and command at greater distances, coded signals, and high-rate video or radar imaging; develop new techniques and ensure availability of cost-effective support
Network Control and Operations Technology	1	GSFC, JPL	Develop techniques for network and station control and operations such as unattended systems operation, radio-frequency inteference monitoring and control, and systems tests in an operational enviroment
Data Handling and Processing	2	GSFC, JPL	Develop techniques, data processing, and control software for tracking and data acquisition functions such as integration through networking, program operations control, and modeling networks and radio-frequency interference data-processing network operations

*Includes funding for work by universities, industry, and the listed NASA field centers.

SCHEDULES AND MILESTONES

Table 6 presents a chronological list of the significant events that are connected with or will result from the NASA program described in this report.

Figure 6 shows when the major capabilities and facilities that the program will produce will become available.

Table 7 tabulates the estimated launchings of the Shuttle and its payloads, including Spacelab, and displays the estimated number of Shuttle orbiters that are expected to be in service each year from 1979 through 1984.

FUNDING REQUIRED

Figure 7 shows the funding required for the program described in this plan. The funding trends apparent on the figure show the effects of the major goals described on pages 1, 3, and 4. Funding for the Shuttle decreases rapidly as Shuttle development approaches completion and production of the complete fleet progresses. Space Transportation funding increases as the Shuttle makes more space activity possible. Later, Space Transportation funding levels off and then decreases slowly as improvements in operating and managing procedures are developed.

Needs for improvements in the Shuttle and extensions of its initial capabilities are already recognized, and more will be discovered as we gain experience from operating it. In addition, the need for starting several space engineering projects during the later part of the FY 1980-1984 period is apparent. The funding needed for all these activities is represented by the area labeled Space Systems Engineering.

In accordance with the President's Space Policy and the major goals of the Agency, the funding for applications grows rapidly. Funding for aeronautics, space technology, and space science also grows, but at a slower rate.

TABLE 6 - SIGNIFICANT EVENTS

1979-1981

Peak of Solar Activity (Solar Maximum, 11-Year Cycle)

1979

Initiation of Orbital Flight Testing of Space Shuttle
Completion of First Global Experiment in Acquisition of Comprehensive, Worldwide Weather Data in Cooperation with World Meteorological Organization
Launch of High Energy Astronomy Observatory-C
Pioneer 11 Flyby of Saturn (First Saturn Encounter)
Voyager 1 and 2 Encounters with Jupiter
Launch of Solar Maximum Mission (First Reusable Free Flyer)

1980

Completion of World Atlas 1 (Global Geologic Maps Based on Landsat Multispectral Imagery)
Completion of 1980 Global Survey of Earth's Magnetic Field with Magsat
Research and Development Facilities for Materials Experimentation in Space Available for Lease
Completion of Proof-of-Concept Flight Tests of Quiet Short-Haul Research Aircraft and Tilt-Rotor Research Aircraft
Voyager 1 Encounter with Saturn and Titan
Initiation of Long-Term Measurement of the Solar Constant

1981

First Operational Flight of Space Shuttle (First Reusable Space Transportation System)
First Flight of Spacelab (Reusable Space Research Laboratory)
Initiation of Development of Solar Electric Propulsion System
Initiation of Development of 25-KW Power Module (Generation of Power in Space for Use in Space)
Initiation of Development of Tethered Satellite System
Initiation of Development of National Oceanic Satellite System
Introduction of Thematic Mapper on Landsat-D into Earth Resources Program to Increase Resolution and Broaden Spectral Coverage of Earth Observations
Completion of Modification of 40X80-Foot Wind Tunnel at Ames Research Center to Increase Airflow Speed and Add 80x120-Foot Test Section
First Flight of Long-Duration Exposure Facility for Experiments in Space
Initiation of Space-Based Infrared Astronomy Activities with Flight of Infrared Astronomy Satellite
Initiation of Development of Gamma Ray Observatory
Voyager 2 Encounter with Saturn and Titan
Initiation of Development of Venus Orbiting Imaging Radar
Initiation of Development of Origins of Plasma in Earth's Neighborhood
Tracking and Data Relay Satellite System Operational

TABLE 6 - SIGNIFICANT EVENTS (CONTINUED)

1982

Initiation of Design of 200- to 500-KW Power Module
Initiation of Measurements of Global Radiation Balance Using Earth Radiation Budget Satellite
Completion of Ground Testing of Medium-Sized Primary Structures Fabricated from Composite Materials for Current Transport Aircraft
National Transonic Facility (Wind Tunnel) at Langley Research Center Operational
Completion of Spacelab Data Processing Facility
Launch of First Dedicated Shuttle-Spacelab Missions for Physics and Astronomy and for Life Sciences
Initiation of Development of Gravity Probe-B
Launch of Galileo Mission to Orbit Jupiter and Probe its Atmosphere (with Flyby of Mars)
Initiation of Development of Halley Flyby/Tempel 2 Rendezvous

1983

Completion of Shuttle Facilities at Vandenburg AFB
Initiation of Development of Orbital Transfer Vehicle
First Use of Remote Service Module (Teleoperator-Based System) for Placement, Retrieval, Maintenance, and Repair of Satellites
Completetion of Flight Evaluation of Low-Cost Civil User Equipment for NAVSTAR Global Positioning System
Demonstration of 600°F Graphite Polyamide Structures for Future Supersonic Transport Systems
Launch of Space Telescope (First Permanent Observatory in Space)
Initiation of Development of Advanced X-ray Astrophysics Facility (First Permanent X-ray Observatory in Space)
Launch of International Solar Polar Mission (First Spacecraft that will Fly over the Sun's Poles)
First Use of Shuttle-Borne Tether Facility

1984

Launch of First Upper Atmospheric Research Satellite (Scientific Understanding of Physical Processes in Earth's Upper Atmosphere)
Galileo Jupiter Orbit Insertion, Probe, Entry, and Encounters with Jupiter's Satellites
Launch of Venus Orbiting Imaging Radar (First Global High-Resolution Maps of Venus' Surface)
Initiation of Development of Solar Probe

FIGURE 6 - AVAILABILITY OF MAJOR CAPABILITIES AND FACILITIES

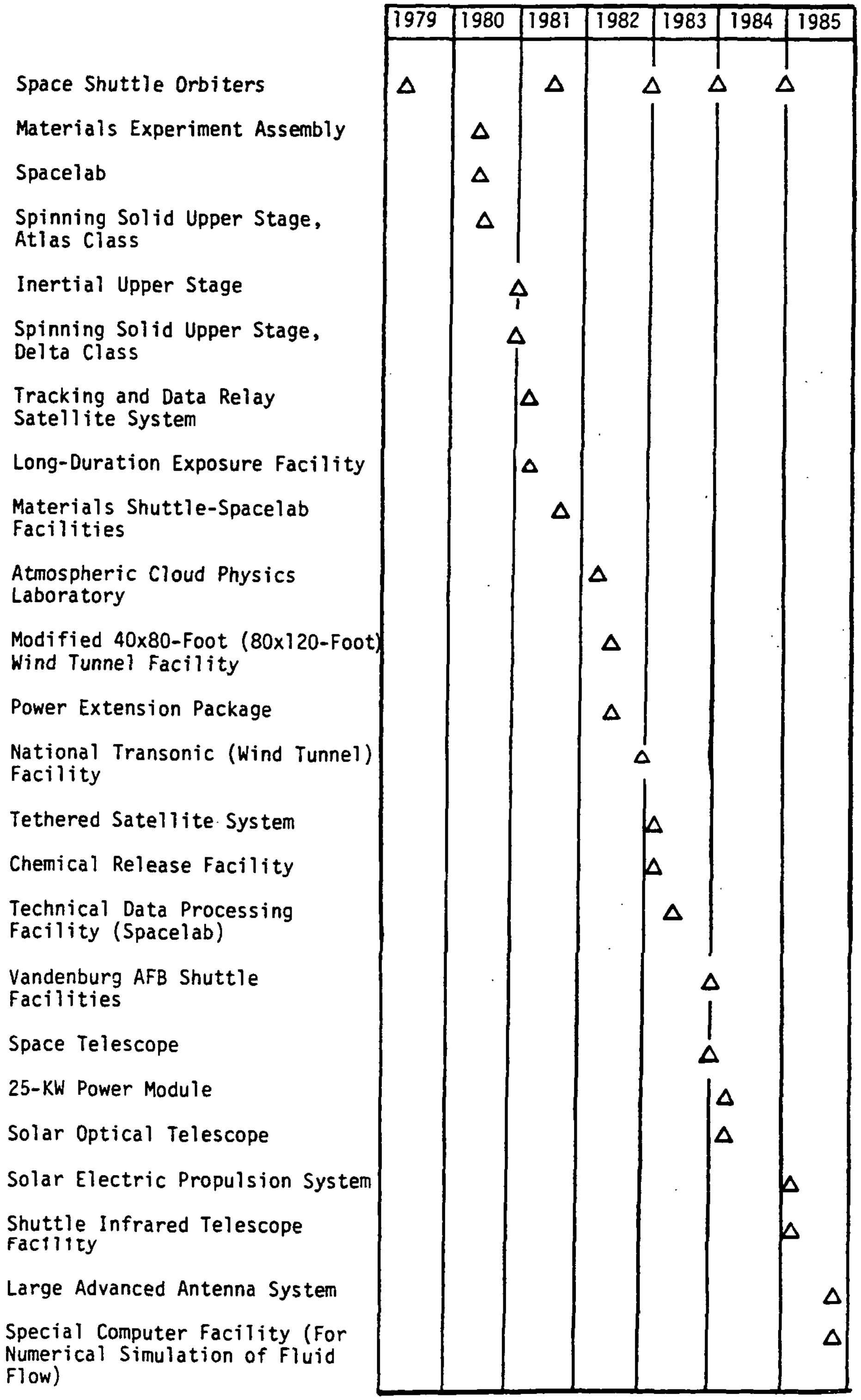
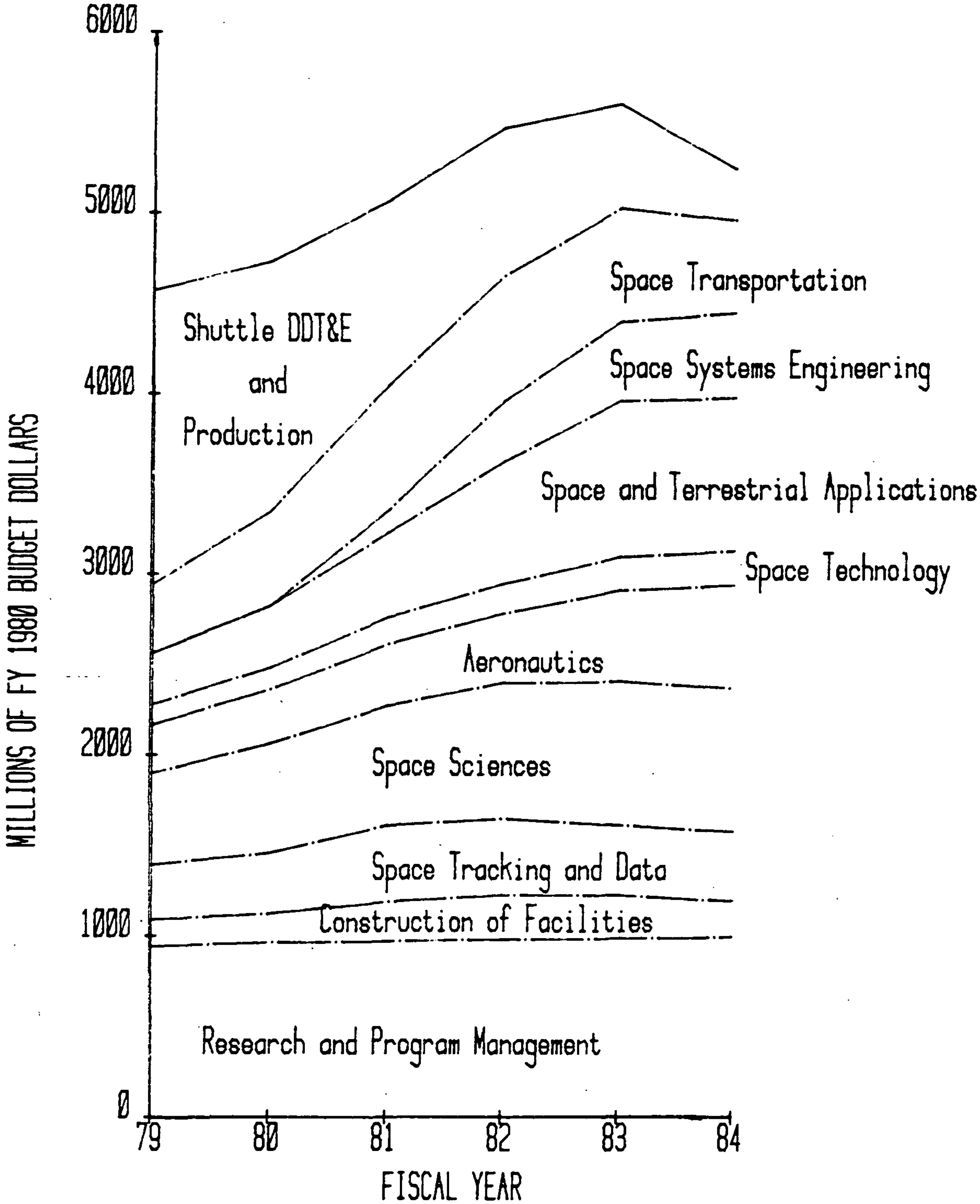


TABLE 7 - ESTIMATED SHUTTLE FLIGHTS

	1979	1980	1981	1982	1983	1984
Orbital Flight Test Flights (NASA)	1	4	1			
Spacelab Flights						
NASA			1	4	5	7
Foreign					2	2
Total			1	4	7	9
Automated Payloads (Free-Flying Spacecraft)						
NASA				3	2	4
Other U.S. Government Agencies (non-DOD)			1	-	-	2
U.S. Commercial			4	3	3	3
Foreign			1	2	2	1
Department of Defense (DOD)				3	5	11
Total			6	11	12	21
Total Launches						
NASA	1	4	2	7	7	11
Other U.S. Government Agencies (non-DOD)			1	-	-	2
U.S. Commercial			4	3	3	3
Foreign			1	2	4	3
Department of Defense (DOD)				3	5	11
Reflights				1	1	1
Total	1	4	8	16	20	31
Shuttles Available (Shuttle-years)	0.1	1.0	1.0	1.6	2.9	3.9

FIGURE 7 - NASA PROGRAM FUNDING



CONTENTS

CONTENTS (CONTINUED)

TABLES

FIGURES

SPACE TRANSPORTATION SYSTEMS PROGRAM

The Space Transportation Systems program is a major element in NASA's conformance to the Space Act of 1958. It provides the required capabilities for "carrying instruments, equipment, supplies, and living organisms through space" and contributes to "preservation of the role of the United States as a leader" in applying space technology for the benefit of all mankind and the permanent occupancy of space. The program is directed toward effective use of humans in space, and is structured to support a national space program that meets the objectives of the current U.S. Civil Space Policy.

The program embraces three classes of capabilities -- transportation, satellite services, and space platforms. Within each of these classes, there is a planned evolution designed to provide increasingly more performance and a progressively broader range of support services.

EVOLUTION OF CAPABILITIES

Figure 8 illustrates that planned evolution and shows the key NASA missions that will require the support the planned program will provide. On that figure, space systems and capabilities currently under development are in shaded areas.

INITIAL TRANSPORTATION CAPABILITY

The Space Shuttle (Shuttle), Inertial Upper Stage (IUS), and Spinning Solid Upper Stages (SSUS) comprise our initial transportation capability. They will provide users with efficient, economical access to space, as well as services that today's expendable launch systems cannot make available.

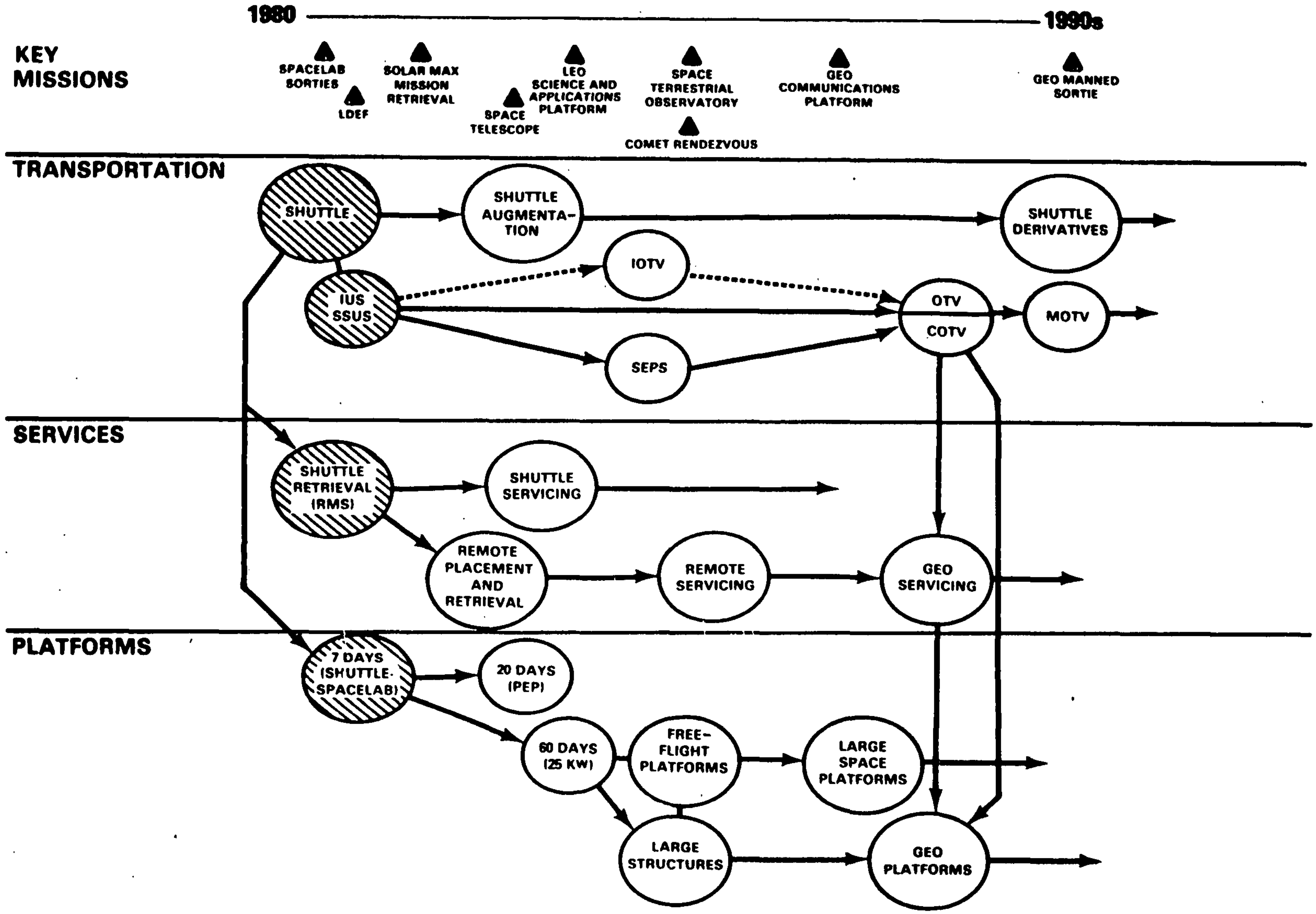
INITIAL SATELLITE SERVICES CAPABILITY

The Shuttle-mounted Remote Manipulator System will constitute our initial capability for providing to satellites the services of retrieval, repair, and maintenance.

INITIAL SPACE PLATFORMS CAPABILITY

Spacelab is a reusable system that will be transported to and from low Earth orbit in the cargo bay of the Shuttle. It will remain in the cargo-bay throughout the flight to serve as a platform for experiments and instruments. It will provide a pressurized "shirt-sleeve" laboratory (the Module), one or more unpressurized pallets, and standard services such as electric power and environmental control for the Module. A team of up to four specialists (men or women) will operate Spacelab's

FIGURE 8—EVOLUTION OF CAPABILITIES



LEO	LOW EARTH ORBIT	IOTV	INTERIM OTV
GEO	GEOSYNCHRONOUS ORBIT	COTV	CARGO OTV
LDEF	LONG DURATION EXPOSURE FACILITY	MOTV	MANNED OTV
IUS	INERTIAL UPPER STAGE	SEPS	SOLAR ELECTRIC PROPULSION SYSTEM
SSUS	SPINNING SOLID UPPER STAGE	RMS	REMOTE MANIPULATOR SYSTEM
OTV	ORBITAL TRANSFER VEHICLE	PEP	POWER EXTENSION PACKAGE

NASA HQ P79 1754-1
4 24 79

experiments and instruments, but will spend their off-duty time in the Shuttle's cabin. The Shuttle will support Spacelab, Spacelab will extend the Shuttle's capabilities, and the Shuttle and Spacelab together will serve as a short-stay (nominal mission duration of seven days) space station.

MID-1980S CAPABILITIES

The initial capabilities just described will satisfy the needs of the key missions shown at the upper left corner of Figure 8: Spacelab sorties for the Office of Space Science (OSS), Space and Terrestrial Applications (OSTA), and Aeronautics and Space Technology (OAST); launch of the Long Duration Exposure Facility for OAST; retrieval of the Solar Maximum Mission spacecraft for OSS; launch of the Space Telescope for OSS; and launch of a low-Earth-orbit platform for OSS and OSTA experiments and instruments. However, by the mid-1980s, needs will develop for additional major capabilities.

The Science and Applications Platform and other satellites will require deployment, retrieval, maintenance, and repair services, both near to and remote from the Shuttle. Those services will require tools for use by astronauts in extravehicular activity and teleoperators (powered spacecraft remotely operated by astronauts in the Shuttle). OSS planetary missions will require the propulsion capabilities that the Solar Electric Propulsion System will be developed to provide. Our platform capabilities will have to evolve to satisfy the increasing needs of experiments for more power and longer duration missions. To increase the capability of the Shuttle-Spacelab platform, we will develop the Power Extension Package. To provide adequate power for some free-flying spacecraft, we will develop the 25-KW Power Module and other supporting elements.

LATE 1980S AND EARLY 1990S CAPABILITIES

Throughout the 1980s and into the early 1990s, the Shuttle will continue to provide our basic capability for transportation to and from space and for providing services to space vehicles. However, as our activities shift with time to larger spacecraft and from low Earth orbit to geosynchronous orbit, increasingly greater augmentation of the Shuttle's capabilities will become necessary. Because the IUS and SSUS will not be able to deliver to geosynchronous orbit the larger, heavier payloads planned for that period, orbital transfer vehicles (OTVs) will have to be developed. An Interim Orbital Transfer Vehicle is under consideration but may be bypassed in favor of going directly to an OTV to transfer cargo, such as elements of large geosynchronous platforms, and an OTV to transfer humans. Concurrent development will be required for special geosynchronous servicing hardware and techniques. The large geosynchronous platforms will evolve from earlier, smaller platforms and will have as much commonality as possible with them with regard to hardware, materials, and structures. This plan addresses those platforms only to the extent of identifying and calling for the initiation of development of some leading technology.

PROGRAM STRATEGY

Our strategy for achieving the evolution of capabilities described above is to capitalize and build on the capabilities of the Shuttle in order to meet, in a timely fashion, the growing requirements for support of missions that will fulfill national space objectives. To implement that strategy, we plan to: reduce the cost of transportation; improve the Shuttle's performance by augmenting its thrust and by extending to high-energy orbits its ability to retrieve payloads; develop capabilities for maintaining and repairing spacecraft in space; extend our ability to provide satellite services to remote and, eventually, high-energy orbits; increase mission duration; and increase the power and services available to spacecraft, ultimately to the point where we can provide those services and power in both low Earth orbit and geosynchronous orbit independent of the Shuttle.

GOALS AND OBJECTIVES

The primary goals of the Space Transportation Systems program are to develop and operate systems that will efficiently and effectively satisfy the space-transportation and space-flight needs of the civil sector of the United States and, when appropriate, to make those capabilities available to all elements of the federal government.

The following specific objectives are directed toward the fulfillment of those goals:

1. Development and production of the Shuttle; participation with the Department of Defense in developing and producing the IUS and with the European Space Agency in the Spacelab program; development of other auxiliary flight and ground systems required in support of the Shuttle, the IUS, and Spacelab; establishment of routine mission operations; and efficient use of expendable launch vehicles until an effective transition can be made to full operations with the Shuttle

2. Development and operation of orbit-transfer vehicles for geostationary, Earth-departure, and other high-energy orbits, with concurrent development and operation of maneuvering, servicing, and retrieval services both near to and far from the Shuttle

3. Evolutionary improvement in the capability of the Shuttle, including its payload delivery performance, flight duration, payload services, power, and other supporting capabilities

4. Development of platforms to host and support aggregated mission equipments for communications, observation, science, and power transmission uses, and to support development testing of new techniques for space construction, materials processing, and instrument tests

5. Provision for evolution of human-tended capabilities leading to permanent functions in space for research, experimentation, industrial processes, and exploration.

Early transportation, satellite services, and space platform operations will expand the opportunities for use of space both for potential applications that are understood today, and for applications not yet conceived. Those operations will also reveal needs for improvements in our capabilities. We will continue to update our program plans to reflect those revealed needs and to define a feasible and evolutionary approach for fulfilling our goals and objectives.

PLANNING ASSUMPTIONS

The Space Transportation Systems program recognizes that users will require, during the next decade, greater transportation and orbital support capabilities such as increased performance, power, and mission duration; reduced cost per operation or experiment; specialized environments; and increased geosychronous services. Demand will increase for reuse of satellites and for services such as maintenance and repair of satellites. Power levels will grow from 25 to multi-100s of kilowatts to allow construction and use of large structures in space, such as solar collectors and large antennas, to fill the Nation's needs for energy and communications.

Future capabilities will be evolutionary and will grow from the existing base consisting of the Shuttle, Spacelab, and Inertial and Spinning Solid Upper Stages, all of which are currently under development.

The program also assumes that science and applications will receive a larger percentage of NASA's budget after Shuttle development is complete, but that adequate funding will be provided to increase transportation, satellite services, and space platform capabilities to provide new vistas for science, applications, and technology development activities. A balanced program is necessary to ensure the continuing technological leadership of the United States in all phases of the space program.

Another assumption is that European cooperative efforts will continue in the form of a limited follow-on program of Spacelab development having potential applicability to space platform development.

We also assume limited, but growing, commercial involvement in space operations, principally in developing end-item equipment rather than basic transportation and support systems.

PROGRAM CONTENT

The Space Transportation Systems program consists of three major activities:

1. Design, development, test, and evaluation (DDT&E) and production of the Space Transportation System (STS) -- the combination of Shuttle, Spacelab, IUS, and SSUS mentioned previously
2. Space flight operations, including those with expendable launch vehicles
3. Space systems engineering -- the evolutionary development of transportation, satellite services, and space platform capabilities.

SHUTTLE DDT&E AND PRODUCTION

Initial Configuration

The Shuttle will provide users with efficient, economical access to space, as well as with capabilities that today's expendable launch vehicle systems cannot supply. Those additional capabilities include retrieving payloads from orbit for reuse; servicing and repairing satellites in space; transporting space laboratories to orbit, operating them there, and returning them to Earth; and performing rescue missions. Those capabilities will greatly enhance the flexibility and productivity of space missions and will reduce the cost of space operations.

Table 8 lists the major capabilities of the STS. The baseline Shuttle will carry personnel and payloads to low Earth orbit, support them and their operations there for a nominal period of one week, and then return them to Earth. It will be able to carry into space in its large cargo bay payloads weighing as much as 29,500 kilograms (65,000 pounds), and will provide a "shirt-sleeve" environment for its crew and passengers. For some years, there will be only one class of passengers-- the science and engineering specialists responsible for the experimental work on each flight.

The Shuttle, IUS, SSUS, and Spacelab are scheduled to become operational in 1981, and will satisfy the transportation needs of the operational and developmental payloads proposed for flight on the Shuttle by many prospective users--NASA, the Department of Defense, other U.S. Government agencies, universities, and commercial and international organizations.

Planned Improvements in Shuttle

Some improvements in the Shuttle will be necessary to bring it up to its full operational specifications. The Shuttle's ability to deliver its maximum (65,000-pound) payload to orbit and to achieve its full

TABLE 8 - STS CAPABILITIES

SHUTTLE

- Delivery of Tended and Untended Payloads and Satellites to Low Earth Orbit
- Repair and Retrieval of Spacecraft
- Delivery of Propulsive Stages and Satellites to Low Earth Orbit for Transfer to High-Energy Orbits
- Delivery of 29,500 kg (65,000 lbs.) of Payload to 150-nmi Circular Orbit (Due East)
- Delivery of 14,500 kg (32,000 lbs.) of Payload to Polar (98^{o}) 150-nmi Circular Orbit and Retrieval of 11,400 kg (25,000 lbs.) of Payload in a Single Flight

SPACELAB

- Payload Capability: 4,800-8,800 kg (10,600-19,400 lbs.)
- Pressurized Volume: 8-22 m^3 (282-777 ft^3)
- Average Electrical Power: 3-5 kW
- Payload Specialists: 1 to 4
- Nominal Mission: 7 Days

IUS

- Delivery of up to 2,270 kg (5,000 lbs.) to Geosynchronous Orbit
- Delivery of 680 to 2,270 kg (1,500-5,000 lbs.) to Sun-Synchronous Orbit from Kennedy Space Center
- Planetary Capability: 900 kg (1,980 lbs.) (Twin Stage with Spinner) to Outer Planets (C_3=115)

SSUS

- Delivery of 1,050 kg (2,300 lbs.) to Geosynchronous Transfer Orbit (SSUS-D)
- Delivery of 2,000 kW (4,400 lbs.) to Geosynchronous Transfer Orbit (SSUS-A)

mission duration will require extension of the operating envelope of the Shuttle's main engines and weight reductions in the external tank and the orbiter. We have provided for those requirements in our DDT&E program. In addition, we are planning thrust augmentation for the Shuttle in the form of strap-on rockets. That capability will be needed in 1984 to meet the most demanding payload-trajectory combination currently expected to be flown from Vandenberg Air Force Base (VAFB).

Fleet Size

Since the decision in 1972 to develop the reusable STS to support all national space activity, both civil and military, NASA has led a continuing multiagency effort to estimate payload requirements, objectives, and levels of activity for a decade ahead. Those projections represent reasonable expectations both for continuing programs and for programs expected to evolve in an environment of increasing dependence on space in support of future national goals.

Concurrently, we have evaluated the flight-rate capability of various sizes of fleets under realistic operating conditions. We have refined those analyses as better data have become available. For example, a fleet of four Shuttles operating from two sites, Kennedy Space Center (KSC) and VAFB, can provide an annual flight rate of 38 (5-day, 2-shift operation) to 53 (7-day, 2-shift operation). With adjustment for a lower rate during the build-up period, those rates will provide 380 to 520 flights during the 1971 through 1992 period. For that same period, the currently estimated need is for 487 flights (Table 9). We revise the STS Traffic Model continuously as users define their plans more completely, but that 487-flight requirement is as accurate an estimate as we can make on the basis of currently available information.

The forecast for full use of the STS is becoming increasingly positive. Nearly all the 1981 and 1982 flights have been booked for customers from whom NASA has received "earnest money," for approved NASA payloads, or for committed Department of Defense payloads; and many additional requests for flight accommodations are under active negotiation. Also, space users have increased significantly the number and depth of their studies and analyses seeking new activities in space that will exploit the Shuttle's unique capabilities. Consequently, increasingly greater exploitation of space appears likely.

Two additional factors must be considered in determining fleet size. The first is that, by the mid-1980s, this Nation's total space activity will be dependent on the STS. The other has to do with the possibility of loss of a Shuttle. The probability of loss is low. However, if one were to occur, it could seriously disrupt our national space program. Considering those two factors and the expected growth in space activities, we have concluded that the 4-Shuttle fleet being build will be adequate during the early years of STS operations, but that a fifth Shuttle may become needed in later years.

TABLE 9 - ESTIMATED SHUTTLE FLIGHTS

NUMBER OF FLIGHTS

LAUNCH POINT	1979	1980	1981	1982	1983	1984	1985	1986	1987	1988	1989	1990	1991	1992*	TOTAL
KSC (ORBITAL FLIGHT TESTS)	(1)	(4)	(1)												(6)
KSC			7	16	18	25	30	36	34	40	38	41	38	30	353
VAFB			—	—	2	6	12	15	18	18	15	16	17	15	134
TOTAL FLIGHTS			7	16	20	31	42	51	52	58	53	57	55	45	487

*9 Months

The current production program provides for four Shuttles and certain items having long lead time. Those items are necessary to ensure efficient initiation of a fifth Shuttle. While an early go-ahead decision on the fifth Shuttle would save some cost, postponement of the decision for a few years would not incur major additional costs and would provide time for assessing more accurately the need for the fifth Shuttle. However, delivery schedules show that deferral of go-ahead for the fifth Shuttle beyond FY 1983 would entail high risk of schedule extensions and prohibitive cost penalties to reestablish phased-out subcontractor capabilities.

This plan includes production of the fifth Shuttle, with funding to start in FY 1981. The funding requirements are shown in Figure 13 (page 63).

SPACE FLIGHT OPERATIONS

Space flight operations encompass all the activities required to plan, schedule, and conduct space missions. They include a variety of elements such as people, ancillary flight hardware, facilities, plans, and operating procedures. Those elements include facilities and equipment on the ground, flight crews, launch crews, flight planning and mission control functions, computers and communications links to support them, logistics support, planning and scheduling functions, user interfaces, and overall management of the complete enterprise.

This second major activity of the Space Transportation Systems program consists of current work that has been approved, in the sense that it is included in the budget runout, and of work we plan to initiate in 1981 to make a number of improvements in the Shuttle. The current "approved" work includes expendable launch vehicles, as well as the Shuttle.

Current Program

Expendable Launch Vehicles (ELVs)

ELVs currently support NASA launches and the launches of other U.S. Government, international, and commercial agencies and organizations, as well. From 1981 through 1984, we will phase ELVs out as the Shuttle takes over all our launching commitments. During this period, however, we will maintain an ELV capability as a back-up in case of a slip in the Shuttle's schedule. That backup capability will be particularly important for critical national security systems that must have assured launch capabilities.

Shuttle

Starting with its first operational flight in 1981, the Shuttle will rapidly replace ELVs as this Nation's launch vehicle. It will reintroduce into the space flight operations equation the factor of flight crews. Another major difference the Shuttle will bring is reusability, with an attendant need for rapid turn-around between flights. The most important improvement it will provide, however, is its versatility. That versatility will challenge our ability to make the most effective possible use of this new system.

Shuttle Improvements

Despite the Shuttle's outstanding capabilities, we fully recognize that further improvements will become necessary. Experience from previous aerospace programs indicates that the need for changes in the Shuttle will become evident as we gain operational experience with its integrated flight and ground systems. We will then have to analyze whether implementation of the changes will increase cost savings, reliability, or safety. The changes involved generally fall into the category of product improvement in such major subsystem areas as propulsion, structures, thermal protection, mechanical, auxiliary power, environmental control, hydraulics, electrical power, life support, and avionics. We expect the engineering design and development activity for those areas of product improvement to focus on clear trade-offs between performance and cost. The improvements may include increased stay time in space, in-orbit power generation, and provision of orbit maneuvering systems and rendezvous and docking equipment.

Recent studies have shown that there are, in addition to those product improvements, two potential areas for Shuttle growth of the type commonly called block changes or model changes in aerospace programs. Those two block changes, described in the next section of this report, are replacement of the Shuttle's solid rocket booster with a liquid rocket booster and development of a heavy-lift launch vehicle derived from the Shuttle.

This plan provides for funding of Shuttle improvements to start in FY 1981, as shown on Figure 13 (page 63).

SPACE SYSTEMS ENGINEERING

The Space Systems Engineering program consists of new initiatives to improve all three of the classes of capabilities comprising the Space Transportation Systems program -- transportation, satellite services, and space platforms.

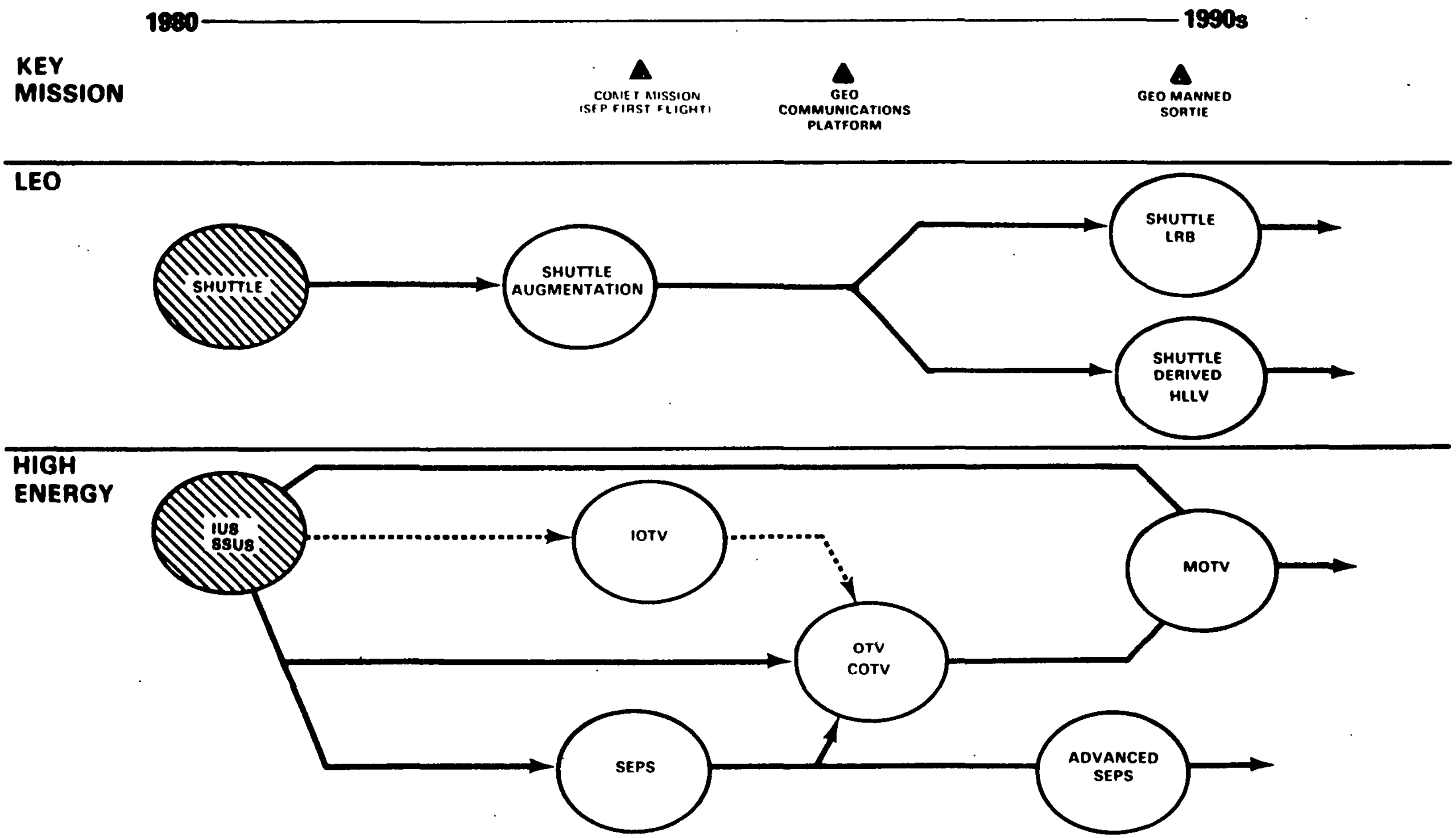
Transportation

Figure 9 shows the planned evolution of space transportation systems during the 5-year period of this plan and on into the 1990s.

Current and Planned Program

The Shuttle is in development and is expected to become operational in 1981, following completion of development flights (orbital flight tests) scheduled to begin in late 1979. By 1984, the Shuttle's low-Earth-orbit

FIGURE 9—EVOLUTION OF TRANSPORTATION CAPABILITIES



SEPS SOLAR ELECTRIC PROPULSION SYSTEM
GEO GEOSYNCHRONOUS ORBIT
LEO LOW EARTH ORBIT
LRB LIQUID ROCKET BOOSTER
HLLV HEAVY LIFT LAUNCH VEHICLE
IUS INERTIAL UPPER STAGE
SSUS SPINNING SOLID UPPER STAGE

OTV · ORBITAL TRANSFER VEHICLE
IOTV · INTERIM OTV
COTV CARGO OTV
MOTV MANNED OTV

NASA HQ P79 1752(1)
4-24-79

performance will have to be augmented for Air Force missions from VAFB that will require placing a 32,000-lb. payload into a 98° polar orbit. We plan to study alternative augmentation methods in substantial detail during 1979 in order to define an orderly program for providing the required improvement.

Preliminary studies have shown how much the Shuttle's performance can potentially be increased with strap-on, solid rocket boosters or by replacing the Shuttle's present Solid Rocket Booster with a liquid rocket booster (LRB). We are continuing to study those forms of augmentation in anticipation of their need in the early 1990s in connection with large space systems. The LRB block change has the potential of increasing the Shuttle's payload delivery capability from 65,000 pounds to 100,000 pounds, with essentially no change in the Shuttle.

The other block change in the Shuttle mentioned earlier is development of a heavy-lift launch vehicle (HLLV) derived from the Shuttle. Our analyses indicate that a recoverable package containing the Shuttle's propulsion and avionics systems could be mated with a reusable LRB, or comparable solid booster, to deliver to low Earth orbit payloads weighing more than 200,000 pounds and having dimensions that the Shuttle's cargo bay could not accommodate. Our studies indicate that the HLLV will be very cost-effective, especially if a substantial volume of traffic materializes in large cargos to be delivered to, but not returned from, low Earth orbit.

The lower half of Figure 9 shows the planned evolution of our transportation capabilities for missions requiring high-energy propulsion. The ability of the STS to provide easy access to space will increase our operational flexibility and decrease the cost of space transportation. In its early years, the STS will be our sole means for deploying, fabricating, and servicing payloads and structures in space. However, the STS will require augmentation for the higher velocity planetary missions planned for the mid and late 1980s, and for deploying and servicing the geosynchronous platforms and large space systems planned for the late 1980s and early 1990s. We plan to satisfy those requirements with various combinations of the Solar Electric Propulsion System, the IUS, and, later, orbital transfer vehicles (OTVs).

New Initiatives

Solar Electric Propulsion System (SEPS) - NASA will use the IUS under development by the Air Force for some high-energy missions, including some automated planetary missions. However, our studies have shown that an additional kind of propulsion system will be needed for some other high-energy missions, especially automated planetary missions. SEPS, a low-thrust ion propulsion system, is one concept we have been studying and developing technology for during the last several years. Teamed with the IUS or, later, an OTV, SEPS is expected to be able to deliver to geosynchronous orbit 50,000 pounds of cargo instead of the 5,000 pounds that the IUS alone will be able to deliver. Initiation of SEPS development is scheduled for 1981 to support the 1985 launch of the Office of Space Science mission, Halley Flyby-Tempel 2 Rendezvous.

Orbital Transfer Vehicle - Scheduled for initiation in 1983, the OTV will expand the STS' ability to deploy to, and service in, geosynchronous orbit large systems such as space platforms, and to perform such advanced missions as disposing of nuclear wastes and demonstrating space-power technology. We are studying how the diverse needs for an OTV can best be accommodated. Those needs may require both a cargo OTV and a manned OTV. In addition, some large structures to be transferred to high orbits may be able to withstand only limited accelerative forces. For those structures, a low-thrust propulsion system, such as SEPS or a limited-thrust chemical propulsion system, would be required.

An interim OTV (IOTV) is a possible addition to our program, but our understanding of what mission needs it could satisfy is not yet sufficient for us to include it in this plan. An IOTV using the existing RL-10 rocket engine could possibly transfer to geosynchronous orbit payloads two to three times as heavy as the payloads the IUS will be able to deliver. It might also provide the throttling capability that would satisfy the low-thrust propulsion needs of some cargos. The concept of an IOTV kind of system originated in the Space Tug studies of some years ago. Our future studies will examine both the requirements that may develop for the IOTV's capabilities and the advantages and disadvantages of the IOTV relative to other possible means for satisfying those requirements.

Satellite Services

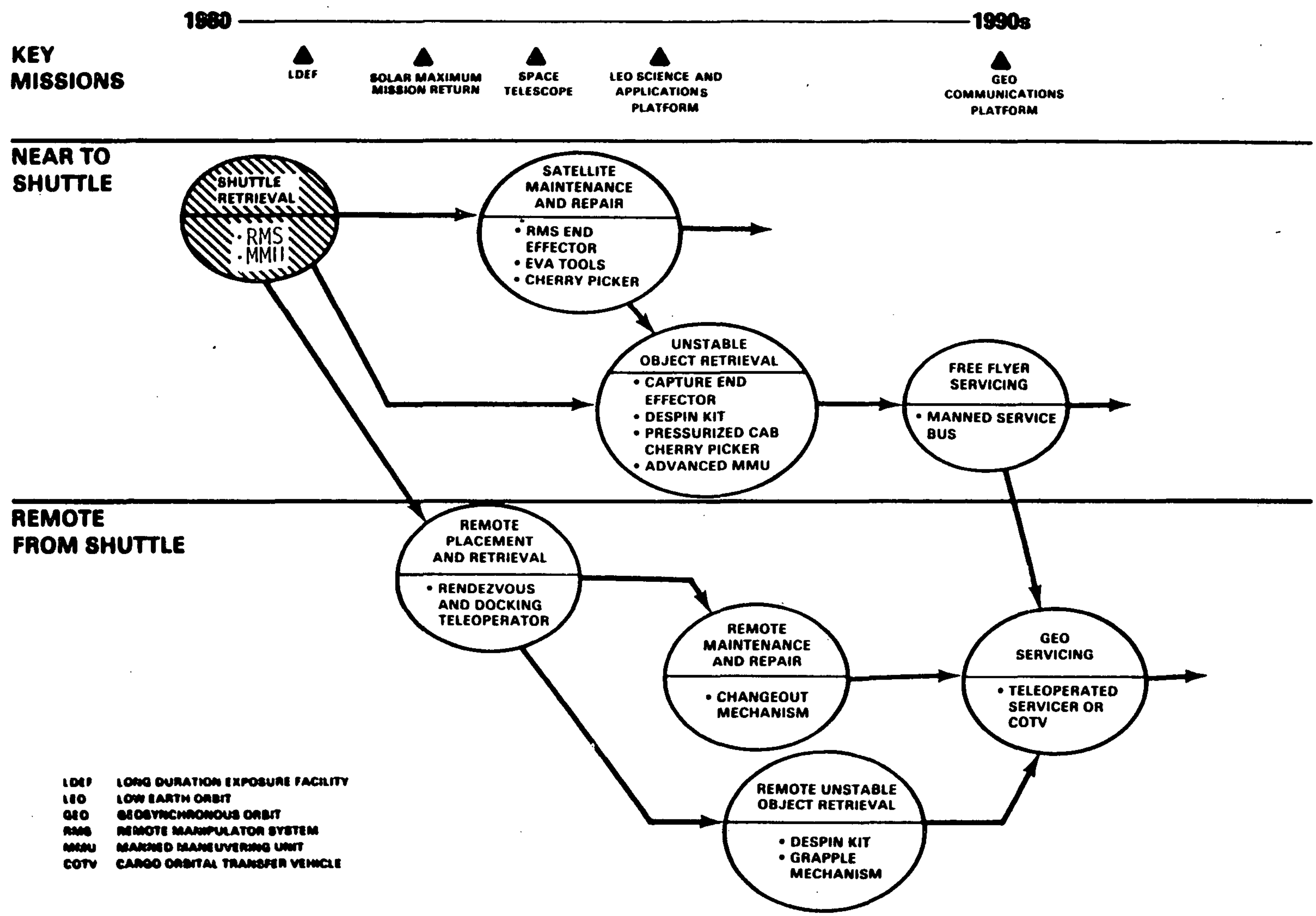
Figure 10 shows the planned evolution of satellite services during the 5-year period of this plan and on into the 1990s.

Current and Planned Program

The objectives of the Satellite Services program are to define, develop, and demonstrate capabilities for placement, retrieval, and in-orbit maintenance and repair of satellites, and for retrieval of unstable satellites and space debris. Provision of those services in locations remote from the Shuttle imposes requirements that are considerably different from the requirements related to the provision of services near the Shuttle.

Services Near to Shuttle - Our initial capability for satellite placement and limited retrieval will be provided by the Shuttle-mounted Remote Manipulator System (RMS), the integrated space suit and backpack, and the Manned Maneuvering Unit. However, space systems

FIGURE 10—EVOLUTION OF SATELLITE SERVICES CAPABILITIES



NASA HQ P79 1753(1)
4 24 79

such as the Long Duration Exposure Facility, Multi-Mission Spacecraft, Space Telescope, and low-Earth-orbit science and applications platforms will require improved and new services, as well as equipment to provide those services.

That needed equipment will include maintenance and repair equipment, end effectors (mechanical hands) for the RMS, tools for Shuttle crew members to use in extravehicular activity (EVA) servicing operations, and a remote work station called the "Cherry Picker" mounted to the free end of the RMS' arm. We plan to develop and demonstrate those items of equipment in the 1983-1984 period, before they are needed for operational use.

In the mid-1980s, we will demonstrate retrieval of unstable satellites and space debris. Candidate systems and equipment to be developed for that task include RMS end effectors designed for capturing those kinds of uncooperative objects, despin kits, and possibly a "cherry picker" with a pressurized cab or a service bus with human operators.

Services Remote from Shuttle - The Remote Service Module will be a teleoperator system benefiting considerably from the technology developed for the recently terminated Teleoperator Retrieval System that we had planned to use to boost Skylab to a higher orbit. It will be able to provide significant services to satellites remote from the Shuttle. We could demonstrate, by the mid-1980s, its ability to retrieve objects 800 to 1,600 kilometers from the Shuttle. Then, equipped with a front end having a mechanism for changing spacecraft modules, it could demonstrate a capability to remotely perform satellite maintenance and repair. Its ability to retrieve remote, unstable objects (satellites or debris) will require front end kits to despin, grapple, and capture those objects. We should achieve that ability about 1985 or 1986. Demonstration of the ability of a teleoperator service module teamed with an OTV to service a satellite in geosynchronous orbit will be possible in the late 1980s.

New Initiatives

Definition of equipment for satellite services near the Shuttle will start in 1981, hardware development and procurement of two Remote Service Modules in 1982.

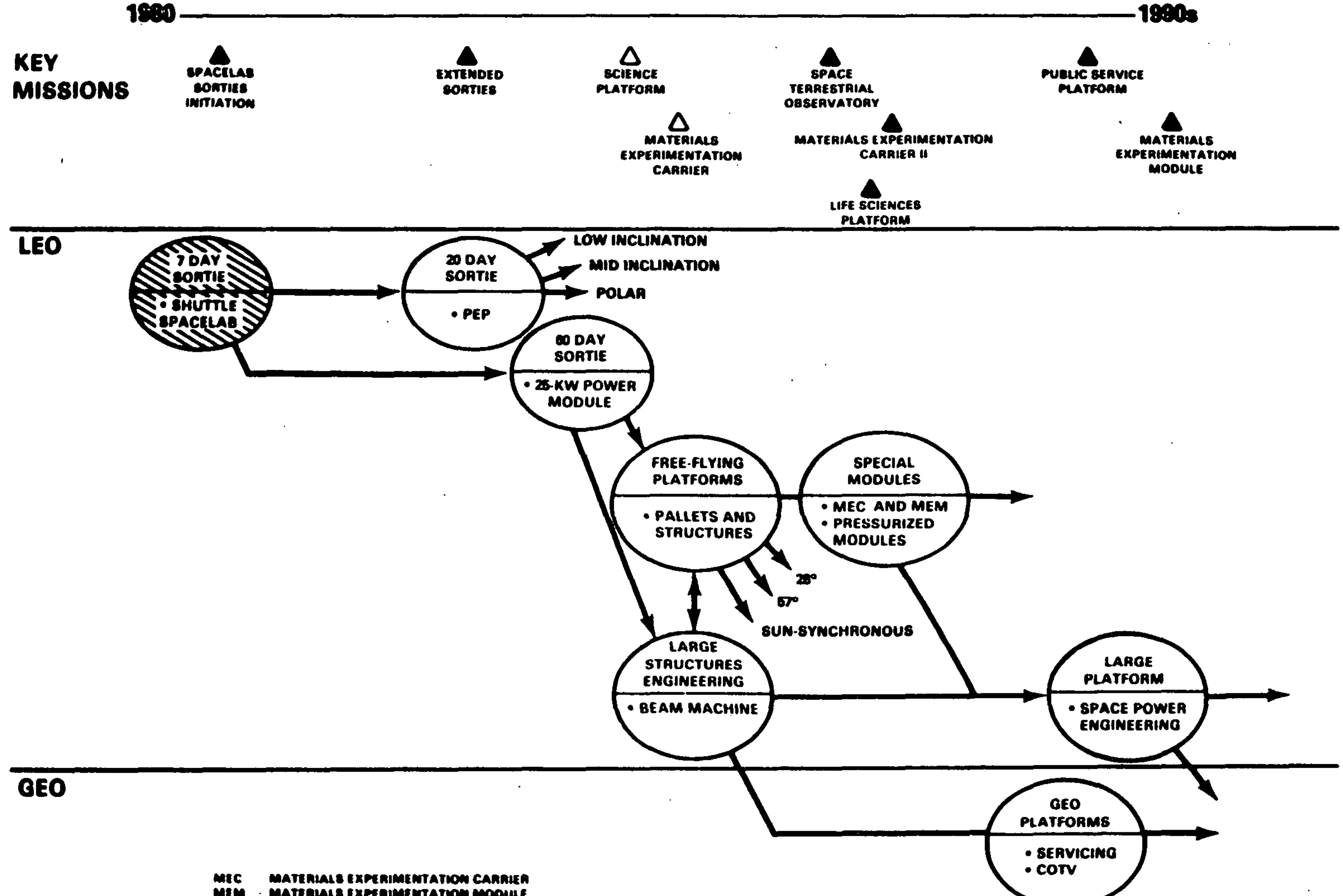
Space Platforms

Figure 11 shows the planned evolution of space platforms during the 5-year period of this plan and on into the 1990s.

Current and Planned Program

The Shuttle is a platform with a nominal stay time in space of 7 days, too short a time for maximum benefit to some experiments. Our

FIGURE 11—EVOLUTION OF SPACE PLATFORM CAPABILITIES



MEC · MATERIALS EXPERIMENTATION CARRIER
MEM · MATERIALS EXPERIMENTATION MODULE
LEO · LOW EARTH ORBIT
PEP · POWER EXTENSION PACKAGE
GEO · GEOSYNCHRONOUS ORBIT
COTV · CARGO ORBITAL TRANSFER VEHICLE

NASA HQ P79 1750-1
4 24 79

initial improvement in platform capability will be to equip the Shuttle with the Power Extension Package, which will increase that stay time to 12 to 20 days and provide 2 to 3 times as much power to payloads. Soon after, the free-flying 25-KW Power Module will be available to provide even greater capabilities. Docked with the Shuttle, it will provide payloads with even more power and extend the duration of Shuttle-Spacelab sortie missions to as much as 60 days. In the free-flying mode, it will permit direct attachment of pallets and modules to form a free-flying platform system that, tended by the Shuttle, will fly for indefinite periods. As experiments continue to demand more and more power and the structures on which they are mounted increase in size, large platforms in low Earth orbit will become a necessity and will evolve from that free-flying platform system.

Some experiments in materials processing, physics and astronomy, and the life sciences will have unique requirements for services or will require a pressurized environment. We will satisfy those requirements by developing special modules. Then, when a number of those science and applications programs can benefit from a geosynchronous orbit location, we will develop suitable geosynchronous platforms, making all possible use of the technology and experience we have derived from development, construction, and operation of low-Earth-orbit platforms.

The larger structures for use in both low Earth orbit and geosynchronous orbit will have to be assembled or fabricated in space. Some of them may be fabricated there by means of the beam fabricating machinery and other hardware to be developed in the Large Space Structures System Engineering program.

New Initiatives

Power Extension Package (PEP) - Shuttle-Spacelab missions will require, or be able to benefit greatly from, more electrical power and longer stay times in space than the baseline Shuttle will be able to provide. They will also require flexibility in selection of orbit inclination. To satisfy those needs, we plan to develop PEP, a solar cell array that will be mounted on the end of the arm of the RMS, which will position and hold it outside the cargo bay. PEP will weigh about as much as one of the cryogenic tanks that hold fuel for the Shuttle's fuel cells. It will allow the Shuttle to fly a variety of orbit inclinations, and increase flight duration and available electrical power.

25-KW Power Module - Some Shuttle-Spacelab sortie missions will need even longer mission durations than PEP can provide; and some science and applications experiments will require large amounts of power and an environment free of the Shuttle's influence, or untended operation over extended periods except for occasional revisits by the

Shuttle to provide needed maintenance, repair, and assembly. To satisfy all those needs, we plan to develop the 25-KW Power Module.

The 25-KW Power Module will be designed to allow the Shuttle to dock with it to fly sortie missions with durations as long as 60 days and payloads requiring significantly more power than the Shuttle alone will be able to provide. It will also be able to function in the free-flying mode in low Earth orbit at a fixed inclination. In that mode, it will support instrument pallets and modules that will be attached to it for long periods and that will be serviced only from time to time by the Shuttle.

Between them, PEP and the 25-KW Power Module will provide a range of capability that will give the STS flexibility to satisfy a wide variety of science and applications needs during its first decade of operations.

Science and Applications Platforms - The Office of Space Transportation Systems provides complete in-orbit support for user-supplied experiments and equipment. To do so for the anticipated wide variety of users, we must develop elements such as pallets, mounting structures, pressurized modules, and other ancillary equipment compatible with the 25-KW Power Module. Depending on future agreements with the Europeans, several of those elements may be Spacelab pallets and modules modified for long-duration free flight and for the increased power and other services users need. Other elements, such as a multiple docking adapter, must be new developments. As the needs of users become better defined, we will be able to define the means for satisfying the needs and will then schedule initiation dates and incorporate funding into our program.

Materials Experimentation Carrier (MEC) - The Office of Space and Terrestrial Applications' analyses of the cost of performing systematic, sustained research on the processing of materials in space have shown that longer stay-time in orbit and more power to run experiment apparatus can significantly reduce the unit cost of research. The MEC will accommodate automated materials-processing payloads and, with the 25-KW Power Module, make extended duration operations efficient and cost effective.

As currently conceived, MEC will be a pallet designed for very early Shuttle flights and for docking with the 25-KW Power Module for 20- to 60-day missions. It will provide the interface systems (e.g., power conditioning and distribution; command, control, and communications; and heat collection and rejection) between the experiment apparatus and the 25-KW Power Module. MEC will provide an orderly transition between early exploratory research activities and later research and development programs that capitalize on the results of that early research.

Materials Experimentation Carrier II (MEC II) - The later research and development programs mentioned immediately above will be carried out on MEC II. The requirements for MEC II are not yet sufficiently known for us to define its configuration, select its initiation date, or estimate its funding requirements. However, we expect MEC II to be a resident, in-orbit, growth version of MEC that will permit materials research and development in sufficient quantities for, and at costs conducive to, industrial research. MEC II will accommodate 2,500 to 7,500 kilograms of processing apparatus having a volume of 9 to 19 cubic meters, provide 6 to 14 kilowatts of power and heat handling capability, and be able to maintain acceleration maxima of 10^{-6}g for periods of 24 to 120 hours. Its human-machine interfaces will permit changeout, maintenance, and repair of equipment in orbit. Its orbital lifetime will be up to one year without ground refurbishment. A mix of tended and automated operations will permit MEC II and its equipment to operate almost continuously. We will design into MEC II provisions for its capabilities to evolve to meet expected increases in research requirements in the mid to late 1980s.

Materials Experimentation Module (MEM) - Materials-processing pilot-plant operations may be possible in the late 1980s. Payloads will then increase in size and support needs, requiring evolution toward larger equipment packages and higher levels of electrical power. Provision of those higher levels of electrical power will be addressed in the Space Power Systems Engineering program described later, while those larger equipment packages may ultimately require development of human-tended space processing facilities such as the currently conceptual MEM. MEM will be the subject of further study during the period of this plan.

Large Space Structures Systems Engineering - Large Space Structures Systems Engineering will be a level-of-effort flight program to develop materials, tools, and techniques for assembling in orbit the first generation of large space structures. Each project in that flight program will demonstrate and test structural concepts applicable to systems that potentially will be required by users. We plan to start designing the first flight project in 1981, for operation in 1984. The following demonstration and test activities are under consideration:

1. Erectable Structures Assembly and Test. A free-flying multipurpose platform docked with a power source promises to provide very attractive payload support for many science and applications payloads. Assembly of a representative platform by means of extravehicular activity and use of the Shuttle's Remote Manipulator System, followed by static and dynamic testing of the assembled platform, is a high-priority objective. A second objective of this flight project is simulation of payload operations for science and applications platforms. Installation of utility services (stabilization, cooling, and data management) and attachment, servicing, and changeout of payloads are essential elements in

cost-effective operation of science and applications platforms. Simulation of those functions will provide data essential to users in designing and constructing their systems.

2. Deployable Antenna Demonstration. Direct deployment of a large structure from the Shuttle offers the earliest and most direct approach to getting large structures into space. A demonstration project providing knowledge and confidence that systems of operational size can be deployed in that way might well provide an operational and technological base that would lead to large antennas in space for communications and other specialized applications, both civil and military. Department of Defense (DOD) agencies have expressed strong interest in this project and have proposed joint NASA-DOD study of it.

3. Space Fabrication Demonstration. In-orbit fabrication of structural elements appears to have significant advantages as a construction technique, both in terms of economy of transportation and as a very important part of highly automated construction in space. Before we apply that technique to user systems, however, we must test it, develop procedures for operating the fabrication machine in orbit, and demonstrate that the elements fabricated meet the structural requirements of those user systems.

Large Geostationary Platform (GP) - Recent NASA studies have shown that a GP will have distinct advantages over the traditional approach of using numerous specialized satellites to accomplish a wide variety of geosynchronous missions. A GP could be host to a wide spectrum of payloads, including meteorology and Earth resources observing systems, scientific instruments, and antennas and transponders for communications purposes such as domestic satellite services, mobile services, maritime services, and educational TV broadcasts. With its inherent ability to carry large-aperture antennas having multiple, narrow beams and the ability to switch signals from beam to beam and antenna to antenna, a GP may provide a means for limiting the radio interference that users of geosynchronous orbits face in the late 1980s. At the same time, it may provide cost savings that can be passed on to users. Current planning supports an initiation date of 1982 for the GP.

Space Power Systems Engineering - Various studies have indicated the need to have a 200- to 500-kW power module operational in the late 1980s to support such space operations as materials processing; space construction, including the construction of advanced communications systems; and other science and applications projects. That module probably will be constructed in orbit with the aid of the 25-KW Power Module and other systems, such as the Remote Service Module. The Office of Space Transportation Systems will continue to work with the other NASA program offices to determine what the next step beyond the 25-KW Power Module should be. Many items of equipment to be developed for use with the 25-KW Power Module could later be used directly with larger power modules. Current planning supports initiation of the Space Power Systems Engineering program in 1982.

Space Power Technology Demonstration - Analytical studies indicate that space solar power is potentially competitive with other concepts for satisfying humanity's energy needs on Earth. The ultimate economic viability of the concept will depend on significant improvement in the cost or energy conversion efficiency of solar cells, and on lower space transportation costs. The concept's technical feasibility will depend on development of efficient techniques for transmitting microwave power and for constructing large systems in space. Space power technology could be demonstrated either by constructing and operating a test article in space or by using a transmitting antenna attached to some available power platform. NASA's Office of Energy Systems is working actively with the Department of Energy to define the concept for a solar power system. After the concept has been defined, the Office of Space Transportation Systems will be able to initiate development of space systems to demonstrate and test the concept.

Tethered Satellite System - The Tethered Satellite System will consist of a subsatellite connected by a tether to a device in the cargo bay of the Shuttle. The device in the cargo bay will consist of an extendable and retractable boom for deploying and retrieving the subsatellite attached to the tether, a reel mechanism, and a base platform. The tether will be a line 1 millimeter in diameter and as long as 100 kilometers. The tethered system will make possible a variety of scientific, engineering, and applications experiments and measurements such as measurements of the structure of the upper atmosphere, chemical releases, ionospheric measurements, electrodynamics experiments, geomagnetic field mapping, and determination of gravity gradients. We plan to initiate this program in 1981.

SCHEDULE AND FUNDING

Table 10 shows the phasing for the Space Transportation Systems program and Figures 12 and 13 show the program's funding requirements. Those funding requirements do not include funding for Spacelab, which is being developed by ESA, or for the IUS, which is being developed by the Air Force.

TABLE 10-SPACE TRANSPORTATION SYSTEMS PROGRAM SCHEDULE

PROGRAM	PROGRAM PHASE			ADDITIONAL IMPORTANT INFORMATION
	DEFINITION	INITIATION	FIRST LAUNCH	
Shuttle DDT&E	Completed	1972	-	Completion 1983
Shuttle Production (First 4)	Completed	1977	1979	First Operational Launch 1981; Completion 4th Shuttle 1983
Shuttle Production (5th)	Completed	1981	1985	Completion 1985
Shuttle Thrust Augmentation	Ongoing	1980	1984	Completion 1984
Expendable Launch Vehicles	Completed	-	1958	Launches As Needed; Completion 1985
Shuttle Space Flight Operations	Ongoing	1981	1981	Orbital Flight Tests- Start 1979, Complete 1980
Shuttle Improvements	Ongoing	1981	-	
Solar Electric Propulsion System	Ongoing	1981	1985	Launches As Needed
Orbital Transfer Vehicle	1981	1983	TBD	Continuing Activity; Launches As Needed
Satellite Services	Ongoing	1981	1983	Continuing Activity
Power Extension Package	Ongoing	1981	1983	Shuttle-Mounted System
25-KW Power Module	Ongoing	1981	1984	Launches As Needed
Science and Applications Platforms	Ongoing	1982	1985	
Materials Experimentation Carrier	Ongoing	1982	1984	
Materials Experimentation Carrier II	1980	1983	1987	
Materials Experimentation Module	*	*	*	
Large Space Structures Systems Engineering	Ongoing	1981	1984	Continuing Activity
Large Geostationary Platform	1980	1982	1988	
Space Power Systems Engineering	Ongoing	1984	1987	Continuing Activity
Space Power Technology Demonstration	1981	*	*	Continuing Activity
Tethered Satellite System	Ongoing	1981	1983	

* =To Be Determined

FIGURE 12—SPACE TRANSPORTATION SYSTEMS PROGRAM FUNDING

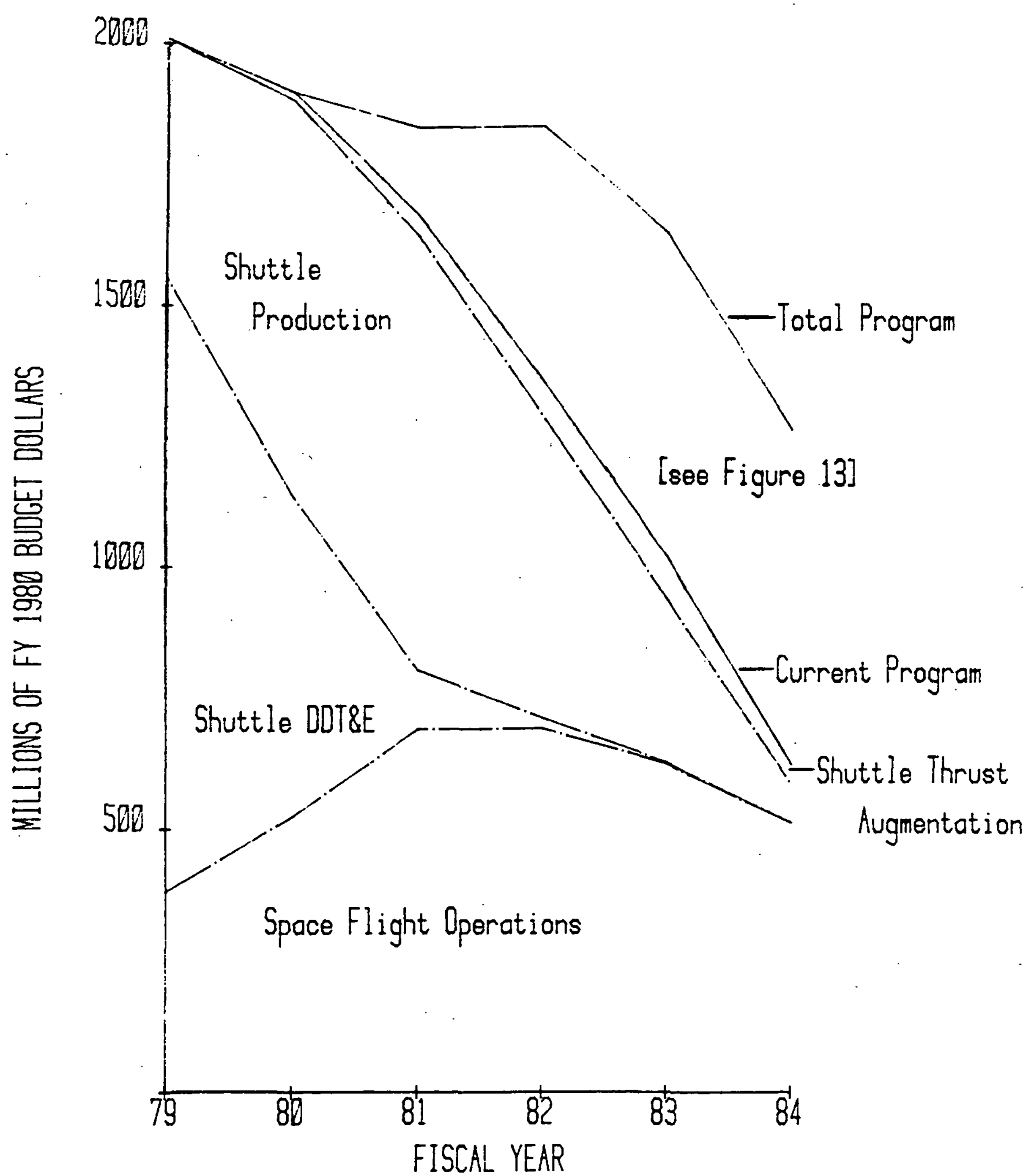
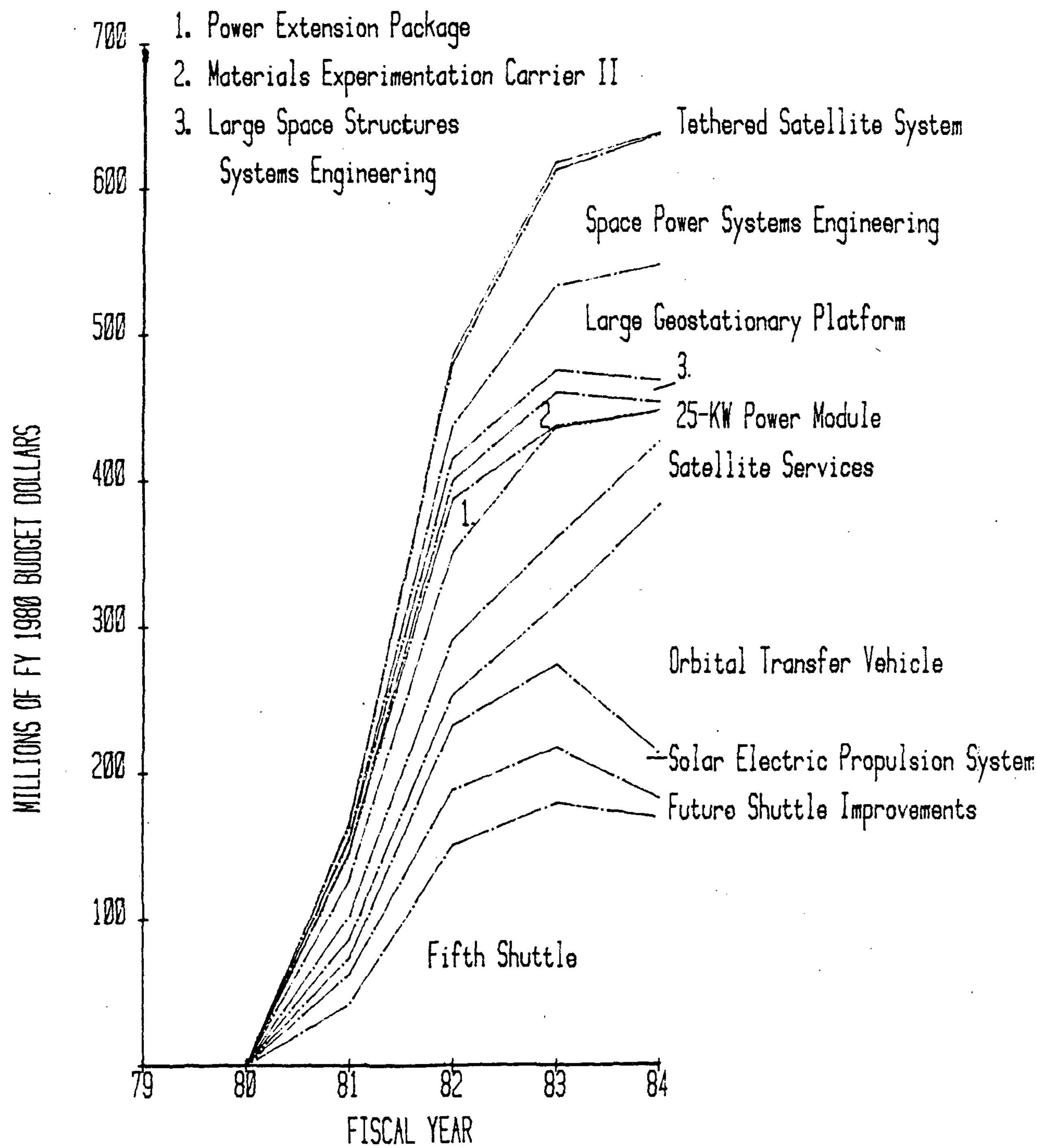


FIGURE 13-SPACE TRANSPORTATION SYSTEMS PROGRAM FUNDING

Augmentations



CONTENTS

Preceding page blank

CONTENTS (CONTINUED)

CONTENTS (CONTINUED)

TABLES

FIGURES

SPACE AND TERRESTRIAL APPLICATIONS PROGRAM

The Space and Terrestrial Applications program has three principal elements:

1. Observation and study of Earth from space to understand and forecast environmental behavior, to assess the productivity of Earth's surface for both renewable and nonrenewable resources, and to develop a "standard" model of the dynamic Earth

2. Performance of research in the space environment to clarify materials processes and to explore feasible and advantageous processing that can be carried out in space

3. Development of selected technology for telecommunications satellite systems that will be more effective and efficient, and provide higher capacity.

Collectively, these three program elements apply NASA's space capabilities to solve many challenging problems related to human welfare and improvement of the quality of life on Earth.

In the last several years, we have successfully demonstrated that space techniques and observations can make substantial contributions to telecommunications, assessment of agricultural productivity, land-use changes, and research in processes related to weather forecasting, climatic fluctuations, human-caused changes in the environment, tracking of severe storms, and motions of Earth's crust.

PROGRAM THRUSTS

For the 5-year period of this plan, the major thrusts of the Space and Terrestrial Applications program will be to:

1. Develop jointly with the Department of Defense (DOD) and the National Oceanic and Atmospheric Administration (NOAA) a national satellite system for limited operational demonstration of ocean monitoring capability

2. Develop jointly with NOAA the next generation of weather satellites

3. Participate in the National Climate Program by initiating the space segment of a climate observing system

4. Develop jointly with the Department of Agriculture improved capability to forecast production of major agricultural commodities in primary producing areas

5. Expand space capability for geological delineation of surface features for resource assessment

6. Develop, over a period of 10 to 20 years, models of contemporary motion (rate and direction) of major tectonic plates; model accumulation of crustal strain in seismically active areas and identify causative relationships for changes in Earth's polar motion and rotation.

7. Renew development of communications-satellite technology, pioneering new frequency bands and developing large spacecraft antennas with multiple beams and spaceborne switching systems

8. Initiate experiments in materials processes using Shuttle-Spacelab capabilities

9. Develop methods for rapid and effective transfer of techniques, technology, and information resulting from NASA activities to potential users.

PROGRAM CONTENT

Figure 14 shows the funding requirements for the Space and Terrestrial Applications program. The sections that follow describe our plans for the three principal program elements described above and also for our Technology Transfer and Applications Data Service activities.

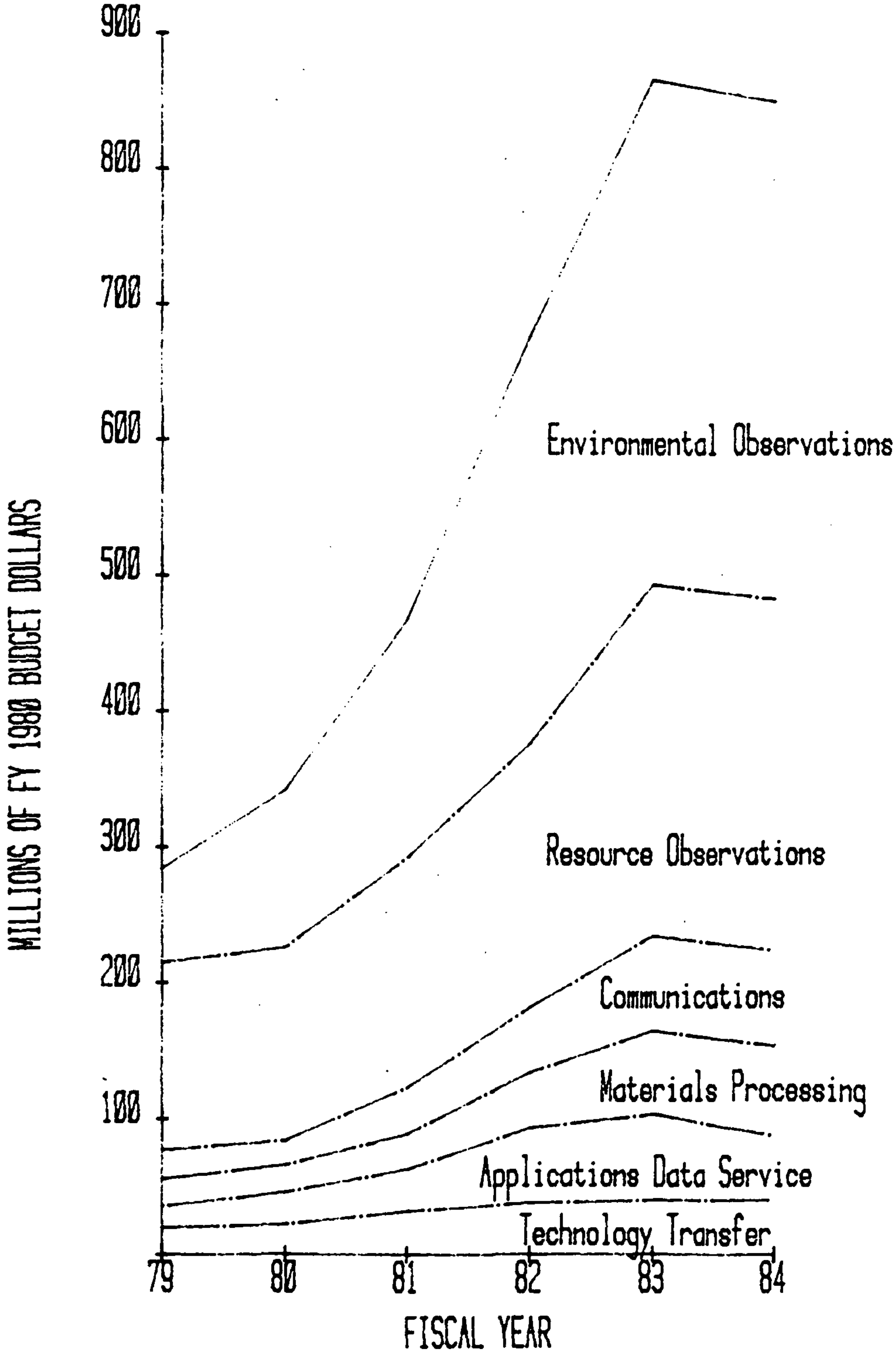
EARTH OBSERVATION: ENVIRONMENT

The Environmental Observation program applies space observations and techniques to increase ability to understand and forecast environmental behavior. That behavior spans the range from global to regional--from global weather, climate, and ocean circulation to regional severe storms and air and water quality. The Environmental Observation program encompasses and integrates the diverse scientific fields of meteorology, climatology, atmospheric chemistry and physics, and oceanography. The program's eventual goal is to define, develop, and demonstrate key aspects of a global environmental data-acquisition and data-processing system.

Earth's environment is a complex system. The complexity is caused largely by interaction among the atmosphere, the land, and the oceans. An understanding of the interaction is necessary for assessment and delineation of the crucial factors that control and adversely affect the environment.

Consequently, we have organized the Environmental Observation program into two major subprograms, Atmospheric Processes and Ocean Processes, and two functions, support cf operations to forecast environmental changes and conduct of research and development to understand the environment.

FIGURE 14 - SPACE AND TERRESTRIAL APPLICATIONS PROGRAM FUNDING



Goals and Objectives

Our goals are to define and develop our oceans activities into a comprehensive research and operational support program comparable to our atmosphere program, and to achieve a balance between the two programs and their elements so that they can most efficiently develop an understanding of the total environment in accordance with the priorities of user agencies.

Our objectives are to:

1. Define, in cooperation with user agencies, next-generation operational systems

2. Strengthen the program's scientific base

3. Implement a planning system that yearly identifies and supports new thrusts and initiatives

4. Increase involvement of researchers and users in the program

5. Define and conduct an integrated modeling and measurement effort

6. Move from single-purpose satellites toward integrated multidisciplinary payloads and missions.

Planning Assumptions

Fundamental to the success of the Environmental Observation program are the basic assumptions that the program will continue to support the operational agencies (NOAA, DOD, Environmental Protection Agency, etc.), that research will be a major activity in the program, and that increased funding will be available to provide for sensor development and new mission initiatives and to make our Applied Research and Data Analysis (AR&DA) efforts more aggressive.

Atmospheric Processes

Global Weather

The Global Weather program improves meteorological satellites and techniques for extracting meteorological information from remotely acquired data, and demonstrates the use of space-acquired data in developing an understanding of atmospheric processes and in improving the accuracy of mid-range (2- to 14-day) weather forecasts. The program is implemented through support to the Global Atmospheric Research Program (GARP) and the GARP Global Weather Experiment (GWE), and it supports the user agencies (NOAA, DOD, etc.).

NASA's GARP project consists of research on numerical models for use in forecasting weather. Over the next five years, our efforts will include assimilation of asynoptic satellite data, assessment of the effect of satellite data on forecasting capability, simulation studies to optimize future observing systems, and development for the GWE of data sets from Nimbus 7.

Our Operational Satellite Improvement Program (OSIP) improves remote sensors and ground-based processing systems. We plan to make the first temperature soundings from geosynchronous orbit and to develop an operational, satellite-mounted ozone sensor for NOAA. Our AR&DA will continue studies that include advanced sensors, improvement in long-duration performance of instruments, a zero-g fluid-dynamics experiment, methods to improve retrieval of data from cloudy atmospheres, and extensive development of numerical models in collaboration with researchers at academic institutions.

Severe Storms

The goals of our Severe Storms program are to increase basic understanding of storms and to help the responsible weather-forecasting agencies, primarily NOAA, to improve the accuracy and timeliness of their severe weather forecasts and warnings. The program has four objectives: to understand severe storm development, to demonstrate and verify space-derived observations, to develop sensors, and to develop models that will improve our ability to predict storms.

During the next five years, we will emphasize transfer of space-derived forecasting aids, comparison of mesoscale models, understanding of the physics relating atmopsheric state and flow to local-weather observables, storm-scale case studies including microphysical and electrical observations, high-altitude aircraft overflights of severe storms to develop methods for quantifying the relationships expected to be found in future observations from space, and development of fast, simplified models for use in predicting storms in near real time.

Several planned projects are essential to the success of those activities. One is a large-scale field demonstration of NASA's technical capabilities for observing and modeling storm development. That demonstration will involve many non-NASA weather research groups. Another planned project is assessment of the Visible-Infrared Spin-Scan Radiometer Atmospheric Sounder's value for measuring and understanding the environments of severe storms, and its ability to measure temperature and moisture profiles from geosynchronous orbit. In addition, development of Shuttle-Spacelab experiments will continue beyond the currently funded third Atmospheric Cloud Physics Laboratory (ACPL) flight. Those low-gravity experiments will become increasingly complex, and some of them will require development of an advanced ACPL by the mid 1980s.

Climate

With help from our scientific advisory groups, we have defined research priorities and plans for our participation in the National Climate Program. We will emphasize use of space-acquired data sets in climate research, application of the results of the research, special studies of important climate processes, development of a broad ability to model Earth's climate, and evolutionary development of a space system for observing Earth's climate globally.

We will continue preparing our Climate Data Set, using data acquired with past and currently operating satellites. We have initiated planning for improvements to data-management procedures that will facilitate access to data sets. We have also initiated planning for use of data from new observing systems (such as Seasat, Nimbus-7, and Tiros N) and from future observing systems (such as the Earth Radiation-Budget Satellite and the Upper Atmospheric Research Satellite). Our plans also include intensive studies of key climate parameters such as aerosol effects, radiation budget, and cryospheric and hydrologic processes.

Our climate-modeling activities will include development of a wide range of models. We will verify the models' capabilities, using conventional and space acquired data, with emphasis on data from studies of the seasonal cycle.

Environmental Quality

This program area has three components. The first component is concerned with the quality of Earth's lower atmosphere (troposphere) and with problems in the troposphere associated with global, regional, and urban air pollution. Our objectives in connection with this first component are to: understand the large-scale dynamic and transport properties of the troposphere, using space-acquired data to expand our understanding of atmospheric processes; improve our current models; provide the Environmental Protection Agency (EPA) with advanced techniques for monitoring and forecasting, on a regional scale, pollutants such as sulfates, nitrates, "hazy blobs," and acid rain; define and develop advanced sensing techniques and systems; and initiate with EPA joint field experiments related to development and demonstration of systems to make global measurements of parameters such as concentration of carbon monoxide in the troposphere and transport of pollutants between Earth's hemispheres.

The second component of this program area has to do with the quality of the surface waters in lakes and at the coastlines of the oceans. The objectives of this component are: to continue our laboratory and aircraft investigations in order to improve our understanding of the physics of remote sensing of waterborne pollutants, and to increase our ability to apply that improved understanding; to conduct joint regional demonstrations with users; and to define an integrated, nationwide system for sensing water quality remotely.

The third component is transfer of technology to users. We plan technology transfer into projects from their inception. We bring users into the planning and development of projects so that they can become familiar with the benefits of the technology as it develops, and so that they can prepare for transfer of the technology to their operational systems. During the next five years, the principal thrust of this component will be initial application of space technology to increase our understanding of the transport of large-scale pollution in the lower atmopshere.

Upper Atmospheric Research (UAR) (and Stratospheric Quality)

This program area stems from congressional mandates in the FY 1976 NASA Authorization Act and the Clean Air Act Amendments of 1977. Its objectives are scientific understanding of, and assessment of threats to, the upper atmosphere. It is focused on the development of a solid body of knowledge of the physics, chemistry, and dynamics of the upper atmosphere.

The UAR program, recently transferred from the Office of Space Science, is concerned with the stratosphere and the mesosphere. Those regions are important because they filter out ultraviolet radiation and may be the primary region of Sun-weather coupling. Over the next five years, the program will concentrate on determining the production, flow, and loss of chemically and radiatively active constituents, such as ozone. We will perform theoretical studies, laboratory investigations, field measurements, and space flights.

The Stratospheric Quality Program will continue to have two main emphases. The first will be on measurements to improve our knowledge of the nitrogen cycle (using Nimbus-G), of the chlorine cycle (using the Halogen Occultation Experiment (HALOE)), of stratospheric aerosols (using Nimbus-G and the Stratospheric Aerosol and Gas Experiment (SAGE)), and of stratospheric transport and dynamics (using Nimbus-G and the UAR Satellite). We will use the data resulting from those measurements to develop multidimensional models to use in studies of transport and chemistry. The second emphasis will be on establishing requirements for new instruments and on validation of concepts for advanced sensors.

Two major flight-project new initiatives, the UAR Satellite and the Multi-User Lidar System were also transferred from OSS to OSTA with the UAR program.

Oceanic Processes

The newest of the environmental observation programs, Oceanic Processes, achieved its first major milestone during the summer of 1978 with the operation of Seasat, the first satellite dedicated to study of the oceans. The value of this demonstration of space acquisition of ocean data encouraged the Agency to organize Oceanic Processes into a major program addressing three broad areas: ocean dynamics (for understanding the general, global circulation and currents), ice dynamics (for amount and location of ice, iceberg location, etc.), and coastal processes (for understanding and monitoring the marine environment for near-shore currents and storms, navigability, and biological resources).

Over the next five years, we will emphasize planning for and definition of the enlarged program and implementation of specific research and operational support activities. The major undertaking related to operational support will be the interagency (NASA, DOD, and NOAA) definition and development of a new initiative, the National Oceanic Satellite System (NOSS), a follow-on to Seasat.

The major undertaking related to research activities will be definition of two new initiatives: study of ocean circulation and climate research with emphasis on the cryosphere.

AR&DA efforts in the Oceanic Processes program determine methods for satisfying needs for data on the open oceans such as wind fields, surface winds and temperatures, steady and transient currents, liquid water and water vapor in the atmosphere, and global tides.

Coastal zone and lake investigations will include continental-shelf and near-shore circulation processes, storm surge and setup, pollution, lake ice, and Polar area data vital to statistics on ice dynamics, ice mapping, and sea ice.

National and International Interrelations

Our environmental observation work spans a very broad range of activities at the national and international level that are essential to a sound and comprehensive applications program. Those activities range from adjunct relationships to formal operational support commitments.

Our national commitments encompasses all the program elements within our Environmental Observation program and include major program involvement with NOAA, EPA, and DOD. Examples are the design, fabrication, launch, and checkout of operational weather satellite systems for NOAA and participation in the NOAA-managed National Climate Program under the National Climate Act.

Internationally, our activities range from participation in United Nations programs to programs conducted directly with one or more other countries. Examples are: our major contribution to the international Global Atmospheric Research Program (GARP) and the GARP Global Weather Experiment; our participation, through our Upper Atmospheric Research program, in the multiyear, multination study, "The Middle Atmosphere Program": and a U.S., France, and Great Britain Tripartite Agreement on Ozone Monitoring .

New Initiatives

Operational Support

National Oceanic Satellite System (NOSS) - NOSS is a joint undertaking by NASA, NOAA, and DOD of a Seasat follow-on mission. Considering Seasat as proof-of-concept, we are preparing NOSS as a "limited operational" demonstration employing two satellites to observe the oceans in order to describe ocean processes, ice dynamics, and coastal processes.

System 85 - This next-generation global weather satellite system will be a follow-on to the current TIROS and Geostationary Orbit Environmental Satellite systems. It will consist of Shuttle-compatible, low-Earth-orbit and geostationary satellites that will ensure continued NOAA meteorological operations by providing studies of severe storms and measurements of surface temperatures, winds, clouds, and Earth's radiation budget. Those studies will increase understanding of atmospheric processes and improve the accuracy of mid-range (2- to 14-day weather forecasts.

Research

Ocean Research - The objective of this mission is to increase understanding of the global circulation of the oceans and to demonstrate the usefulness of remotely sensed data in studying the oceans. Definition studies currently underway may dictate a change, but present science priorities indicate that this mission should be an altimetry mission at a relatively low (about 65°) inclination.

Climate Research (Cryosphere) - Currently under study, this mission will emphasize the cryosphere (ice) and its interaction with the atmosphere, and hence with Earth's climate. A near-polar orbit is required.

Upper Atmospheric Research Satellite (UARS) - The objectives of UARS are to aid in our understanding of the mesosphere and stratosphere by making chemical and physical measurements of their constituents, temperatures, and other dynamic characteristics, and to observe the interaction of the stratosphere and mesosphere. .Two overlapping spacecraft missions are desired.

Instrument Definition and Development - We plan to initiate definition of six instruments and development of one instrument. The instrument planned for development is the Advanced Meteorological Temperature Sounder, a passive infrared sensor. Ground tests have demonstrated its feasibility and operational readiness. It is expected to reduce the temperature-profile error and to double the current vertical resolution of temperature measurements in the troposphere.

The six instruments proposed for definition are lidar temperature and pressure sounders, an instrument for mapping lightning, and instruments for measuring precipitation, wind, and solar spectral irradiance. Those instruments will either provide new measurement capabilities (e.g., the Lightning Mapper) or improve current capabilities (e.g., the Solar Spectral Irradiance Instrument). They are vital to progressive observation and forecasting programs. The Solar Spectral Irradiance Instrument has been identified for flight on Shuttle sortie missions. Flight arrangements for the remaining instruments are yet to be determined.

Spacelab Principal Investigator (PI) Instruments - The UAR program issued an Announcement of Opportunity in 1978 for PI instruments for atmospheric investigations. Evaluation of the proposals received will be completed in 1979.

Multi-User Lidar System - The objective of this instrument package will be to investigate the upper atmosphere and evaluate its susceptability to natural and human-caused perturbations.

Schedule and Funding

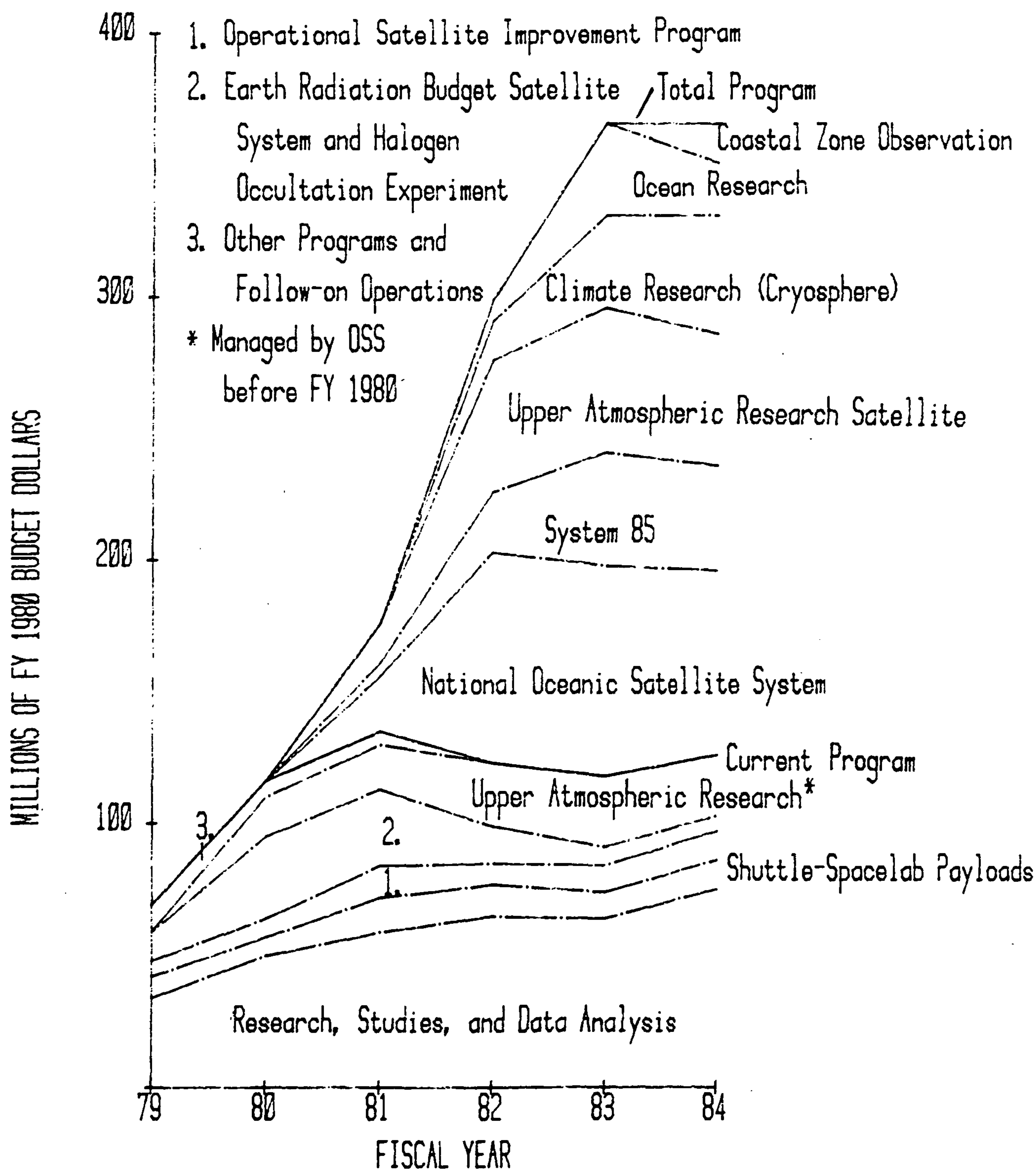
Table 11 shows the phasing of the Environmental Observation program and Figure 15 shows the program's funding requirements.

The phasing shown for the program is not optimal. The level of the FY 1980 budget and the expected level of the budgets for the remaining four years of this plan will not permit an optimum schedule. We have, therefore, had to assign priorities, with resulting delay in some programs and deferral of other programs to years beyond the period of this plan. The plan does, however, support our operational commitments, provide some AR&DA augmentation to the FY 1980 runout budget, support a minimum funding level for development and flight of payloads on Spacelab, and provide initiation for three high-priority missions.

TABLE 11 - ENVIRONMENTAL OBSERVATION PROGRAM SCHEDULE

PROGRAM	PROGRAM PHASE			ADDITIONAL IMPORTANT INFORMATION
	INITIATION	COMPLETION	LAUNCH	
Seasat-A	Ongoing	1979	1978	Failed after collecting data that demonstrated value of microwave systems for measuring ocean conditions
Nimbus-G	Ongoing	1981	1978	
Tiros-N	Ongoing	1985	1978	
Geostationary Orbit Environment Satellite-3	Ongoing	1985	1978	
Stratospheric Aerosol and Gas Experiment	Ongoing	1981	1979	
Earth Radiation-Budget Satellite-A	Ongoing	1983	1982	
Measurement of Air Pollution from Shuttle	Ongoing	1981	1981	Shuttle-attached payload
Atmospheric Cloud Physics Laboratory	Ongoing	-	1982	Shuttle-attached payload; repeated flights
National Oceanic Satellite System	1981	-	1985	Two satellites
System 85	1981	-	1985	Two satellites
Ocean Research	1982	-	1985	
Climate Research (Cryosphere)	1982	-	1985	
Upper Atmospheric Research Satellite	1981	-	1984	Second launch in 1985
Instrument Definition and Development	1980-4	-	1983-7	
Spacelab Principal Investigator Instruments	1980	-	1983	
Multi-User Lidar System	1981	-	1984	

FIGURE 15-ENVIRONMENTAL OBSERVATION PROGRAM FUNDING



EARTH OBSERVATION: RESOURCES

The Resource Observation program develops and demonstrates the application of space observations and techniques in meeting national and global needs for improved management of food, fiber, water, and land resources, for improved effectiveness of exploration for mineral and energy resources, and for understanding Earth's dynamic characteristics, including processes related to earthquakes.

The Resource Observation program has three major elements: Renewable Resources, Non-Renewable Resources, and Geodynamics. The program's capabilities depend on multispectral visible and infrared remote sensing systems and on laser-ranging and Very-Long-Baseline Interferometry (VLBI) measuring systems. Those space sensors and the techniques attendant to their use have provided unique contributions in many Earth-related applications; for example, techniques for forecasting wheat production, capability for inventorying land cover, changes in coastal zone shorelines, use of hydrologic land, determination of water impoundments covering more than two acres, use of data on the areal extent of snow in water-supply models, discrimination of bare rock, analysis of the structure and form of land, measurements of gravity and magnetic fields, analysis of crustal features, measurements of the motion of tectonic plates, and classification, location, and mensuration of major types of forests.

Objectives

The 5-year objectives of the Resource Observation program are to:

1. Extend our ability to make production forecasts to include major agricultural commodities in primary producing areas
2. Improve our ability to identify, discriminate, and measure major types of forests
3. Extend our ability for monitoring and analyzing to include the mapping of changes in land use and the determining of the potential productivity and capability of the land
4. Increase our ability to forecast water supply and water demand
5. Expand our ability for delineating, by use of stereoscopic data and spectral bands that are more optimum for the purpose, geological surface features that will aid in resource assessment
6. Develop and demonstrate precise systems for measuring the motion of tectonic plates and crustal deformation
7. Develop new concepts for acquiring space data, for extracting information from the data, and for making that information available to users on a timely basis.

Planning Assumption

Underlying the entire Resource Observation program is the assumption that the application of remote sensing must be accomplished in conjunction with the user community: federal agencies; state, regional, and local users; private industry; and the scientific community. NASA must work with those users to understand their problems and to jointly develop applications of space remote sensing systems that will meet their requirements for operational data. We jointly determine the directions to be followed by matching NASA's techniques and ability to acquire space data with the user's needs for information. We establish the pace for a program to be consistent with the rate at which technology development, user understanding, testing, and adoption of new or improved space data or techniques can occur. This meshing of capabilities and needs is essential to a productive program and to success in laying the foundation for definition of needed future techniques and systems developments.

Program Principal Emphases

The Resource Observation program will focus on the following four major areas, the first two of which constitute the Renewable Resources element mentioned above:

1. Agricultural Production Forecasts. On the basis of the success of the Large Area Crop Inventory Experiment project, the U.S. Department of Agriculture (USDA) has identified a need to broaden the application of aerospace technology to help it meet its requirements for additional high-priority information. Included are use of remote sensing to obtain information on commodities important to world trade, such as wheat, soybeans, corn, barley, sorghum, sunflowers, and rice, and to improve early warning of episodic events such as drought, floods, insect infestations, and extreme weather conditions, as well as to assess the effect of those episodic events on the quality or quantity of the above products. We will initiate research to expand the use of satellite-acquired global data in predicting crop production, and we have formulated a program for remote sensing of soil moisture that will provide data and information useful to agriculturalists, hydrologists, and climatologists. The soil moisture program will assess the value of visible, infrared, and active and passive microwave techniques for quantifying soil moisture.

2. Land Use and Water Resources Management. This program area will emphasize collaborative work with users to increase the accuracy of land-use classifications and to improve information-system interfaces and our ability to detect changes and develop models. We will focus our water-resources research on hydrologic modeling and on the monitoring of soil and snow moisture, with particular emphasis on

microwave techniques. We will expand our demonstrations for users to include detailed hydrologic measurements obtained by incorporating higher-resolution data collected by the Thematic Mapper.

3. Non-Renewable Resources. We will continue development of sensors and techniques for remote sensing in order to improve discrimination among types of rock, both when the rocks are covered and when they are exposed. We will augment the Landsat base of synoptic data with geomagnetic, microwave, stereoscopic, and thermal-inertial data. Our emphasis will be on evaluating the utility of the augmenting data in expanding our knowledge about Earth's surface characteristics, geologic structures, tectonic processes, and physiographic features. Knowledge of those features is of great value in exploration for mineral and energy resources.

4. Geodynamics. This program area will emphasize application of space technology to gain a more complete understanding of dynamic processes within the solid Earth. In cooperation with the U.S. Geological Survey (USGS), the National Science Foundation (NSF), the National Geodetic Survey (NGS), the Defense Mapping Agency (DMA), and other groups within this country and abroad, we will plan and initiate an international program to observe crustal movement and deformation. The program will concentrate on the use of space techniques to complement and augment ground-based observation systems. Additional information will be provided by an improved system for monitoring Earth's polar motion and rotation that NASA and NGS will jointly develop and validate. NASA will develop improved models of Earth's gravity field and of dynamic processes within Earth's crust, mantle, and core.

Agriculture Research

The objectives of this program area are: to determine the extent to which aerospace remotely sensed data can be used to improve the objectivity, reliability, timeliness, and adequacy of information available to help USDA establish national agriculture and trade policies; and to integrate space technology related to agriculture research into either existing or new information systems of USDA and the Department of the Interior, for their routine use in those systems. Our overall approach is a balanced program of remote-sensing research, development, and testing that addresses management of domestic resources as well as needs for information on production of commodities.

The program addresses all seven information requirements identified in the USDA Secretary's "Joint Program of Research and Development of Uses of Aerospace Technology for Agricultural Programs," dated February 1978. However, the emphasis of the program is on forecasts of commodity production and early warning of changes affecting the production and quality of commodities and renewable resources.

We plan to have in limited operation by 1980 a capability to qualitatively assess 19 combinations of crops and regions for 6 major commodities in the United States and 7 foreign countries. By 1985, we will expand that capability to provide full operation and quantitative assessments. In addition, we will observe 12 combinations of crops and regions in the United States and 6 foreign countries to improve the precision of acreage estimates in this country and to provide an operational capability for providing improved forecasts of production in the foreign areas. USDA has targeted its investment decision for late FY 1981 to support the 1985 date for achieving the desired cumulative operational capability.

We plan to satisfy requirements for inventory and assessment information on renewable resources by use of the Landsat Multispectral Scanner (MSS), the higher resolution Thematic Mapper on Landsat-D, and, in the mid 1980s, the improved sampling capability of the Multispectral Resource Sampler.

Land Use Classification and Inventory

The primary emphasis of this program area will be on improvement of predictions and management models, changes in monitoring capabilities, and establishment of common data bases to facilitate timely, periodic, and objective updating of land-use categories. Secondary emphasis will be given to collection of data on coastal zone, urban, and suburban regions. Because the most dynamic changes in land use are occurring in those regions, repetitive remote sensing appears promising. During the next five years, we will exploit our existing and future data-acquisition capabilities to evaluate our potential capabilities for modeling important land-resource phenomena and to improve our basic land-use classification accuracies, change-detection capabilities, and information-system interfaces.

Water Resources and Hydrology

Remote sensing from space can meet the need for timely synoptic data on water supply, water demand, and measurement of excess water for an entire watershed. We will use requirements for data on water resources and hydrology that the World Meteorological Organization derived in 1976 as the basis for our development of remote sensing systems and techniques. Our current and planned systems will meet some of the requirements, but other requirements will call for improvements in spatial, spectral, and temporal resolution. We will emphasize determination of soil and snow moisture and hydrologic modeling during the next five years because of their importance to both agriculture and water resources. Continued development and use of active and passive microwave measurement techniques will be essential to those areas of emphasis.

Non-Renewable Resources

This program area will use space technology to improve strategies used in exploring for natural resources. One activity will be to develop better methods for making geological models and maps that take full advantage of remote-sensing techniques. Another activity will be to advance the state-of-the-art in resources exploration and assessment by synthesizing all possible remote and direct geological and geophysical methods. Yet another activity will be to develop a better understanding of the relationships between potential field anomalies, both gravity and magnetic anomalies, and the presence of mineral and petroleum deposits.

To achieve success in improving our exploration strategies, we must:

1. Develop an ability to discriminate specific types of rocks on a global basis and produce geologic maps useful for mineral and petroleum exploration. Our 5-year objective is to be able to distinguish twenty major types of rocks worldwide.

2. Develop an ability to identify the compositions of soil and rock that underlie vegetative covering, and ultimately to detect mineral and petroleum resources therein.

3. Develop an understanding of the relationships between the structural framework of a large area and its superficial and topographic expression. Our 5-year objectives are to acquire global stereoscopic data with vertical and horizontal resolution of 15 meters and to use that body of 3-dimensional data to study lineaments and their cause and significance in terms of the rock units within which they are found. Success in meeting those objectives will allow us to establish the relationships between Earth's structure, topography, and mineral deposits.

4. Develop an understanding of the relationship of gravity and magnetic force-field anomalies to significant mineral deposits in Earth's upper crust. Our objective over the next five years is to improve our ability to distinguish, globally, contrasts in crustal density and crustal magnetization. Currently, we are correlating force-field data with locations of mineral deposits, identifying regions for which models should be developed, and initiating studies to improve our understanding of the origin of rock-bearing minerals within Earth's crust.

5. Develop an understanding of both the effects of humanity's engineering activities on the natural geologic environment and the effects of that environment on humanity's engineering activities.

Geodynamic Processes

NASA will develop and execute its Geodynamic Process Program in concert with other federal agencies (USGS, NSF, NOAA, and DMA) having responsibility for geodynamics research, and in cooperation with other countries and international entities. NASA will assume primary responsibility for developing space systems and precise-measurement technology. NASA will transfer technologies to operational agencies (e.g., NGS), as appropriate. In addition, NASA will initiate and conduct geodynamics research to formulate an integrated, comprehensive model of dynamic processes worldwide. Our objectives are to produce, over a period of 10 to 20 years, models of the rate and direction of the contemporary motion of the major tectonic plates, to model the accumulation of crustal strain in seismically active areas, and to identify causative relationships for changes in Earth's polar motion and rotation. In support of those objectives, we will use laser ranging data acquired with Lageos in plate-motion studies initiated in 1979.

We will initiate in 1980 studies of the stability or deformation of the North American, Pacific, and Australian plates. In those studies, we will use fixed VLBI stations, fixed laser stations, and mobile lasers. If we find evidence of appreciable deformation, we may have to undertake long-term (10- to 20-year) measurement to gain an understanding of the processes and their geophysical significance.

Starting in 1980, we will initiate intensive studies of the relative motion of the North American and Pacific plates, using VLBI and laser systems. Those studies will extend and expand the San Andreas Fault Experiment measurements that began in 1972. Annual measurements for those plates will continue to 1984 or 1985, and will be incorporated into a global plate-monitoring system as facilities for the system become available in other countries.

In support of regional deformation measurements, NASA will upgrade in 1980 the mobility and performance of the 9-meter and 4-meter VLBI systems. Regional deformation measurements in the western United States will be underway by 1980 and will be taken over by NGS in 1983. The regional measurements will be extended to Central America and other Caribbean areas in 1981. Surveys in other seismically active areas will start in 1982. These regional measurements will continue through 1985 on the basis of two to three visits per year to selected locations. Depending on progress with international arrangements, detailed regional studies will be initiated after 1983 in Alaska, South American, New Zealand, Europe, and Asis.

We will initiate in 1980 studies of the performance and cost effectiveness of several competitive systems for making local strain measurements. The competitive systems include radio interferometric methods using the Global Positioning System and spaceborne laser-ranging to ground retroreflectors.

New Initiatives

Renewable Resources

Soil Moisture Mission - Two important capabilities must be developed to support the major objectives related to commodity forecasting and early warning of episodic events: a capability to determine and monitor soil moisture and a capability to increase temporal coverage in primary producing areas. Research has shown that passive and active microwave techniques can be used to determine soil moisture, and investigation of the possible extension of those techniques to measurement of snowpack properties is underway. The purpose of the Soil Moisture Mission, which we plan to initiate in 1982, is to demonstrate, in 1985, soil moisture measurements with microwave sensors. We will develop later, for deployment in the late 1980s, a soil-moisture monitoring mission using visual and infrared measurement techniques, as well as passive and active microwave sensors.

Multispectral Resource Sampler (MRS) - MRS will provide increased temporal coverage without additional satellite systems. It will be able to point off-axis, both front-to-back and side-to-side. In addition, it will have greater spatial and spectral resolution and will support a variety of multidisciplinary applications. It will operate in two modes. In one mode, it will have a 15-meter instantaneous field of view (IFOV) and a 15-km swath width. In its other mode, its IFOV will be 30 meters and its swath width will be 30 kilometers. MRS will have 12 spectral bands in the 0.4-1.1 micrometer region. Each spectral band will have a 20-nanometer bandwidth and 4 of the 12 bands will be selectable for concurrent use. We plan to deploy MRS in the mid 1980s to replace the Multispectral Scanner and complement the Thematic Mapper.

Non-Renewable Resources

Stereosat - Meeting the objectives for exploration for mineral and energy resources will require satisfaction of two needs: a capability to acquire stereoscopic imagery and a capability to use spectral bands that are more effective than currently used bands for discriminating between types of rocks. The Stereosat mission will use a polar orbiting satellite to acquire global stereoscopic data that can be merged with Landsat data. Stereosat's sensors will be three solid-state, imaging, pushbroom scanners pointed fore, aft, and along Stereosat's nadir to obtain base-to-height ratios of 0.5 and 1.0 at an IFOV of 15 meters.

Advanced Geology Satellite - Data showing what spectral bands are optimum for determining surface composition and discrimination between types of rocks will be obtained with the Shuttle Multispectral Infrared Radiometer on the second orbital flight test of the Shuttle. On the basis provided by those data, we will initiate in 1982 development of the Advanced Geology Satellite. That system will consist of a polar orbiting satellite carrying an imaging system with high spectral resolution in the 1.0- to 2.5-micrometer region, an infrared laser reflectometer operating in the 10-micrometer region, and a passive fluorescing device using a Fraunhofer Line Detector and operating in the visible region.

Multidisciplinary Satellite Systems

Operational Earth Resources System (OERS) - We will develop several satellite systems, each of which will be designed to acquire data for several disciplines. For example, a requirement exists to maintain continuity in acquiring remote sensing data beyond Landsat-D's useful lifetime. We have completed studies of concepts for typical ground and space segments needed for OERS and have performed economic assessments of the system. We are currently examining institutional and policy questions in cooperation with other agencies.

OERS will build on Landsat-D, the Thematic Mapper, and the Multispectral Scanner, and will incorporate additional capabilities such as those of the Multispectral Resources Sampler as they become available. We plan to retrieve and refurbish Landsat-D to provide the initial space segment of OERS. Another requirement for OERS is a data system capable of routinely distributing corrected and uncorrected data to users within two to seven days. In satisfying that requirement, we will build on the Landsat-D Data Management System.

Earth Resources Synthetic Aperture Radar (ERSAR) - We plan to develop this multidisciplinary radar research facility to provide continuity in research on the use of active microwave systems for exploration for mineral and petroleum resources and for monitoring water and vegetation resources. ERSAR will fly on Spacelab missions and will operate at multiple frequencies and with multiple polarizations and look angles.

Thermosat - Organizations working in a variety of disciplines require data on the thermal inertia of soil. Evidence indicates that the best way to acquire those data is to use a thermal infrared sensor in a near-noon orbit. Consequently, we will initiate Thermosat as a follow-on to the Heat Capacity Mapping Mission. Thermosat will include an instrument to collect narrowband, high-spatial-resolution thermal data. In preparation for developing that instrument, we will conduct research on narrow thermal spectral bands early in the 5-year period of this plan.

Geodynamics

Spaceborne Geodynamics Ranging System (SGRS) - In 1980, we will initiate studies to determine the relative performance and cost-effectiveness of several methods for measuring local strain with space systems. Those methods include use of the Global Positioning System for radio-interferometry measurements, and ranging to ground reflectors with a spaceborne laser. SGRS, which will employ that second method, will be a new initiative at the end of the 5-year period of this plan. In a network covering up to a million square kilometers, SGRS will need only a few days of observation to obtain relative locations with a precision of ± 1 centimeter. SGRS will be able to monitor crustal movements in many areas of the world and to provide almost real-time detection of ground motions before and after large earthquakes. We will select, in 1981, the most appropriate system to develop.

Tethered Magnetometer - Analysis of data from the 1979 flight of Magsat will provide an assessment of the desirability of defining Earth's magnetic anomalies more accurately. The Tethered Magnetometer, to be initiated at the end of the planning period, will obtain magnetic measurements with better definition and resolution than Magsat can provide. The Tethered Magnetometer will be a "subspacecraft" tethered to the Shuttle and trolled through Earth's upper atmosphere at an altitude between 100 and 150 kilometers.

Gravsat - Another initiative, Gravsat, will precisely define Earth's terrestrial gravitational anomalies by use of satellite-to-satellite tracking to determine details of the short wavelength components of Earth's gravitational field. The satellite-to-satellite tracking concept has been demonstrated by use of the Apollo-Soyuz Test Project mission in conjunction with Nimbus-6, and by use of GEOS-3 in conjunction with the Advanced Technology Satellite. Gravsat, in low Earth orbit (150 to 250 km), will be tracked either by a constellation of high-altitude satellites or by another satellite in low Earth orbit. Gravsat will support studies of ocean currents and circulation, crustal anomalies, and forces driving Earth's tectonic plates.

Schedule and Funding

Table 12 shows the phasing of the Resource Observation program and Figure 16 shows the program's funding requirements.

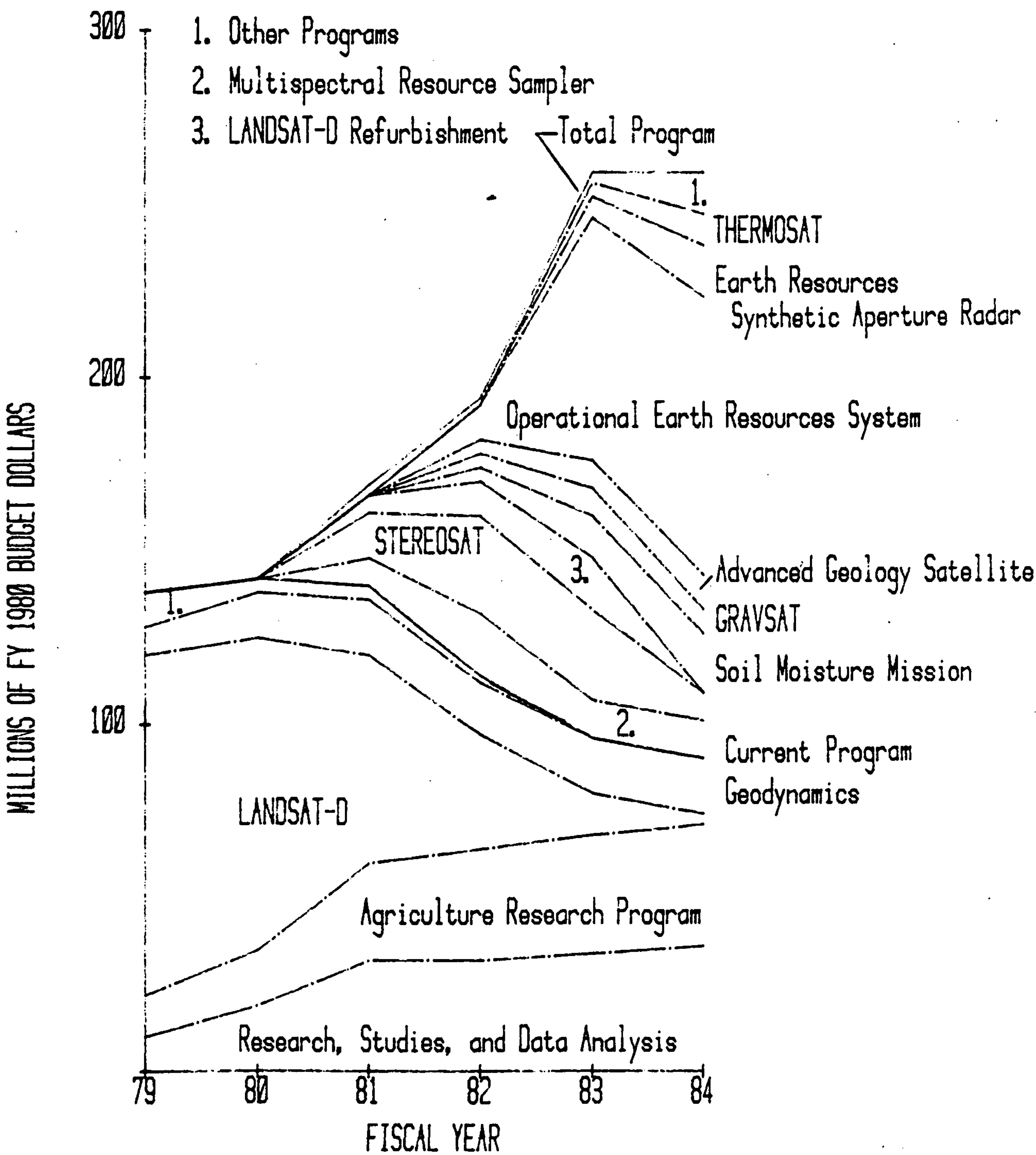
TECHNOLOGY TRANSFER

The Technology Transfer program seeks to ensure that the public and private sectors derive maximum possible benefits from the technology that NASA develops. The program includes efforts to promote and develop capabilities to use remotely sensed data within federal agencies, state and local governments, and private industry, and to identify and develop secondary applications (often referred to as spinoffs) of aerospace technology. Encouragement of users to apply space technologies related to primary missions, such as remote sensing, is the responsibility of the User Awareness and Technology Demonstration part of the program, while secondary application and transfer is the function of the Technology Utilization (TU) part of the program.

TABLE 12 - RESOURCE OBSERVATION PROGRAM SCHEDULE

PROGRAM	PROGRAM PHASE	
	INITIATION	LAUNCH
Landsat-C	Ongoing	1978
Heat-Capacity Mapping Mission	Ongoing	1978
Magsat	Ongoing	1979
Landsat-D	Ongoing	1981
Multispectral Resource Sampler	1981	1985
Stereosat	1981	1984
Soil Mosture Mission	1982	1985
Advanced Geology Satellite	1982	1986
Operational Earth Resources System	1982	1985
Gravsat	1982	1985
Earth Resources Synthetic Aperture Radar	1983	1987
Thermosat	1983	1986
Spaceborne Geodynamics Ranging System	1984	1987
Tethered Magnetometer	1984	1987

FIGURE 16 - RESOURCE OBSERVATION PROGRAM FUNDING



Program Strategy

The strategy of the Technology Transfer program is to identify public sector problems, understand user needs, and anticipate emerging NASA technologies that may provide solutions -- all in an active environment characterized by changing national economic, technical, and societal goals and priorities. The success of that strategy depends on our awareness of users' needs and on our ability to identify problems, to educate and train users to adopt NASA technology, and to develop, demonstrate, and promote diffusion mechanisms. The following activities support that strategy:

1. Stimulation of the university community through grants sponsoring research, education, and public service activities that could aid NASA's technology transfer efforts

2. Systematic identification of user needs and priorities and of NASA technologies that are potentially applicable to the satisfying of those needs

3. Development of new technology-transfer opportunities through use of TU Applications Teams, liaison with industrial associations, and cooperative activities with user representative groups such as the National Governors Association and National Conference of State Legislatures

4. Demonstration and verification of technologies in users' environments by means of Applications Systems Verification and Transfer activities, TU's Technology Applications Engineering Projects, and demonstration activities related to civil systems

5. Diffusion of technologies to, and if necessary adaption of them for, the user community through Regional Remote Sensing Applications activities, and dissemination of the results of NASA's technology activities to the private and public sectors through NASA Tech Briefs, Industrial Applications Centers, and other media.

Goals and Objectives

The goal of the Technology Utilization program is to maximize the socio-economic benefits from application of NASA primary and secondary, technology by: improvement of our knowledge and understanding of users problems and environment; creation of an informed, receptive user community; and use of improved and diversified user awareness and transfer mechanisms.

The objectives of the program are to:

1. Transfer remote sensing technology to new user markets, including substate governments (e.g., regional commissions, counties, and

cities) and private industry, and increase the use of remote sensing in developing countries

2. Introduce to users of remote sensing new technologies such as those associated with the Return Beam Vidicon and the Landsat-D Thematic Mapper, as well as new technologies derived from space research and technology activities in areas such as classification of land cover and detection of changes in it

3. Transfer new knowledge and technology from NASA's aeronautical and space research and development for secondary application by industry, the medical community, and important public sector areas such as transportation, environment, urban development, ocean survey, agriculture, and public safety

4. Develop and diversify technology transfer mechanisms, with emphasis on innovative arrangements with producers and suppliers in industry and business, governmental groups, universities, community colleges, industrial associations, and professional societies.

Planning Assumptions

The Technology Transfer program assumes that during the 5-year period of this plan:

1. NASA will continue to develop remote sensing systems and other state-of-the-art advances suitable for primary and secondary application

2. Industry, public sector, and governmental organizations will continue to need technological solutions to problems

3. An adequate user market for remote sensing data will continue to develop

4. Economic and social considerations will continue to demand a return on the Nation's investment in aerospace research and development

Program Content

The Technology Transfer program consists of the two major elements described below.

User Awareness and Technology Demonstration

The activities under this program element and the purpose of each activity are as follows:

User Requirements, Analyses, and Awareness - To maintain formal institutional relationships and continuing two-way communications with the user community in order to determine and analyze user needs and markets, inform users of existing and planned technological capabilities, identify new and unique opportunities for technology transfer, and obtain user feedback as an input to NASA's program planning.

Applications Systems Verification and Transfer (ASVT) - To demonstrate, verify, and transfer total applications systems to users in representative user settings and with the participation of the user organizations. ASVTs emphasis adaptive engineering, development of compatibility with users' existing systems, and cost reduction and refinement of the total system. The products of an ASVT are verified processes or techniques for the use of applications technologies to solve operational problems such as those related to maintaining the quality of the environment, monitoring Earth resources, and managing water resources.

Regional Remote Sensing Applications - To systematically transfer remote sensing capabilities to state and local governments through effective liaison, information dissemination, technical training, cooperative demonstration projects, and follow-up technical assistance. All of NASA's field centers participate in the liaison and information dissemination activities, while responsibility for the remaining transfer activities (user training, demonstration projects, and technical assistance) has been assigned to three field centers (Ames Research Center, Goddard Space Flight Center, and National Space Technology Laboratory) that have been designated Regional Centers.

University Applications - To award grants to universities for the conduct of research, education, and public service activities aiding transfer of NASA applications technology. In addition to developing recognized centers of expertise in space technology and its application, the University Applications activity serves as the major instrument for encouraging the universities to include in their curricula basic and specialized courses in space applications, as well as for producing the trained people that are critical to any successful long-term technology transfer program.

Technology Utilization

There are four principal activities under this program element:

Technology Dissemination - To distribute technology developed by NASA and its contractors. Dissemination media include the publication, NASA Tech Briefs, and seven NASA-sponsored Industrial Application Centers and two State Technology Assistance Centers that provide computerized access to the NASA technical information data bank for state and local governments and industry. COSMIC, a specialized center, collects, evaluates, and disseminates NASA-developed computer programs to U.S. industrial firms and other users in the public sector.

Technology Applications - To direct technology adaptation toward the solution of public sector problems identified by user organizations at the federal, state, and local levels. The program is implemented by Applications Teams, which maintain liaison with those user organizations and help them define their problems, and by Applications Engineering Projects, which adapt aerospace technology for field testing and application by those user organizations.

Civil Systems - To apply NASA technology and systems engineering expertise to the development of ocean-science technology and environmental and agricultural monitoring systems, and to conduct exploratory studies to verify the applicability of NASA technology to a spectrum of problems in the public sector.

Program Evaluation and Control - To evaluate technology transfer mechanisms in order to optimize their effectiveness. That evaluation emphasizes interaction and follow-up with users and is based on qualitative and quantitative economic analyses, including cost-benefit studies.

Emphases for FY 1980-1984

During the 5-year period of this plan, our emphases will be as follows:

User Awareness and Technology Demonstration

1. To develop a strong geobase information-system orientation in ASVT and Regional Demonstration projects emphasizing integration of remotely-sensed data into information systems, better use of data in analytical models, and distributive processing capabilities using low-cost terminals. That information-systems orientation will form a basis for later introduction of the Applications Data System described in the next section of this report.

2. To increase private sector involvement in technology transfer, both as a supplier of services and equipment and as an end user. We will make greater use of private industry as principal agents, and eventually as self-sustaining agents, in transfer projects.

3. To increase development of university curricula through University Applications activities to ensure that future resource managers are intimately familiar with remote sensing as a basic tool and to accelerate user self-sufficiency.

4. To expand the transfer of remote-sensing technology to a "critical mass" of the substate market (e.g., regional commissions, counties, and cities) and to coordinate those transfer activities with appropriate representative groups, such as the National Association of Regional Councils, in order to generate a multiplier effect.

5. To incorporate into ASVT and Regional Demonstration projects not only new technologies such as those in Return Beam Vidicon, Landsat-D Thematic Mapper, Seasat, Multispectral Resource Sampler, Passive Microwave, Large Format Camera, and Imaging Radar, but also enhanced applications resulting from space research and technology related to increasing the accuracy with which we can detect and classify changes in land cover, forecast agricultural yield and water supply and demand, and delineate geologic surface features.

6. To expand use of change agents such as intergovernmental interest groups, universities, community colleges, industrial associations, and professional societies, and to increase emphasis on systematic documentation to improve lateral transfer of "exportable" experience.

Technology Utilization

1. To direct funding on major research and development programs to ensure that contractors identify and report the technology they develop in order to promote secondary application of the technology.

2. To centralize computer support and management for the three Industrial Application Centers (IACs), to establish two new IACs in the Midwest and the Northwest, and to expand penetration of industrial markets.

3. To develop and establish one Application Team containing across-the-board disciplines and, therefore, having the ability to work on a broad range of public sector problems in, for example, medicine, environmental monitoring, public safety, and transportation.

4. To triple, by 1984, the number of applications projects devoted to solving public sector problems; for example, providing facilities for the functionally handicapped, developing imaging processes for medical diagnostics, developing viable technology transfer mechanisms for telemedicine, applying ground-based mobile lasers to the monitoring of pollution and the environment, and applying NASA's risk-management techniques to ensure safe storage and transportation of liquid natural gas.

5. To initiate a cooperative Civil Systems project to survey and explore -- using a sea-bed lander capable of prolonged ocean-floor operation -- the high-energy, strongly advective, benthic boundary layer at ocean depths of 4,000 to 5,000 meters.

6. To expand our development and testing of a systems engineering model for the technology transfer process and to statistically analyze the economic benefits of that development and testing work. That work will involve classification of existing and emerging technologies and their research and development origins, and predictive modeling of the process of transfer, use, and economic growth.

Interrelations with Other Programs

Strong interrelation with other NASA programs, including those of other divisions of the Office of Space and Terrestrial Applications (OSTA), are vital to continued effectiveness of the technology transfer program. For example, the User Awareness and Technology Demonstration activity must be closely linked to OSTA's research and technology (R&T) programs because that activity provides an outlet for the applications development programs resulting from the R&T programs and because it provides a valuable channel for gathering, synthesizing, and focusing user requirements for use in planning new technology programs. Another example is that the Technology Utilization activity must have intimate knowledge of the complete spectrum of NASA's technological developments to be able to match user needs with potential secondary applications of resulting technology.

Funding

The Technology Transfer program's funding requirements are shown on Figure 14 (page 71).

APPLICATIONS DATA SERVICE (ADS)

In the 1980s, applications programs will mature to the extent that successful use of their results will require very effective processing and use of data from many sources. It will be an era in which technical disciplines from agriculture to oceans and weather will be formulating large-scale models that will require timely access to and integration of data from a dozen or more sources. To satisfy those data access and integration needs efficiently and economically, we are planning to develop the ADS.

Program Strategy

We will build the ADS on existing and planned applications data systems, converging those systems into an integrated structure by defining standards for data and data systems and by developing a network service for data transmission and integration.

The standards will guide future programs. Their application will ensure that the data and data systems that evolve will be compatible. Their successful implementation is critical to assurance that the data and data products from next-generation systems such as the National Oceanic Satellite System, System 85, and the Operational Earth Resources System are compatible and can be readily exchanged and integrated.

The network service, which we will superimpose on today's system, will streamline that system and make it more efficient. It will furnish a common service that will provide access to data, provide required format conversions, and integrate the cross-correlative data sets required by multiple users. A user will be able to obtain aggregated data for any geographical region he wishes. He will be able, for instance, to request a LANDSAT image of New England and have the image overlaid with temperature and soil moisture data. The network, catalog, and data preparation services of the ADS should make it easier to determine what data are available and to provide those data in a more timely manner and a more usable form.

Program Content

We will complete current studies of ADS requirements, concepts, and feasibility by the end of 1979. The results will support, in 1980, definition of standards and initiation of the parallel contracts for definition of network service required by the Office of Management and Budget's Circular A109. We plan to initiate implementation of the ADS network in 1982. Consequently, a partial ADS capability will be available by early 1983; full capability by the end of 1984.

As part of our ongoing activity, we will assess several methods for acquiring ADS services, including leasing some or all of them from the commercial community. That method would use a commercially developed and financed system. We will determine the probable availability of commercial services, the steps that would be required in arranging to use them, and the advantages and disadvantages of using them. To gain the interest of the commercial community, we plan to hold individual discussions with potential vendors and to give a general presentation on ADS to all interested vendors.

Funding

The ADS program's funding requirements are shown on Figure 14 (page 71).

MATERIALS PROCESSING IN SPACE (MPS)

The MPS program emphasizes the fundamental science and technology of processing materials under conditions that allow detailed examination of the constraints imposed by gravitational forces. It focuses on selected materials and processes that will best show what limitations are imposed by gravity, and will demonstrate the enhanced process control that the weightless environment of space is expected to provide.

During the 5-year period of this plan, we will concentrate on consolidating available data and supporting studies in the areas of materials science and technology that we will address in our initial investigations aboard the Shuttle. We will place secondary emphasis on identifying and understanding the requirements that drive the designs for experiments, and on initiating technology development studies that will reduce the risk associated with future development of experimental equipment. Late in the planning period, we will build on the experience gained from ground-based research and expand the program to include a wider base of investigations. Those investigations will be ones that can be conducted using existing hardware. This 5-year plan includes acquisition of new space flight hardware to support the science requirements that will evolve from the early Shuttle experiment program and from ground-based research. The initial flight of the new hardware will occur either late in the planning period or, because of lead times for hardware development, beyond the planning period. The principal elements of the program that will be conducted using the hardware include crystal growth and solidification, containerless processing, fluid and chemical processes, vacuum research, and commercialization studies.

STAMPS Committee Assessment

The committee on the Scientific and Technological Aspects of Materials Processing in Space (STAMPS), sponsored by the National Research Council, recently assessed the MPS program. Its recommendations stressed the need for more extensive research on the ground to serve as a base for the evolution and assessment of experiments that would increase understanding of the role played by gravity in materials processes. The committee recommended that recourse to the weightless environment of space be based primarily on the understanding gained from the ground-based research and on the needs identified by means of it. It recommended, in addition, that the first phase of NASA's program in space be a demonstration of technology developed in the ground-based program and that, after its demonstration, the technology be transferred to user organizations. A second phase, funded primarily by those user organizations, should then be to develop a laboratory in space, the National Materials Laboratory, and to make that laboratory's capabilities available to all for a reasonable charge.

The National Materials Laboratory concept will begin with use of the experimental equipment and systems described in this plan, and will develop into a unique facility as the MPS goals of user organizations mature and become more focused. The committee recommended closer ties between the materials communities and NASA in the form of peer review of all proposals -- for ground-based research as well as for research in space -- and of policies and plans, also.

We have been restructuring the MPS program on the basis of the committee's recommendations ever since the committee's earliest deliberations. We also have established an inhouse advisory committee and have given it responsibility for providing guidance to our program planning and policy making for MPS. Those actions are consistent with the spirit and principle of the STAMPS recommendations.

Program Strategy

The current emphasis of the MPS program on fundamental science and technology in selected areas of processing will continue throughout the period of this plan as the program builds an active constituency and addresses problems of interest to the public and private sectors. We will develop and demonstrate space technology for materials processing and transfer it, as appropriate, to users. We will encourage early involvement of independently funded scientific and commercial users through cooperative arrangements such as appointment of guest investigators, cost reimbursable use of hardware, and joint endeavors in which NASA will supply space flight services and technology and the user will supply experimental hardware and data on a no-exchange-of-funds basis. The Commercial Applications Office has been formed within the Materials Processing in Space Projects Office at Marshall Space Flight Center to resolve institutional constraints serving as disincentives to cooperative involvement, to serve as a single point of contact for interested parties, and to represent the interests of those parties within NASA.

We anticipate that commercial involvement in the program will become progressively more sophisticated -- that it will start with breadboard experiments on the ground and in aircraft and will grow to full reimbursement for the costs of operating hardware in space. NASA's activity will be limited to funding a small number of case studies until the program resources required for more extensive involvement can be identified and obtained. We will emphasize expansion of currently funded ground-based and space flight investigations to obtain all possible benefits from them, and will encourage to only a limited degree initiatives requiring hardware that cannot be made available during the period of this plan. That expansion of current efforts involves ground-based activities focused on selected areas and an increase in support for current space flight investigations. That support consists of forming facility experiment teams to provide advice and to identify the best type and amount of future involvement.

Goals and Objectives

The goals of the MPS program are to demonstrate to the scientific and commercial user communities the capabilities the space environment offers for materials processing and to provide opportunities for independently funded users to exploit the space environment to satisfy their materials processing needs.

The objectives of the program are to:

1. Develop and demonstrate processes in space with a higher degree of control over the process variables than is achievable on Earth. Experiments we will conduct to meet this objective will be to control thermal fields in materials systems involving fluid phases, increase compositional uniformity in crystals, decrease the concentrations of defects in crystals, align the internal structure of metal alloy systems, increase the purity of optical glass systems, increase the stability range of new glass systems, increase the geometrical uniformity of glass microshells, reduce the self-deformation and dislocation density of growing crystals, improve the effectiveness of electrokinetic separation, and produce monodisperse polymer latex spheres with large diameters.

2. Develop and demonstrate the capabilities of containerless processing techniques to handle and to measure the properties of molten reactive materials on which experiments cannot be performed in Earth-based laboratories. This objective will require: experiments related to viscosity and surface tension, dynamic and equilibrium vapor pressures, and the enthalpy of solution and reaction; measurements of enthalpy, emissivity, and temperature; studies of phase equilibria; and the processing of droplet arrays.

3. Study the nature of the vacuum achievable in space and its utility for extending the range of important experimental parameters in the science of extra-high vacuums, as well as its potential for making novel capabilities possible in materials processing.

4. Provide opportunities for independently funded scientific and commercial users to perform materials processing in the space environment.

Program Content

During the period of this plan, the MPS program will conduct systematic, correlated space and ground-based investigations in areas that past research has shown to be of interest, and will explore new technical areas and research methods. In 1983 and 1984, space investigations in materials science will begin to be a continuing "level-of-effort" activity in order to provide the continuity that is vital in materials research. In preparation, beginning in 1980, we will increase the level of effort in the ground-based part of the MPS program in order to provide the research background needed for those systematic space investigations.

Research on Crystals

Crystal growth and solidifcation, one of the MPS program's more established areas, will emphasize research on applying floating zone techniques to crystal growth, and improvement of methods for preparing materials for infrared detectors. Activities in this area will also include containerless processing experiments on new glass materials and fluid and chemical process research on the transfer of heat and mass that occurs in the growth of crystals in solution and in electrokinetic separation processing to produce biological materials. In addition, the MPS program will seek to facilitate entry of private users into this and other areas through joint projects with those private users and through leasing to them Shuttle-Spacelab materials processing equipment that the Office of Space Transportation Systems (OSTS) plans to develop.

Containerless Processing

In newer areas of endeavor, the MPS program will emphasize containerless processing methods to produce target structures for use in research on inertially confined fusion reactions; make accurate measurements of the high-temperature properties of reactive materials; grow crystals from solutions, using a recently invented method of electroepitaxy; and investigate research applications for the large-volume, ultrahigh vacuum available in space. Technology development efforts will include application of high-temperature heat pipes to thermal systems for crystal growth, and development of electrostatic levitation methods for containerless processing.

Materials Experimentation Carrier

The usual flow of MPS activity is from ground-based research and technology development to continuing flight investigations, and one aim of the MPS program is to establish means to verify, at as low a cost as possible, new equipment systems and experimental concepts before commiting them to full-scale flight projects. Some of that verifying can be done under simulated space conditions and at low cost on the ground. However, some verification must occur in space and will need kinds or amounts of support that the Shuttle-Spacelab will not be able to provide. Therefore, concurrent with OSTS' definition and development of the 25-KW Power Module, the MPS program will define the requirements for, and OSTS will develop, the Materials Experimentation Carrier (MEC). The MEC will be a hardware system that will provide an interface between MPS payloads and the 25-KW Power Module. The payloads will remain attached to the 25-KW Power Module as it flies freely between two or more Shuttle visits. This mode of operation will provide two advantages over the services that the Shuttle-Spacelab can provide: increased power resources to support larger and more sophisticated experimental apparatus and longer stay times in space. It will be available toward the end of the planning period.

Research Activities and Hardware Projects

The research activities and hardware projects required to implement the above plans are outlined and cross-referenced in Table 13. The MPS program will also continue to study mission and hardware configurations that could provide sufficient power for experiments while reducing overall mission costs. Completed studies have already identified one configuration, a free-flying module that would serve very effectively as a platform for, and supplier of power and other services to, MPS experiments. In the 1980 through 1984 period, our definition studies will identify a series of phased options for providing such flight opportunities. We anticipate that some of the associated hardware development activities can be initiated in 1982.

TABLE 13 - RESEARCH TASKS AND HARDWARE PROJECTS

DISCIPLINE	TECHNOLOGY AREA	RESEARCH TASK	APPLICATION	IMPLEMENTATION
Crystal Growth and Solidification	Infrared Detector Materials	Study problems associated with compositional control	Infrared detector materials for Earth-sensing applications, law enforcement, scientific instrumentation, medical diagnosis, military surveillance	1981 - Floating - Zone Experiment 1982 - High-Gradient Furnace System 1983 - Floating Zone Processing Module
	Floating-Zone Experiments	Study Melt surface and flows related to surface tension gradients in the floating-zone configuration	Separation and quantification of fluid flow effects in Earth-based floating-zone processes, as well as study of new configurations for space experiments	1981 - Advanced Solidification Experiment Systems
	Composite Materials	Study preparation problems and physical properties of variable density solids	Foam metals for shock loading; fiber reinforced materials for high strength and high ductility; phase-aligned structures for directional properties (for use in turbine blades, large space structures, ceramic bone implants, semiconductor heterostructures)	

TABLE 13 - RESEARCH TASKS AND HARDWARE PROJECTS (CONTINUED)

DISCIPLINE	TECHNOLOGY AREA	RESEARCH TASK	APPLICATION	IMPLEMENTATION
Containerless Materials Processing	Inertial Confinement Fusion Targets	Study problems associated with geometrical control to produce more efficient implosion conditions in large-size, hydrogen-filled glass	Short-range applications in fusion research for power generation and weapons programs; long-range possibilities for energy production	1981 - Acoustic Containerless Processing Module II 1982 - Electromagnetic Containerless Processing Module
	High-Temperature Material Property Measurements	Study reactive materials, including property measurements and production of standard reference materials	Material properties for design applications	1984 - Electrostatic Containerless Processing Module
	Preparation of Unique or Pure Materials	Study preparation problems of suitable starting materials and suitable aggregation under low-g; establish suitable characterization techniques	Standard reference materials or refractory materials for optical or other use, such as optical glass fibers, high-power glass lasers, and self-focusing lenses	

TABLE 13 - RESEARCH TASKS AND HARDWARE PROJECTS (CONTINUED)

DISCIPLINE	TECHNOLOGY AREA	RESEARCH TASK	APPLICATION	IMPLEMENTATION
Fluid and Chemical Processing	Fluid Dynamics Studies	Explore detailed relations between inertial environment and density-gradient flows in fluids, as well as new convection phenomena at low gravity; study multiphase liquid flows and chemical precipitation kinetics	Casting structure control, crystal growth control, electrophoretic separation, blood rheology data	1981-Advanced Fluids Experiment System 1982 - Bioprocessing Module
	Bioprocessing Studies	Study of heat and mass transport problems limiting separation and synthesis of biomaterials in Earth-based technologies	Improved efficiency for ground-based bioprocessing methods, and identification of candidate techniques that take unique advantage of weightless conditions	
Vacuum Research	Surface Physics Ultrapure Materials	Identification of extra-high-vacuum characteristics associated with orbiting molecular wake-shield environment	Extended range for important experimental parameters in performing vacuum science experiments and in identifying utility of that new environment for materials processing	1984 - Space Vacuum Research Facility

TABLE 13 - RESEARCH TASKS AND HARDWARE PROJECTS (CONTINUED)

DISCIPLINE	TECHNOLOGY AREA	RESEARCH TASK	APPLICATION	IMPLEMENTATION
Commerciali-zation	Commercial Space Applications	Examine institutional constraints discouraging privately funded research and serve as point of contact for joint endeavors with private sector	Development and leasing of Materials Experiment Assembly for performance of simple, exploratory, space flight experiments, and start of joint ventures	1981 - Commercial Space Applications 1981 - Materials Experimentation Assembly II
	Carrier for Commercial Flight Opportunities	To be defined by user in accordance with program objectives	Self-contained carrier designed to fly in Shuttle cargo bay and support experiments developed within MPS program or by commercial users	

TABLE 13 - RESEARCH TASKS AND HARDWARE PROJECTS (CONTINUED)

DISCIPLINE	TECHNOLOGY AREA	RESEARCH TASK	APPLICATION	IMPLEMENTATION
Program Support	Operations Verification	Demonstrate technical means for satisfying subsystem requirements such as for accelerometers, optical system for flow visualization, high-temperature heat pipes	Tests of breadboard models of proposed space systems in an environment duplicating essential elements of operational conditions	1981 - Science Demonstrations and Operations Verification 1982 - Materials Experimentation Carrier
	Science Demonstrations	Conduct typical experiments: bubble migration, polymer reaction data, meniscus behavior, non-cylindrical floating zones, electrogrowth of crystals, Ostwald ripening, blood rheology, self-focusing lenses, cell culturing	Easy access to space environment for program participants to enable them to obtain preliminary data and test concepts; packages useful as space fillers on Spacelab module missions	
	Materials Experimentation Carrier	Conduct Shuttle experimental program and reduce cost of space experiments	Satisfaction of power requirements of MPS Experiment Program by providing, via the Shuttle, access to 25-KW Power Module in free-flying mode for periods of 30 to 60 days	

Interrelations with Other Programs

The MPS program will undertake the following interrelations with other NASA programs during the next five years:

1. It may join with the STS Operations Division of OSTS to fly, on a limited number of demonstration missions, hardware and facilities developed by non-NASA sources, such as private industry, in joint ventures with NASA.

2. It will define and give to the Advanced Programs Division of OSTS its requirements for support so that OSTS can define and design the 25-KW Power Module, the corollary Materials Experimentation Carrier, and the follow-on Materials Experimentation Carrier II and Materials Experimentation Module. It will provide the experiments and experimental facilities, while OSTS will provide the platforms and services for the experiment packages.

3. It will continue to coordinate with the Research and Technology Division of the Office of Aeronautics and Space Technology and to mutually support basic research activities in the materials sciences. That cooperation will include direct participation on the Physics and Chemistry Experiments Committee, funding of appropriate studies, and coordination of research on infrared detector materials, composite materials, and processing of extraterrestrial materials.

4. It will continue to coordinate bioprocessing activities with the Life Sciences Division of the Office of Space Science, with MPS emphasizing the technology (methodology) of processing.

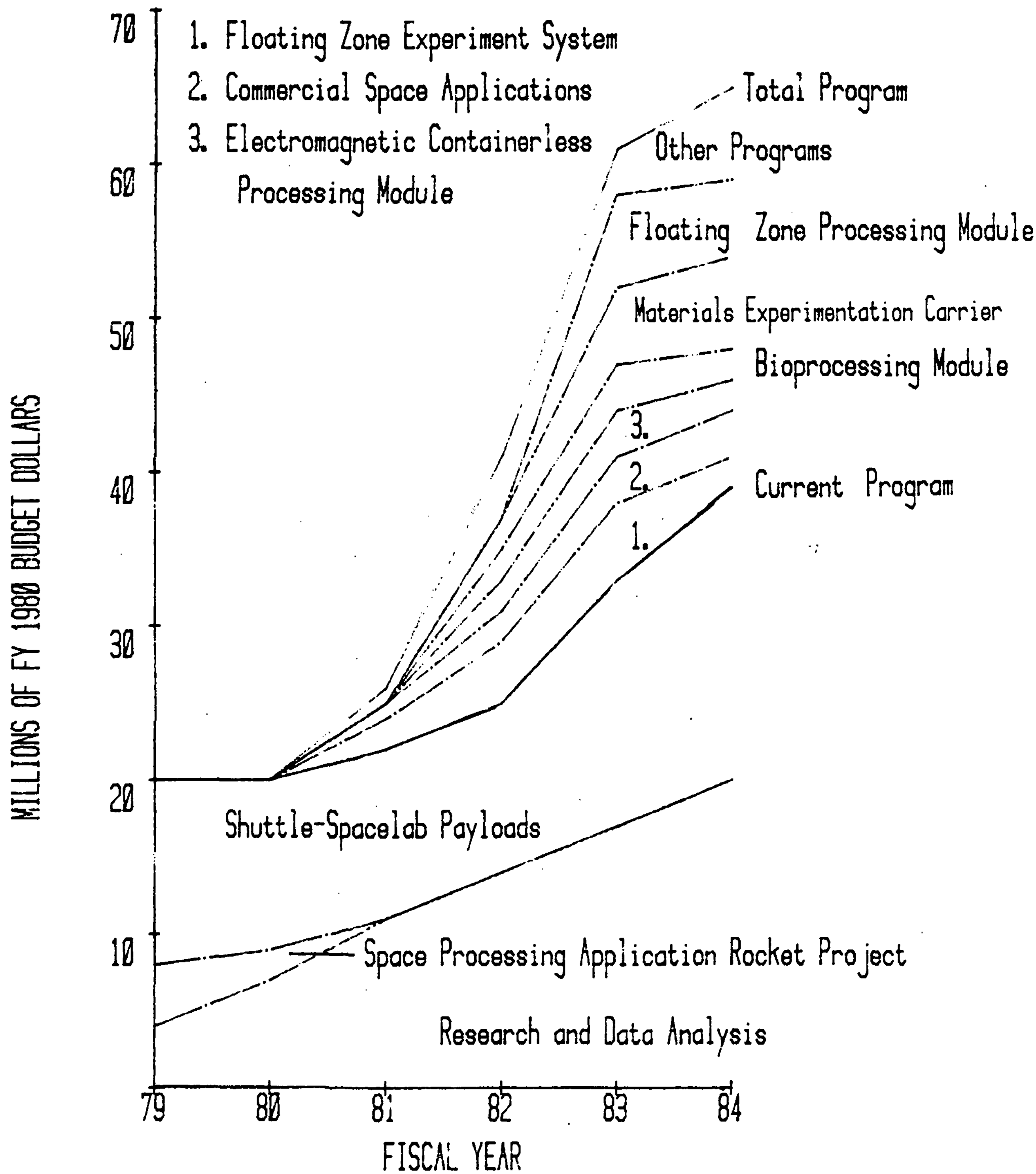
Program Funding

Figure 17 shows the funding requirements of the Materials Processing in Space program.

COMMUNICATIONS

NASA's plan for development of technology for satellite communciations responds to a growing need for new and improved commercial services. The President's October 1978 Civil Space Policy removed former concerns about the direction of the NASA program following the 1974 phasedown of activity in NASA's research and development (R&D) flight program. In response to that policy, we will undertake carefully selected communications technology R&D, focusing on effective and efficient use of the limited radio spectrum and geosynchronous orbit resources.

FIGURE 17-MATERIALS PROCESSING IN SPACE PROGRAM FUNDING



Planning Assumptions

Projection of the demand for satellite communications indicates that saturation of the geosynchronous orbit and radio spectrum space in useful view of the United States is imminent. Users of point-to-point and broadcast services must compete for orbit and spectrum space. Consequently, we assume that imminent saturation coupled with a continuing growth in demand has created a requirement for new technology that will provide more effective use of the orbit and spectrum resources.

The K-band (30/20 GHz), allocated in 1971 to increase satellite communications capacity, has been inadequately explored and developed for use in the United States. Meanwhile, R&D programs in foreign nations are proceeding with development of technology for that band. We assume that foreign development could reduce U.S. participation in the growing worldwide market for K-band (30/20 GHz) systems.

As in past technology developments, NASA's R&D can supply the significant advance in the state-of-the-art for the K-band (30/20 GHz) needed to satisfy the expanding demand for communications, thereby enabling U.S. industry to meet competitive requirements in the world market. We assume that, because the private sector's R&D must be based on near-term profit potentials, the necessary long-term, underlying R&D must be conducted by the Government and that, once developed, that R&D will enable industry to confidently offer new and expanded services.

Program Strategy

The Communications program is based on a strategy to accomplish several objectives from a single fundamental technology base. While providing expanded use of the limited spectrum, we can improve on our current use of spacecraft antennas with wide coverage patterns, and on the separation of traffic among ground terminals by frequency channelization. High-performance, non-interfering, multibeam spacecraft antennas will allow the entire spectrum to be reused at separate ground locations communicating through a single satellite on different antenna beams. A natural adjunct to that technology for adding flexibility to a communication system is "onboard switching"; i.e., flexible routing of traffic among beams. Further, synchronized, time switched access for traffic, if fast and efficient, is a strong advantage of that kind of technology.

We will pursue those combined antenna, switching, and access capabilities in parallel to provide insight into communications satellite systems that will be commercially desirable. Ground terminals working with that satellite system could be simpler and more affordable than those using more advanced, but also more complicated, systems to be able to work with space elements having less capability. Also, later implementation of the multibeam antenna technology at the broadcast-allocated Ku-band could result in development of braodcast satellites with recontourable beams, which could increase the much-needed isolation between national borders.

We will develop these and other technologies needed to meet the Nation's communications needs late in this century by means of a modest, but broad, R&D program. We will conduct that program within NASA's own resources, partly at two or three NASA field centers and partly through those centers' contracting with industry in order to exploit specific industry expertise and to derive "leverage" from our internal R&D resources.

Flight-Test Program

We have received strong recommendations for conducting a flight-test program to provide proof-of-concept and lifetime testing in the space environment in which commercial systems are expected to operate. While that flight program will serve an important function and is technically and operationally feasible within this 5-year planning period, it will be initiated only when its need becomes clearly evident. We will define the program to protect our decision-to-proceed option for experimental flights, but flight testing of advanced hardware may evolve into new forms. Developing relationships among NASA, the Department of Defense, and the communications carrier and supplier industries show strong promise for effective conjunctions of effort in flight testing.

Program Guidance

Continuing guidance for the Communications programs stems from established relationships among the program's staff, managers at NASA's field centers, and a subcommittee of the NASA Advisory Council (NAC). The NAC subcommittee consists of senior experts from industry who review, discuss, and provide recommendations on the program's content and management, and in the process, give us needed insight into industry's activity in communications.

Interrelations with Other Program Offices

The Communications Division of the Office of Space and Terrestrial Applications (OSTA) maintains close coordination with other NASA program offices. It identifies and defines the basic long-term research and technology requirements for the advancement of in-orbit capability by performing advanced system studies (characterizations of potential service systems, including conceptual designs and rough cost estimates), by closely observing industry cost and performance trends, by identifying legal and regulatory constraints on spectrum and orbit use, and by assessing user needs. As those research and technology requirements take form, OSTA and the Office of Aeronautics and Space Technology (OAST) make coordinated evaluations so that OAST's R&D to develop technology for hardware components can be included in the regular planning cycle. In preparation for each succeeding subsystem phase of applied R&D, OSTA keeps informed continuously on developmental progress to be able to ensure that subsystem- and system-level technologies and techniques will be available for use in industry initiatives, as needed.

When programs approach system-level activity, OSTA and OAST hold joint readiness reviews to provide for orderly transfer of responsibility from OAST to OSTA.

Goals and Objectives

The goal of the Communications program is to provide for:

1. U.S. technological leadership in satellite communications

2. Effective and efficient use of orbit and radio spectrum resources.

The objectives of the program are to:

1. Develop the state-of-the-art in multibeam antenna and onboard switching systems to provide significant increases in communications capacity

2. Conduct carefully selected R&D applicable to the K-band (30/20 GHz) to ensure technological readiness for system testing by 1984

3. Conduct, for the same purpose, R&D in UHF and L-band regions applicable to small, low-cost user equipment and to systems with service costs that are affordable by low-volume users; conduct flight demonstration in 1986

4. Determine by 1981 the technical, economic, and institutional feasibility of using large geostationary platforms for satellite communications

5. Identify the services and users potentially best suited to the characteristics of the K-band (30/20 GHz); by 1982, plan internal allocations in that band as a guideline for industry and the regulating agencies.

Program Content

Major Program

The principal effort in our planned R&D is a new one, the development of multibeam antennas for the K-band (30/20 GHz) and of onboard switching techniques essential to efficient use of orbit and radio spectrum resources.

Continuing Activities

Several current activities of the Communications program will continue into the planning period. One is to provide technical consultation support to other OSTA divisions, to other NASA elements, and to the Federal Communications Commission, the National Technical Information Service

(NTIS), and the Department of State. That support is related to orbit and radio spectrum management, including studies of the propagation of signals and the sharing of radio frequencies. Another continuing activity is to conduct search-and-rescue experiments to provide the Department of Transportation (DOT) and the U.S. Air Force with an alert-and-locate capability. That capability will be based on the relaying by satellites of distress signals from emergency transmitters on ships and aircraft in trouble. Flight testing will occur in 1982. The third continuing activity is to fabricate an L-band, adaptive, multibeam, phased-array antenna system, and to flight test it on Spacelab in 1982. Three studies on the state-of-the-art of, and potential needs for, various types of onboard switching comprise the fourth activity. Those studies are scheduled to end in 1981. The fifth activity consists of two experiments for DOT. In the first experiment, we will relay location data from LORAN-C mobile transmitters to a central point via an existing commercial satellite. The other will be an electronic mail experiment to assess the use of high-speed, state-of-the-art, commercial facsimile equipment to satisfy the communications needs of industrial supply organizations. The sixth continuing activity is to provide technological support to NTIS. Two items of support that we already know will be required are to engineer the transfer to commercial communications services of experimenters currently using the ATS-6 and CTS satellites, and to continue operating the ATS-1, -3, -5, and -6 satellites, if their health continues to be adequate.

Advanced Studies

The Communications program for FY 1980 through 1984 contains the following advanced study areas:

1. Applied Research and Data Analysis. This area provides the core R&D that serves as the base for all our communications work. It will focus on development of technology for K-band (30/20 MHz) multibeam antennas and onboard switching, with associated activity in systems developments such as multiple access, compressive modulation, and advanced hardware based on microwave integrated circuitry and other emerging basic advances.

2. Large Geosynchronous Platforms. This area will consist of studies to define requirements for large platforms in geosynchronous orbit. Those studies will address potential payloads and design concepts for the platforms, the amount of projected communications traffic that could be handled via various alternative space systems, radio-frequency interference problems, reliability, and institutional relationships.

3. Orbiting Standards Platform. The purpose of the studies in this area is to assess the ability of radio-frequency test beacons at geosynchronous altitude to serve the needs of the developers of low-orbit and ground-based antennas.

4. Intersatellite Relay. The studies in this area are to develop an understanding of uses and networks for spacecraft that could serve as relays for the communications of other spacecraft. That understanding will help us define systems technology requirements.

New Initiatives

The two major new initiatives planned for the FY 1980 through 1984 period are described below. Also, assuming that the studies for the Intersatellite Relay mentioned immediately above show that development should proceed, that system will be a 1983 new initiative.

Wideband Program - As noted in the planning assumptions, the technological development of the K-band (30/20 GHz) is essential to the growth of satellite communications. NASA's initial assessment of this area is being managed by Lewis Research Center. It consists of two activities, market analyses and systems analyses. The market analyses are being conducted by two communications common barriers, who are under contract to: forecast the demand expected to develop in the 1980 to 2000 period; characterize the demand with regard to type of user, size of the demand, and demographics; project service costs for both terrestrial and satellite systems; and forecast the satellite systems' share of the predicted market. The systems analyses are being conducted by two satellite manufacturers, who are under contract to assess the technological state-of-the-art, define systems concepts, analyze competitive alternatives, identify critical technology, and estimate system costs.

The next steps in this initiative will be to establish conceptual designs; to develop critical technology, including that for multibeam spacecraft antenna and onboard switching systems; and to determine the need for flight verification tests. Those activities will begin with project definition in 1981 and are expected to lead to program initiation in 1982.

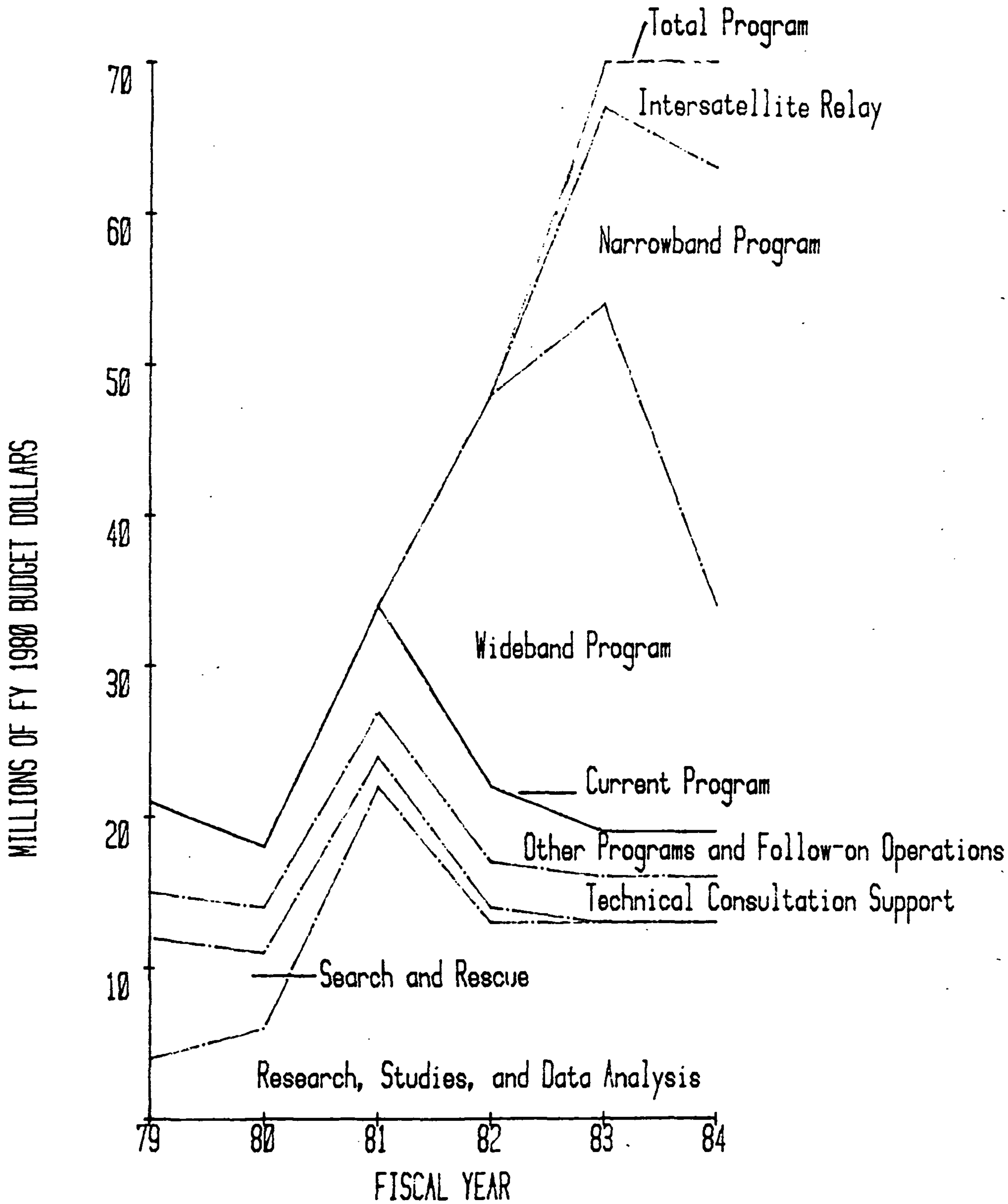
Narrowband Program - The Wideband Program will satisfy some needs for additional communications capacity, but additional provisions will be necessary for many applications, such as emergency and disaster communications, automatic data platforms, and land-mobile voice communications. Hardware for UHF terrestrial terminals has already been developed to serve a large and growing market. Consequently, use of UHF frequencies via satellite promises the low costs required for service to low-volume users. It is likely that a portion of the UHF spectrum will soon be allocated for communications satellites to provide land-mobile communications. NASA's program will approach the development of those satellites by application of multibeam techniques to provide as much frequency reuse as practical in an anticipated spectrum allocation of only a few megahertz. In seeking systems concepts, we will explore only narrow bandwidth types of service -- voice and low-rate data communications.

Developments at K-band (30/20 MHz) on multibeam antennas and onboard switching will contribute to this program also. A key technology, that for the large antenna required for a UHF multibeam system, will be the first item for consideration. The remaining technology for the Narrowband Program is sufficiently close at hand that system development can be accomplished within that antenna's development and test period. The requirements for the antenna's components (reflector, lens, phased array, and combinations) and their characteristics are under study. As they are defined and the expected frequency allocations are made, the Communications Division will be able to accelerate its planning with the Office of Aeronautics and Space Technology and the Office of Space Transportation Systems toward project definition of structures technology.

Program Funding

Figure 18 shows the Communications program's funding requirements.

FIGURE 18-COMMUNICATIONS PROGRAM FUNDING



CONTENTS

AERONAUTICS PROGRAM

Aviation is important to the United States as a mode of transportation, as an element in national defense, and as a source of economic strength. The United States dominates the Free-World marketplace in transport and military aircraft and holds a leading position in other types of aircraft. Continued preeminence in aviation will demand progressive advances in the Nation's aircraft and system capabilities, in the productivity and profitability of the U.S. aviation industry, and in the environmental acceptability of U.S. aircraft. Growth of air travel, which is forecast to increase by a factor of three to four by the year 2000, and rising foreign competition in world aircraft markets cause the maintenance of U.S. technological leadership to be a matter of urgent national importance and concern.

NASA'S ROLES

NASA's roles in aeronautics are, by charter, to improve the usefulness, performance, speed, safety, and efficiency of U.S. civil and military aeronautical vehicles and to preserve U.S. leadership in aeronautical science and technology and the application thereof. To fill those roles, NASA has oriented its aeronautics research and technology (R&T) program to meet the near-term and far-term technology needs of the aviation industry, aircraft operators, government regulatory agencies, and the Department of Defense. NASA coordinates closely with each of those components of the aeronautics community in defining the R&T needs and the objectives for its aeronautics program. NASA technology has influenced the design of virtually every civil and military airplane built in the United States.

PROGRAM GOAL

The goal of NASA's aeronautics program is to generate technology required for:

1. Safer, more economical, efficient, fuel-conservative, and environmentally acceptable air transportation systems to satisfy current and projected national needs

2. Assurance that the United States will maintain its competitive position in the international aviation marketplace

3. Maintenance of the superiority of the Nation's current and future military aircraft.

Preceding page blank

PLANNING ASSUMPTIONS

The NASA Aeronautics program is based on the following fundamental assumptions regarding needs and responsibilities:

1. Air transportation of passengers and cargo will continue to expand, creating demands for new transport aircraft in many sizes and for large, dedicated cargo aircraft.

2. The rate of growth in the use of helicopters and general-aviation aircraft and in the movement of cargo by air will continue to be higher than the rate of growth in commercial air passenger travel.

3. Energy availability will continue to be a serious problem, but kerosene-based fuels will be available (at a price) into the next century.

4. Continued improvement in environmental acceptability of aviation will persist as a national concern.

5. The unique characteristics of supersonic, short-takeoff-and-landing, and vertical-takeoff-and-landing aircraft and the latent demand for the transportation services they can provide will eventually justify their development for both civil and military use.

6. NASA, as the Nation's primary agent for civil aeronautics research and technology, will continue to be depended on for technological support to aircraft developers, producers, and operators; to regulatory agencies; and to the Department of Defense.

PROGRAM ELEMENTS

FOCUSED R&T

The Aeronautics program concentrates on continuously expanding the base for aeronautics technology, developing systems technology, and conducting experimental programs. Many activities within those categories of technical effort focus on individual classes of aircraft, each of which presents unique technological problems and opportunities. Those focused research activities are sometimes directed at timely readiness of technology for industry development of needed aeronautical systems. Preparing long-lead technologies and ensuring their timely readiness necessitate assuming dates by which development decisions may be required. We make those assumptions in cooperation with appropriate industry and military planners. When high development risk is recognized as a potential deterrent to incorporation of important technical advances into systems, NASA may extend its focused R&T program to include demonstration of the technology involved.

GENERIC R&T

Underlying NASA's focused R&T efforts is a core of generic R&T consisting of continuous fundamental research in individual technical disciplines that are broadly applicable to many, frequently all, of the classes of aircraft. This aeronautics plan includes significant growth in generic R&T--about 30-percent real growth in the 1981 through 1983 period -- to increase activity in computational fluid dynamics, experimental methods, test techniques, propulsion and airframe integration, and avionics and safety technology. The growth and the areas of concentration are responsive to recommendations and advice from both in-house and external committees and groups. The R&T will emphasize far-term activities, and a significant portion of it will be research contracted to universities.

PROGRAM CONSTRAINTS

Actual budget limitations in 1980 and expected budget limitations for the four remaining years of this plan have constrained the plan's content and pace. The results have been deferral of several activities that could begin earlier and, therefore, delay in the availability of the technologies that the activities will produce. Principal examples are a delay from 1980 to 1981 in augmenting the R&T Base and deferral of part of formerly planned increases in rotorcraft R&T and in development of advanced propeller technology.

CONTENT OF FOCUSED R&T PROGRAMS

The R&T activities planned for each class of aircraft are as follows.

CONVENTIONAL TAKEOFF AND LANDING (CTOL)

These R&T activities include both the Aircraft Energy Efficiency (ACEE) program and non-ACEE CTOL work to improve the operational efficiency and safety of aircraft and to reduce their environmental effects.

ACEE Program

Continuation of the ACEE program includes technology to improve engine components. It also includes energy-efficient engines, energy-efficient transport aircraft, advanced turboprop aircraft, laminar flow control, and ground testing of composite structures. A new program to be started in 1981 to develop propeller technology will support the ACEE Advanced Turboprop program. The next phase of the Laminar Flow Control (LFC) program, to begin in 1982, will provide data on and flight experience with an advanced LFC wing. New airframe efficiency programs starting in 1981 will first address long lead-time technology for composite wings and then extend composite-material applications to wings, nacelles, and fuselages.

Non-ACEE CTOL Work

The CTOL programs, Aeroelasticity of Turbofan Engines, Fire Resistant Materials Engineering, Human Factors in Safety, and Digital Fly-by-Wire, will be completed in 1980. Continuing CTOL work includes the Terminal Configured Vehicle, Materials for Advanced Turbine Engines, and Broad Specification Fuels programs.

We will initiate CTOL programs in 1981 and later to support the long-term objective of identifying and demonstrating new engine cycles. Those programs will include development in the late 1980s and the 1990s of concepts for advanced gas generators. The first phase of research will identify technological options for new engine cycles and techniques for monitoring and retaining engine performance. We will verify the results of our advanced engine research in a technology demonstration program on gas generators for engines.

Work to improve the environmental acceptability of transport aircraft will make use of the results from previous programs that have demonstrated advanced concepts for low-emission combustors and reduction of engine and airframe noise.

Research to develop advanced avionics and increase the operating efficiency of transport aircraft will start in 1981 with programs in human factors of automation and integrated controls, roles of ground and air crews in flight-path management, and active controls.

Development of systems technology for advanced transport aircraft will commence in 1982 for cargo aircraft, alternate-fueled aircraft (aircraft that use hydrogen or methane fuel), and aircraft having improved resistance to damage from crashes. Later on, the systems-technology development work will address small transport aircraft to serve areas with low densities of traffic.

ROTORCRAFT

The ongoing rotorcraft technology program continues development of the R&T base for rotorcraft aerodynamics, avionic components, and flying qualities and for flight evaluation of components fabricated from composite materials. Ongoing systems-technology work in advanced rotor systems will enter the flight-test phase in the Rotor Systems Research Aircraft in 1982, soon after initiation of flight research on operating systems with the Tilt Rotor Research Aircraft (XV-15). Research on helicopter transmission systems will continue with tests on the ground.

We will initiate a new Advanced Rotorcraft Technology Program in 1981. It will emphasize discipline-oriented development and verification of techniques for designing rotorcraft aerodynamics, acoustics, propulsion, and flight control. In 1982, we will increase emphasis on structures and reduction of vibration. In 1983, we will increase emphasis on high-speed concepts and large rotorcraft.

SUPERSONIC CRUISE

Our supersonic cruise research program will continue to study major technical problems inherent in advanced military and civil aircraft of this class. Those problems are all related to integration of advanced technologies and optimization for fuel efficiency, operating economics, and environmental acceptability. The ongoing program addresses the integration of systems; the discipline technologies of aerodynamics, structures, and materials; and the interactions between propulsion systems and airframes. The test program on variable-cycle engine components is scheduled for completion in 1980.

We will augment our near-term work on supersonic aerodynamics and systems technology in 1981 to permit acquisition and testing of refined and optimized wind-tunnel models and to broaden our studies of system integration. The content of later work will be dependent on decisions on two major program elements. One element is the planned initiation in 1983 of the Supersonic Cruise Technology Validation Program which follows, in general, the outline of a report, A Technology Validation Program Leading to Potential Technology Readiness Options for an Advanced Supersonic Transport, prepared at the request of the U.S. House of Representatives in September 1978. However, initiation of that program must be preceded by decisions to initiate in 1981 two programs described in the High Performance Aircraft section of this report, High Speed Aircraft Structures Technology and Variable Flow Propulsion Systems Technology.

The other major program element is the 1983 initiative, Variable Cycle Experimental Engine(s) Program, which will complement the Supersonic Cruise Technology Validation Program.

GENERAL AVIATION

The ongoing program emphasizes efficient aerodynamics and reduced drag, avionics and systems requirements to improve single-pilot instrument flight, efficient low-noise propulsion systems, and safety-oriented efforts related to improving stall and spin characteristics and structural crashworthiness.

Improved low-noise, high-efficiency propellers for general aviation aircraft will be the objective of a program to be initiated in 1981. We will also initiate in 1981 development of technology that will permit industry to develop a class of small, efficient turbine engines. Another 1981 initiative, Avionics and Control, will enhance the transfer to industry of the technology for integrated avionics being developed in the ongoing program. Under a 1982 initiative, a multiphase program will focus on achieving maximum efficiency in the use of energy through integration of advanced aerodynamics and systems technologies.

VERTICAL AND SHORT TAKEOFF AND LANDING (V/STOL)

NASA's relatively mature STOL program will consist only of flight experiments, using primarily the Quiet Short-Haul Research Aircraft, to establish the technology base for powered-lift aircraft that can provide design and certification criteria for future short-haul transport aircraft.

The ongoing VTOL program consists of a low level of effort to build a technology base. A near-term program, VTOL Integration Technology Enhancement, will initially build on and then expand the activities of the ongoing VTOL Experiments program, which will end in 1982. The new activities will emphasize development of an adequate data base and of prediction methods for use in establising design criteria for military and civil V/STOL aircraft. The activities will address key problems and systems both for terminal-area flight (takeoff, transition, hover, and landing) and for high-speed cruise and maneuvers.

Later, a program--VTOL Flight Systems Technology Enhancement--will be initiated to develop a modern VTOL inflight simulation facility and to evaluate, over several years, simulated advanced V/STOL aircraft and flight systems.

HIGH PERFORMANCE

The programs for this class of aircraft will focus on improving the performance and effectiveness of high-performance aircraft and missiles. They will address variable-flow propulsion, high-speed structures, and selected flight experiments that stress technology integration. A strong basic research and technology program will be conducted to provide new concepts and technologies for the far-term future.

Activities in 1980 will continue work initiated in preceding years. The major experimental program will be the Highly Maneuverable Aircraft Technology (HiMAT) program, with completion of the basic flight program scheduled for late 1981. Specific NASA flight experiments investigating the angle-of-attack characteristics of the F-14 will commence in early 1981 after a period of joint testing by NASA and the Navy in 1980. Testing connected with integration of engine and airframe control systems will continue on the F-15. As part of the Air Force's Advanced Technology Fighter Integration program, NASA and the Air Force will initiate joint flight research in the ongoing Mission Adaptive Wing program.

Near-term activities will focus on follow-on experiments, with the HiMAT vehicles modified to accommodate advanced technologies stressing integrated aerodynamic concepts. One 1981 program will address broad application of the technology of variable flow propulsion. It will investigate duct-burner stability and performance, advanced control concepts, and control and performance of remote burning. Another 1981 program will address structures for high-speed aircraft. It will stress technology associated with the design, fabrication, and testing of highly loaded, high-temperature, complex structural elements for flexible, high-performance aircraft.

Far-term activities will emphasize basic research and development of technology. We will start demonstrating a concept for a variable-cycle experimental engine in 1983. We will define conceptual designs for a high-speed research aircraft during the 1981-1983 period, and decide in a later year whether to build and fly a research airplane. The research-aircraft activity, possibly a joint effort with the military, will provide a focus for critical technologies and for development of a design data base for future military and civil supersonic aircraft.

SCHEDULE AND FUNDING

Table 14 shows the phasing of the Aeronautics program and Figure 19 shows the program's funding requirements.

TABLE 14 - AERONAUTICS PROGRAM SCHEDULE

PROGRAM	PROGRAM PHASE		ADDITIONAL IMPORTANT DATES
	INITIATION	COMPLETION	
CTOL:ACEE			
Engine Component Improvement	Ongoing	1980	
Energy Efficient Engine	Ongoing	1982	
Turboprops, Phase 1	Ongoing	1981	
Energy Efficient Transport	Ongoing	1982	
Composite Primary Structures	Ongoing	1983	Composite Secondary Structures - Complete 1981
Laminar Flow Control, Phase II	Ongoing	1982	
Advanced Turboprop	1981	1989	Advanced Propeller Flight Research - Initiate 1982 Turboprop Technology Demonstration - Initiate 1984
Laminar Flow Control, Phase IIA	1982	1986	Validator Aircraft - Delivery 1985 Validator Flight Tests - Complete 1986
Airframe Efficiency	1981	-	Composite Nacelle and Wing Development - Initiate 1982 Composite Fuselage - Initiate 1983 Composite Wing Damage Tolerance Tests - Complete 1984
CTOL: NON-ACEE			
Research and Technology Base	Ongoing	-	Digital Fly-By-Wire - Complete 1980 Broad Specification Fuels - Complete 1983 Stratospheric-Cruise Emission Reduction - Complete 1984
Terminal-Configured Vehicle	Ongoing	1984	
Advanced Engine Technology	1981	1988	Low-Emission Combustor Concepts - Initiate 1981 Engine Gas Generator Technology - Initiate 1982 Full-Scale Rig Performance - Complete 1984 Flight-Evaluation Performance-Monitoring System - Complete 1986
Avionics and Operating Efficiency	1981	-	Integrated Controls - Initiate 1980 Propulsion Controls Tests - Complete 1985 Human Factors Guidelines - Complete 1986 Integrated Avionics and Controls Flight Experiment - Initiate 1988
Advanced Transport Aircraft Technology	1982	-	Cargo and Alternate-Fueled Aircraft Technology and Transport Crashworthiness - Initiate 1981 Small Transport Aircraft Technology - Initiate 1982 Air-Cushion Landing System - Initiate 1983
ROTORCRAFT			
Research and Technology Base	Ongoing	-	
Rotor Systems	Ongoing	1984	Advanced Rotor System Flight Test - Initiate 1981
Operating Systems	Ongoing	1984	XV-15 Operating Systems Flight Test - Initiate 1981
Helicopter Transmission Systems	Ongoing	1983	500-HP Traction-Drive Bench Tests - Complete 1983
Advanced Rotorcraft Systems Technology:			
• Aerodynamics	1981	1987	Ground-Based Verification Tests - Initiate 1986
• Structures	1982	-	Major Composite-Fuselage Components Ground Test - Initiate 1986
• Propulsion	1981	1988	Power-Transfer System Ground Tests - Initiate 1982 Integrated Engine-Transmission-Controls Test - Initiate 1986

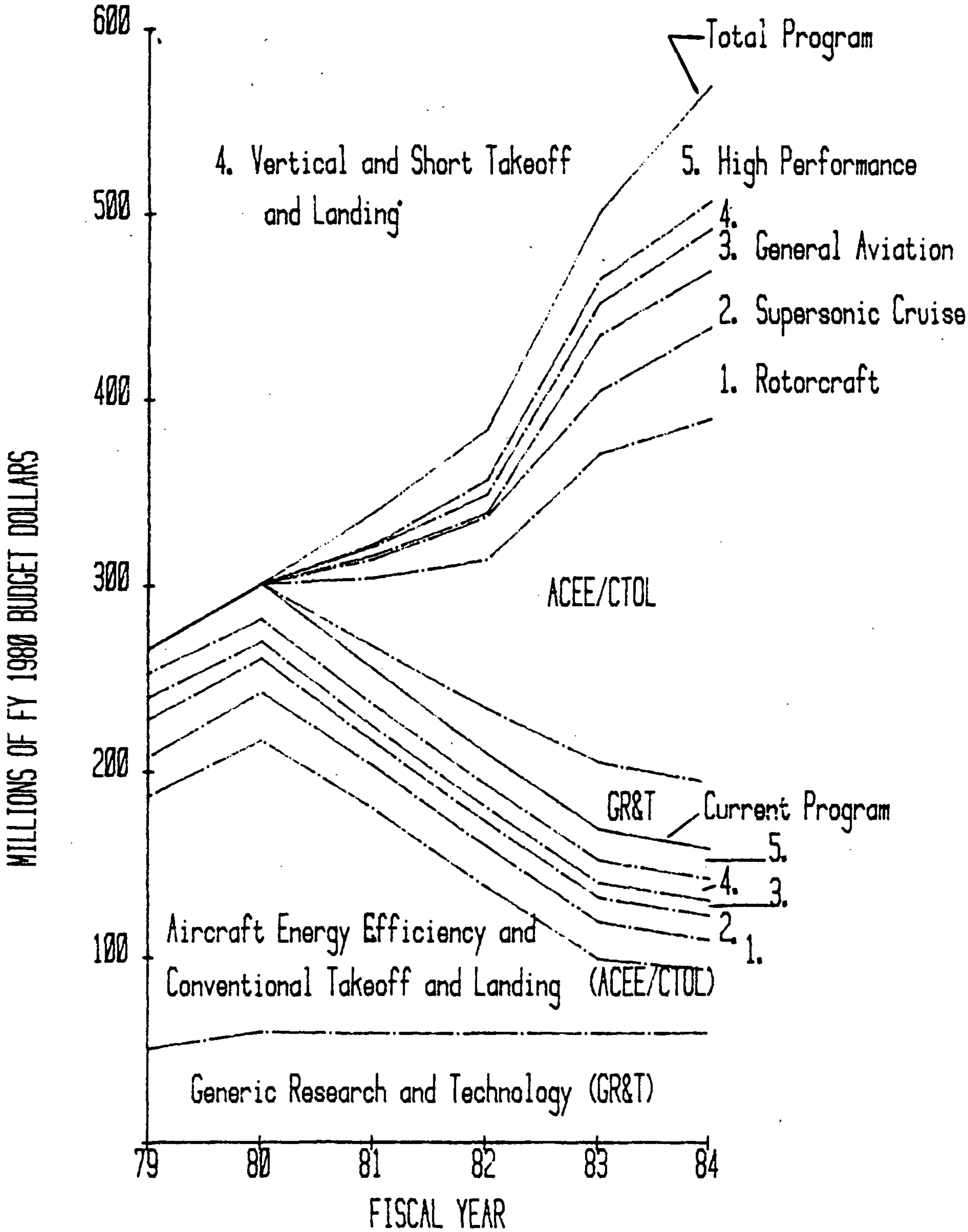
TABLE 14 - AERONAUTICS PROGRAM SCHEDULE (CONTINUED)

PROGRAM	PROGRAM PHASE INITIATION	PROGRAM PHASE COMPLETION	ADDITIONAL IMPORTANT DATES
Advanced Rotorcraft Systems Technology: (Continued)			
• Flight Control	1981	1989	Remote-Site, "All-Weather" Flight Evaluations - Initiate 1981 High-Density Terminal-Area Operations Simulation - Complete 1985
Vibration Reduction	1982	-	Initial Assessment Active-Controls Vibration Reduction - Complete 1982 Active-Controls Flight Evaluation - Complete 1986
Advanced Vehicle Technology	1983	1989	Conceptual Advanced High-Speed Vehicle Assessment - Complete 1983 Large Rotorcraft Systems Ground-Based Evaluation - Complete 1986
SUPERSONIC CRUISE			
Research Discipline Technology	Ongoing	-	Advanced Large-Scale Airframe Components Test - Complete 1981
Variable Cycle Engine Component Test	Ongoing	1980	
Supersonic Aerodynamics and Systems Technology	1981	1986	Concept Refinement and Wind Tunnel Tests - Complete 1984
Supersonic Cruise Technology Validation	1983	1986	Design-Cruise Wind Tunnel Tests - Complete 1983 Inlet-Nozzle Interaction Tests - Complete 1984 Propulsion-Technology Validation - Complete 1985 Supersonic Cruise Technology Validation - Complete 1986
GENERAL AVIATION			
Research and Technology Base	Ongoing	-	
Advanced Avionics	Ongoing	1981	
Propeller	1981	1985	Design Definition - Complete 1982 Full-Scale Test - Initiate 1984, Complete 1985
Turbine Engine	1981	1986	Gas-Generator Fabrication - Complete 1983
Avionics and Control	1981	-	
System Technology Integration	1982	1987	Single-Pilot IFR Program - Initiate 1981, Complete 1985
VERTICAL AND SHORT TAKEOFF AND LANDING (V/STOL)			
Research and Technology Base	Ongoing	-	
Quiet Propulsive-Lift Systems Technology	Ongoing	1982	Quiet Short-Haul Research Aircraft Flight Experiments - Initiate 1980
VTOL Experiments	Ongoing	1982	Propulsion-Simulation Model Test - Complete 1980
VTOL Integration Technology	1981	1986	First Large-Scale Model Test - Complete 1982
VTOL Flight Systems Technology	1982	1987	Inflight Simulation - Initiate 1984
HIGH PERFORMANCE			
Research and Technology Base	Ongoing	-	
High Angle-of-Attack Experiment	Ongoing	1981	
Highly Maneuverable Aircraft Technology (HiMAT)	Ongoing	1981	

TABLE 14 - AERONAUTICS PROGRAM SCHEDULE (CONTINUED)

PROGRAM	PROGRAM PHASE INITIATION	PROGRAM PHASE COMPLETION	ADDITIONAL IMPORTANT DATES
HIGH PERFORMANCE (CONTINUED)			
Engine-Airframe-Controls Integration	Ongoing	1986	Fully Integrated Control-System Flight Research - Initiate 1981
Mission Adaptive Wing	Ongoing	1983	Flight Test Program - Initiate 1981
HiMAT Advanced Aerodynamics Experiment	1981	1986	Modified HiMAT Flight Test Program - Initiate 1983
Variable-Flow Propulsion Systems Technology	1981	1985	Duct Burning Stability and Performance Assessment - Complete 1982 Inlet Capability Test - Complete 1984
High-Speed Aircraft Structures	1981	1985	Fabricate Test Structure - Initiate 1981 Structural Test Program - Initiate 1983
Variable-Cycle Experimental Engine (VCEE)	1983	1987	Competitive Design Phase - Initiate 1984, Complete 1987 VCEE Fabrication - Initiate 1984, Complete 1987
High-Speed Research Airplane	1981	-	Conceptual Design - Initiate 1980 Preliminary Design - Initiate 1981 Final Design and Fabrication - Initiate 1983

FIGURE 19-AERONAUTICS PROGRAM FUNDING



CONTENTS

TABLES

FIGURES

Preceding page blank

SPACE TECHNOLOGY PROGRAM

Timely investment in technology is beneficial if the technology will enhance the results obtained by current and planned missions or if it will enable missions that require capabilities that are beyond the anticipated state of the art. Consequently, in planning its space technology program, the Office of Aeronautics and Space Technology must consult extensively with the other program offices to determine both the contents and the schedules of their current and projected programs, and must keep informed about possible advances in technology of all sorts that could contribute to NASA's space activities.

Use of technology to enhance missions is evident, for example, in both the Office of Space Science's Viking program and the Office of Space Transportation Systems' program to develop the Space Shuttle. The excellence of the Viking orbiter's performance was possible because of the availability of advanced technology in thermal control materials, rocket nozzles, low-temperature solar cells, and optical navigation. The Viking lander could meet its critical requirements because of the availability of technology in 3-color facsimile cameras, engine catalysts, sterilizable batteries, and a proven parachute system. The capabilities of the Shuttle were considerably enhanced by the availability of technology in fly-by-wire controls, composite materials, and fuel cells.

Use of technology to enable a mission is also evident in the Shuttle program. Fundamental enabling technology that allowed NASA to undertake that program was related to lifting-body vehicles, high-pressure liquid-fuel engines, reusable surface-insulation materials, and solid-fuel motors.

PROGRAM GOAL

The principal goal of the Space Technology program is to generate advanced technology for application in cost-effective and reliable space systems that are of public benefit and that support national needs. The program is designed to support and enhance approved space programs, to provide technology options for planned programs, and to enable potential programs.

PLANNING ASSUMPTIONS

The Space Technology program is based on the following assumptions regarding needs and responsibilities:

1. NASA will continue to be the Nation's principal source of advanced research and technology for civil space programs.

2. NASA will provide research and technology for military space programs if requested to do so, and if the work to be done is agreed to in specific, joint-agency actions.

3. The Offices of Space Science, Space and Terrestrial Applications, Space Tracking and Data Systems, and Space Transportation Systems will continue to conduct supporting research and technology for their approved and planned flight projects.

4. The Shuttle-Spacelab will become available as a facility for space research in Earth orbit and for flight qualification of development hardware.

5. Space missions after 1990 will have four major goals:

   - Use of space for research and development including, for example, processing of materials, construction of large space structures, and evaluation of sensor systems

   - Exploration of the universe

   - Provision of global services such as worldwide communications and weather and climate forecasting

   - Transportation to, within, and from space.

PROGRAM ELEMENTS

PRINCIPAL ELEMENTS

The space technology program described below is based on the planned programs of the flight program offices as described elsewhere in this report, and on a set of representative missions for the 1980 to 2000 period that will require significant technological advances. We have structured the technology requirements derived from those two sources into three major program elements: Information Systems, Spacecraft Systems, and Transportation Systems.

CROSS-CUTTING TECHNOLOGY TEAMS

Some areas of technology are applicable to the activities of two or more program offices. For those areas, "cross-cutting teams" consisting of representatives of all the affected program offices have been established. Those teams assess user requirements in their assigned high-technology program areas and develop intensive planning recommendations. Their results have been incorporated into this space technology plan to ensure that it is in consonance with the plans of the other program offices. Cross-cutting teams currently exist in the areas of spacecraft, space power, chemical propulsion, and information systems.

PROGRAM CONSTRAINTS

Actual budget limitations in FY 1980 and expected budget limitations for the remaining years of this plan have constrained the plan's content and pace. The results have been deferral of several activities that could begin earlier and, therefore, delay in the availability of the technologies that the activities will produce. Principal examples are: delay to 1981 of an increase in effort on efficient sensing systems and system technology for space structures; deferral to 1982 of programs on automated spacecraft systems and reflights of the Long-Duration Exposure Facility; and a gradual stretching out of work on advanced power, sensing, and information systems. Although the effect of those deferrals on the mission accomplishments of the other program offices is difficult to judge, some reductions in capability and payoff are inevitable.

PROGRAM CONTENT

RESEARCH AND TECHNOLOGY BASE

Underlying the development of space technology that specifically addresses the three principal program elements listed above is our Space Research and Technology (R&T) Base Program. That program consists of fundamental research in individual technical disciplines that are broadly applicable to more than one, generally many, space programs. Serving, as it does, as the foundation of the Space Technology program, the R&T Base Program develops technology to a level of readiness where it is evident that application of the technology in one or more user programs is both desirable and feasible. Although its primary purpose is to satisfy long-term needs, the R&T Base Program is kept current and relevant by continual assessments against the Agency's priorities. The R&T Base Program in this plan reflects recent assessments and includes many changes from earlier plans.

Often, readiness of technology for application in user programs requires flight validation. The Shuttle and Spacelab will be valuable new facilities for that purpose. Later, the Science and Applications Platforms that the Office of Space Transportation Systems plans to develop will add still more capability.

PRINCIPAL PROGRAM ELEMENTS

The plans for the three principal elements of the Space Technology program are described below. The descriptions detail the major areas of technology to be developed, the objectives sought, the applicability of results to the programs of the other program offices, and the benefits expected to be realized.

Information Systems

This program element develops capabilities for acquiring, processing, and disseminating data in a form responsive to specific user needs. Its objective is to provide broader synoptic coverage, wider spectral range, more rapid access to useful information, and, ultimately, systems with lower costs. User needs are derived from the science and applications programs of the Agency. Major constituents of this

Information Systems program element are sensing and data acquisition, sensor support systems, communications, data reduction, and data dissemination for the Office of Space and Terrestrial Applications' environmental observation, resource observation, and geophysical science programs.

Communications R&T

A major initiative in 1980 will be development of technology for advanced components of communications satellites, including multibeam antennas, power amplifiers, switching circuits, and low-cost receivers.

Efficient Sensing Systems Technology and NASA End-to-End Data Systems Development

In the early part of the 5-year period of this plan, we will place increased emphasis on activities related to Efficient Sensing Systems and NASA End-to-End Data Systems (NEEDS). Our near-term objective is to provide more efficient acquisition and dissemination of information from space platforms. The specific objective for the Efficient Sensing Systems part of the work is to increase substantially the information return from applications and planetary missions, at less than current costs, by improving the spatial, spectral, temporal, and radiometric resolutions of remote sensor systems. This program element will develop and demonstrate technology for passive and active microwave sensors, as well as for optical sensor systems able to provide high-resolution sensing for terrestrial, planetary, and astrophysics missions. The overall objective of the NEEDS part of the program is significant improvement in the effectiveness of processing and distributing space information. Planned expansions of the ongoing NEEDS program will complement our current Phase II activities in technology for real-time data management. Phase III of NEEDS will develop technology for low-cost distribution of data and information, and Phase IV will provide a demonstration of an end-to-end data system.

High-Rate Communications Systems

A 1983 objective is to integrate advances in communications technology from the R&T Base Program to provide system-level verification of the capabilties of high-rate communications systems in space-to-space and space-to-ground applications.

Spacecraft Systems

This program element includes technology for structures, materials, guidance, navigation and control, automated systems, power, onboard propulsion, and entry into planetary atmospheres.

Structures

Our work on structures technology is concentrated on space systems larger than the orbiter cargo bay. Such structures will have to be constructed or deployed in orbit and will therefore require new construction techniques and components. In 1981, the structures program will be directed toward the development of technology for large, deployable microwave antennas and multipurpose science and applications platforms. Reflectors measuring more than 30 meters across will be necessary for several programs, including the Office of Space and Terrestrial Applications' Narrowband (communications) Program and the Office of Space Science's Very Long Baseline Interferometer. We currently are analyzing platform concepts for cost effectiveness as a means for providing the structure and support services for various science and applications payloads.

Materials

The objective of the Materials Technology program is to identify and qualify long-life materials for use in future space systems. Advances in materials technology can provide economies by increasing stay times in space and by enabling system reuse. A payload support platform at geosynchronous altitude will, for example, have to retain its structural integrity for more than 15 years.

Automated Systems

The objective of our automated-systems technology work is to reduce the costs of ground operations, space navigation, and space operations by increasing the level of automation. This program will improve significantly the efficiency of planetary missions through automated navigation, lower the cost of science and applications missions through greater autonomy of ground operations, and enhance assembly of spacecraft systems in orbit. A sustained effort in the R&T Base Program will be followed by emphasis on systems technology in 1982.

Power and Onboard Propulsion

We are planning several advances in critical space power technology; namely, improvements in low-cost solar arrays, high-capacity energy storage, power management, and automated, active thermal control. Those advances are needed for space power modules and for Earth-orbital platforms that the Office of Space Transportation Systems is planning for use in the late 1980s. One planned activity is to determine the feasibility of a high-power, heat-pipe-driven thermal conversion system. That planned activity will be compatible with a possible mid-1980s decision to initiate development of a nuclear-electric propulsion system. Heat-pipe-driven thermal conversion is a long-range technology potentially applicable to solar system exploration, nuclear waste disposal, lunar-base power, and advanced solar-thermal systems. If R&T Base Program results demonstrate the technology's feasibility, we will focus our attention on exploring space-to-space transmission of electrical power.

Planetary Atmosphere Entry

We are conducting research and technology related to entry into planetary atmospheres to make possible the designing of probes that will have minimum weight but will be able to survive severe planetary environments. Analytical and experimental programs will provide greater understanding of the aerothermodynamic and materials behavior of entry bodies and therefore improve our predictive design techniques.

Transportation Systems

The objective of this program element is to provide the technology required for a more fully reusable space transportation system with substantially lower operating costs. The current R&T Base Program includes development of technology for structures, materials, chemical and electric propulsion, and aerothermodynamics. That work will be supported by flight experiments aboard the Shuttle, in both the Orbiter Experiments program and the Spacelab program. A system technology program in primary structures fabricated from graphite-polyamide composite materials is also part of our ongoing work.

Orbital Transfer

In 1981, we will initiate development of technology for orbital transfer, including low-thrust propulsion for orbital transfer of large space systems; for example, the Office of Space Transportation Systems' planned Large Geostationary Platform.

Fully Reusable Space Transportation Systems

We plan to expand our orbital-transfer technology work in 1982 to provide a basis for fully reusable space transportation systems, both Earth-to-orbit and orbit-to-orbit. Effort will be directed toward all-metallic primary structures and thermal protection systems that will permit far more reflights and will weigh less, thereby increasing payload capacity.

Shuttle Launched Entry Research Vehicle

In 1982, we will start to develop a recoverable research vehicle to be launched into Earth's atmosphere from the Shuttle. We will use that vehicle to explore many facets of reentry technology.

Liquid Propulsion

NASA is the Nation's principal agent for large liquid-rocket propulsion and will continue to be depended on to conduct a program of technology development that will be adequate to maintain a competitive industrial base. This type of propulsion is likely to be needed in the orbital transfer and fully reusable transportation systems programs discussed above.

Aerothermodynamics

We are determining by analysis and experiment the aerothermodynamic characteristics provided by configurations, materials, and controls more advanced than those in the Shuttle. In addition, we support the Shuttle development program by providing independent aerothermodynamic analyses on a demand basis.

SPACE FLIGHT PROJECTS

The Space Technology program uses space flights when the space environment is essential to the research to be performed, a space experiment is more cost effective than alternative experiments, or a demonstration in space is required to accelerate transfer of technology.

Experiments requiring long exposure to the space environment will be considered for flight on the Long-Duration Exposure Facility (LDEF). LDEF will be a free-flying spacecraft that the Shuttle will transport to and leave in space for 6 to 9 months. It will accept 71 trays of passive experiments for long-term exposure to the space environment. Experiments are being selected from those suggested within NASA as well as those suggested by external sources in response to Announcements of Opportunity. LDEF's structure currently is undergoing tests to demonstrate its flight readiness.

We have selected experiments in support of the Space Technology program to be flown on several of the Shuttle's Orbital Flight Tests and on Spacelabs I, II, and III.

Our Orbiter Experiment program will use routine operations of the Shuttle to develop technology for flight controls, materials, structures, and propulsion. In addition, we are developing aerodynamics and aerothermodynamics experiments to be conducted on early Shuttle flights.

Our Free-Flying Experiment program uses free-flying spacecraft when experimental objectives cannot otherwise be achieved. For example, two 8-cm ion engines are scheduled to be tested on the flight of the Air Force's Teal Ruby planned for the early 1980s.

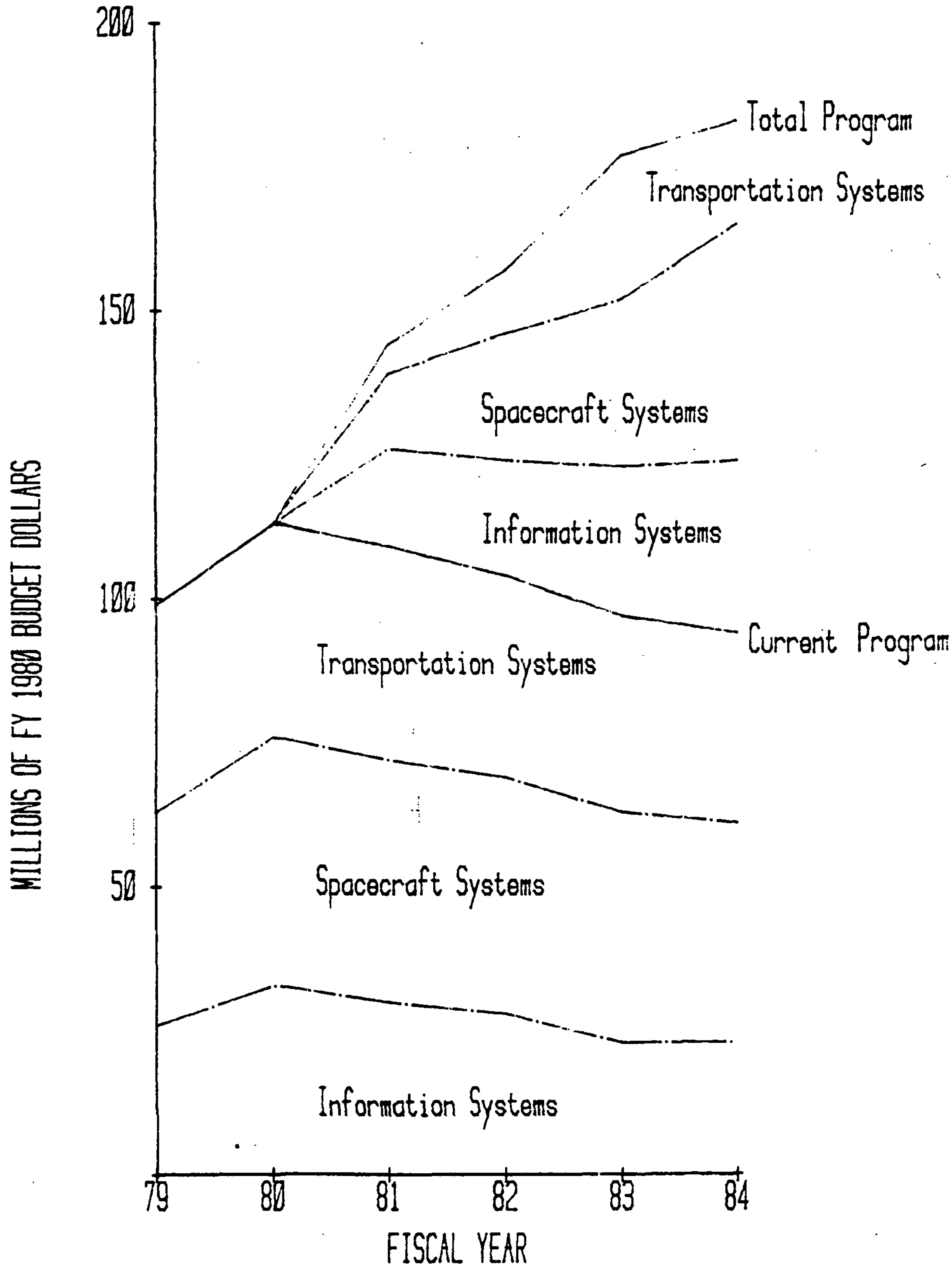
SCHEDULE AND FUNDING

Table 15 shows the phasing of the Space Technology program and Figure 20 shows the program's funding requirements.

TABLE 15 - SPACE TECHNOLOGY PROGRAM SCHEDULE

PROGRAM	PROGRAM PHASE			ADDITIONAL IMPORTANT DATES
	INITIATION	COMPLETION	LAUNCH	
INFORMATION SYSTEMS				
Research and Technology Base	Ongoing	-	-	
NASA End-to-End Data Systems (NEEDS) Technology	Ongoing	1982	-	Phase II, Real-Time Data Management - Complete 1982
Communications R&T	1980	-	-	
Efficient Sensing Systems Technology	1981	1986	-	
NEEDS Development	1981	1989	-	Phase III, Low Cost Distribution of Data and Information - Initiate 1981; Phase III, End-to-End Real-Time Information Distribution - Demonstrate 1986; Phase IV, End-to-End System Demonstration - Initiate 1984
High-Rate Communications System	1984	1988	-	
SPACECRAFT SYSTEMS				
Research and Technology Base	Ongoing	-	-	
Structures Technology	Ongoing	-	-	
Small Experiment			1987	Test of Figure Sensor for Large Microwave Antennas - Complete 1980
Large Experiment			1988	Component Test of Hoop-Column Antenna Structure - Complete 1981
Long-Duration Exposure Facility (LDEF)	Ongoing	-	1981	LDEF Sample Return 1983; Reflights-1984, 1985, and 1986; Extended LDEF 1987
Materials Technology	Ongoing	-	-	Compilation of Data on Radiation Effects on Composites - Complete 1980
Power and Onboard Propulsion:				
Test of Array for Solar Electric Propulsion System	Ongoing	-	1981	
Antenna and Platform Technology	1981	1989	-	
Test of Large Reflector or Its Components			1983	
Demonstration of Multibeam Mobile Communications Satellite			1987	
Orbital Energy-Systems Technology	1981	1987	-	Radiation-Hardened Array Test - Complete 1986; Long-Life Energy Storage Test - Complete 1987
Automated Systems	1982	-	-	Human-Assisted Remote Operator - Demonstrate 1983
Shuttle Automated Manipulator			1985	
Free-Flying Automated Teleoperator			1988	
TRANSPORTATION SYSTEMS				
Research and Technology Base	Ongoing	-	-	
Orbiter Experiments	Ongoing	-	-	Shuttle Entry Air Data System and Shuttle Infrared Leeside Temperature Sensing - Flight-Ready 1985
Long-Life Chemical Propulsion	Ongoing	1981	-	Systems Tests - Complete 1981
Electric Propulsion: 8-cm Ion Engine	Ongoing	1981	1982	
Orbital Transfer Technology	1981	-	-	Cryo Management Experiments - Flight-Ready 1985
Fully Reusable Systems Technology	1982	-	-	Technology - Ready 1986
Shuttle Launched Entry Research Vehicle	1982	-	1985	

FIGURE 2Ø - SPACE TECHNOLOGY PROGRAM FUNDING



CONTENTS

TABLES

FIGURES

Preceding page blank

ENERGY SYSTEMS PROGRAM

NASA is authorized to conduct programs in support of the Nation's energy research and development needs by the Energy Reorganization Act of 1974, the Department of Energy (DOE) Organization Act of 1977, and the National Aeronautics and Space Administration Act of 1958, as amended. The DOE-NASA Memorandum of Understanding dated March 21, 1978, describes the general conditions under which DOE-NASA cooperative efforts are formulated and conducted.

PROGRAM STRATEGY

The Energy Systems program uses NASA's aeronautics and space technologies, experience, and facilities to satisfy the energy research, development, and design (RD&D) needs of the DOE and other government organizations.

GOAL

The goal of the program is effective use of NASA capabilities to accomplish specific technical and programmatic goals resulting from national energy policy. We follow two approaches in meeting this goal.

APPROACHES

NASA SPONSORSHIP

One approach is to identify emerging technology requirements, verify NASA capabilities to effectively support program needs of DOE and other agencies, and prepare soundly conceived plans to advance energy technology. We use NASA "seed" money and manpower within approved areas of emphasis. This approach is important because definitions of energy problems and their possible solutions change as the national perception of energy needs and options becomes more clearly defined, and because NASA's aeronautics and space capabilities continue to develop and expand.

SPONSORSHIP BY OTHER AGENCIES

The second approach is for NASA to perform RD&D using funds provided by other agencies. The work to be done originates either from the NASA-sponsored planning discussed above or from ideas conceived by the other agencies. In either case, the RD&D programs and their funding are agreed upon with the appropriate agencies. This approach permits NASA to continue to be responsive to national energy program needs, wherever they evolve.

PROGRAM CONTENT

The Energy Systems program consists of three major types of activity. Each includes projects wholly funded by NASA, but the majority of activities are funded by other agencies. The projected NASA and reimbursable funding levels are shown on Figure 21 (Page 152).

NASA-FUNDED ACTIVITIES

The activities that NASA funds concentrate on specific technologies that show potential to satisfy emerging requirements of other agencies. Examples follow.

Small Integrated Solar Power Systems

Solar energy technology promises early benefits for remote areas that have ample sunshine but few resources to import scarce, expensive fuels for conventional power systems. Studies to be initiated in 1979 are exploring the feasibility of and potential benefits from small solar-power systems for remote communities in the United States and in lesser-developed countries. We will coordinate the studies closely with the U.S. Agency for International Development and DOE with a view toward development of fully reimbursable projects.

Industrial Gas Turbines

We are identifying and studying stationary power-generation concepts that are based on aerospace technologies and have significant potential to provide improved efficiency, reduced emissions, and greater fuel flexibility. Our current work is focused on refining and verifying by experimentation techniques for analyzing thermodynamically the steam injection concept for operating industrial gas turbines. We also are investigating combustion and materials associated with stationary and mobile advanced power-generation systems and evaluating an automated process for depositing thermal-barrier coatings on the blades of utility-sized gas turbines.

Coal Utilization

Expanded use of coal is a major thrust in the Nation's energy program. In seeking new technological concepts, we are emphasizing chemical processes for low-cost removal of sulfur before combustion, and improvement in processes for converting coal into clean gaseous and liquid fuels.

Stirling Engines

NASA's Lewis Research Center (LeRC) is identifying and verifying advanced technology for Stirling engine components and concepts for engines for use in stationary power systems, while the Jet Propulsion Laboratory (JPL) is identifying and validating requirements for a simple, low-cost Stirling engine that can be used by industrial, university, and government laboratories for general research on Stirling engines.

ACTIVITIES PARTLY OR ENTIRELY FUNDED BY OTHER AGENCIES

The three major types of activities constituting the Energy Systems program mentioned earlier are described below.

Space Utilization

This type of activity addresses technologies that could exploit the unique characteristics of space to help solve energy-related problems on Earth. Current work includes the following subjects.

Nuclear Waste Management

DOE is assessing methods for disposing of wastes from nuclear reactors. As part of that assessment, we are studying disposal of the wastes in space, with assistance from DOE in analyzing technology related to waste-processing, packaging, and ground transportation. Our study includes concept definition, systems definition, impact assessment, economic comparison, and benefit analysis.

Satellite Power System (SPS)

Under recently completed agreements the SPS project is a jointly-managed, DOE-funded activity. NASA is responsible for defining all technical systems, while DOE is responsible for assessing the systems from the standpoint of environmental and socioeconomic factors, including comparative evaluation of SPS with alternative energy sources. DOE's assessments will be the basis for determining whether a focused program on SPS technology is technically and economically justified. It is expected that an exploratory research program continuing DOE's efforts will be initiated in 1980 to resolve, by experiment, some of the critical issues surrounding the use of microwave power beams to transfer electric power from space to Earth.

Solar Terrestrial

This program activity encompasses Earth-based technologies related to the use of solar and solar-derived energy. Current work addresses the subjects described below.

Solar Heating and Cooling

The objective of this DOE 5-year program is to develop cost-effective, reliable, commercially acceptable solar heating and cooling systems and subsystems, and to demonstrate their effectiveness under various climatic conditions. The program has two major components, both of which are managed by NASA's Marshall Space Flight Center (MSFC). The purpose of the first component is to complete development of solar heating and cooling systems and subsystems that are essentially "state-of-the-art" but not yet qualified for use in planned residential and commercial demonstration programs. The purpose of the second component is commercial demonstration of available solar heating and cooling systems in nonresidential applications. All commercial demonstration projects that NASA is managing will be completed by early 1980.

Photovoltaic Conversion (Solar Cells)

NASA's role in DOE's Photovoltaic Conversion Program involves major long-term (10-year) participation by JPL and LeRC. JPL is responsible for advancing production technology for silicon solar cells to a competititve level. LeRC is to develop and test concepts for integrating the solar cell arrays from the JPL project for use in a variety of practical terrestrial applications. The JPL work is underway, mostly under contracts with industry. Key milestones are to develop technology for mass production and demonstrate pilot plant operation by 1983, and to establish by 1986 a national capability to produce more than 500 MW per year of solar cell arrays at a cost in 1975 dollars of less than $500 per kW. LeRC's principal objectives are to stimulate the near-term market for photovoltaic systems in order to determine their operational characteristics, devise measurement and diagnostic techniques, and determine the durability of solar cell systems under realistic conditions.

Wind Turbo-Generators

LeRC manages a major portion of DOE's Wind Energy Program, and DOE has assigned LeRC responsibility for developing large, horizontal-axis, wind turbo-generators (WTGs). Ensuring that WTGs have potential for cost-effective commercial operation will require demonstration of a number of machines in realistic applications. A 100-kW WTG (MOD-0) designed and constructed by LeRC at Plum Brook Station, Sandusky, Ohio, began test operations in September 1975. We will test four additional machines, uprated to 200 kW (MOD-0A), in conjunction with small electric-utility companies in New Mexico, Puerto Rico, Rhode Island, and Hawaii. A 1.8-MW WTG (MOD-1) erected late in 1978 on Howard's Knob near Boone, North Carolina, began operation in early 1979. An even larger WTG (MOD-2) is being designed to produce approximately 2.5 MW, with first operation scheduled for late 1979 at a site yet to be selected.

Solar Thermal-Electric Conversion

JPL is responsible for a relatively new activity in solar thermal-electric conversion. JPL's role is to help develop the plan for DOE's Thermal Power System Program and to manage the portions of the program related to advanced technology and to applications for small power systems. LeRC is helping JPL in the energy-conversion portion of the work.

Energy Storage

DOE's Energy Storage Program involves both high-temperature thermal energy and high- and low-temperature heat from industrial processes. LeRC is managing the program's activities related to storage of both of those types of energy, with the objective of developing effective systems for storing thermal energy in both solar and non-solar applications. The principal applications under consideration are for industrial plants and in dispersed solar-thermal energy systems. Use of thermal-energy storage systems by utilities is also under study. Concepts under evaluation include storage in both solids and fluids. LeRC has developed basic technology and is now further developing and evaluating a novel, room-temperature, electro-chemical energy storage system based on the Redox Flow Cell. The Redox Flow Cell functions as a storage battery, allows independent sizing of power level and storage capacity, and costs much less than lead-acid batteries for both utility-storage and photovoltaic stand-alone systems. A 2-kW prototype system will be ready for a proof-of-concept test by early 1980.

Conservation and Fossil Energy

This program activity encompasses technologies to provide automotive propulsion and stationary power systems that are more efficient, and to develop methods that are more effective for extracting coal and converting it to clean gaseous and liquid fuels. Current activities are described below.

Advanced Propulsion for Ground Vehicles

LeRC is managing DOE's program to develop a continuous-combustion automotive engine. The program's objective is to develop technology for automotive gas-turbine and Stirling engines that will be clean, quiet, and efficient and will be able to use a variety of fuels. LeRC's responsibilities include planning and managing a number of industrial contracts and the in-house testing, design studies, and research tasks essential to the accomplishment of that objective. LeRC has awarded a major contract for development of an advanced Stirling engine. Each major U.S. automobile manufacturer has recently completed studies of conceptual designs for advanced gas turbines, and development work will be initiated in FY 1979. A key part of the gas turbine activities is the development of ceramic components.

LeRC and JPL are managing the research and development elements (except those for batteries) of DOE's Electric and Hybrid Vehicle Program. LeRC is managing the development of propulsion technology, and JPL is managing the vehicle-level technology integration and demonstration activities. In FY 1979, JPL-managed contracts to develop electric vehicles and design hybrid vehicles based on near-term technology will be completed, and development efforts on hybrid vehicles will be started.

Advanced Coal Extraction

NASA's responsibility is to develop methods that are more effective for mining coal. MSFC is developing equipment to automate the coal-shearer element of the longwall mining system. One piece of equipment is a detector to locate the interface between coal and overburden, and another piece is a control subsystem to align the coal shearer with the coal seam. JPL is conducting complementary systems-definition studies to establish realistic performance requirements for advanced mining systems and to define mining systems that will be cost-effective, safe, and environmentally acceptable.

Industrial Gas Turbines

LeRC is managing for DOE a long-term project to provide technology that will permit industrial gas turbines to use low-grade petroleum and minimally processed liquid fuels derived from coal. Another objective of the project is to reduce emissions from gas turbines.

Phosphoric Acid Fuel Cell Systems

LeRC is managing the development of technology for phosphoric acid fuel-cell systems for use in on-site, integrated energy systems and electric utilities. The program's objectives are to create a competitive environment for suppliers and to provide the technology necessary to make phosphoric acid fuel-cell systems cost-competitive. Emphasis in the early part of the program is on upgrading cell-stack technology and on reducing the cost of other system components.

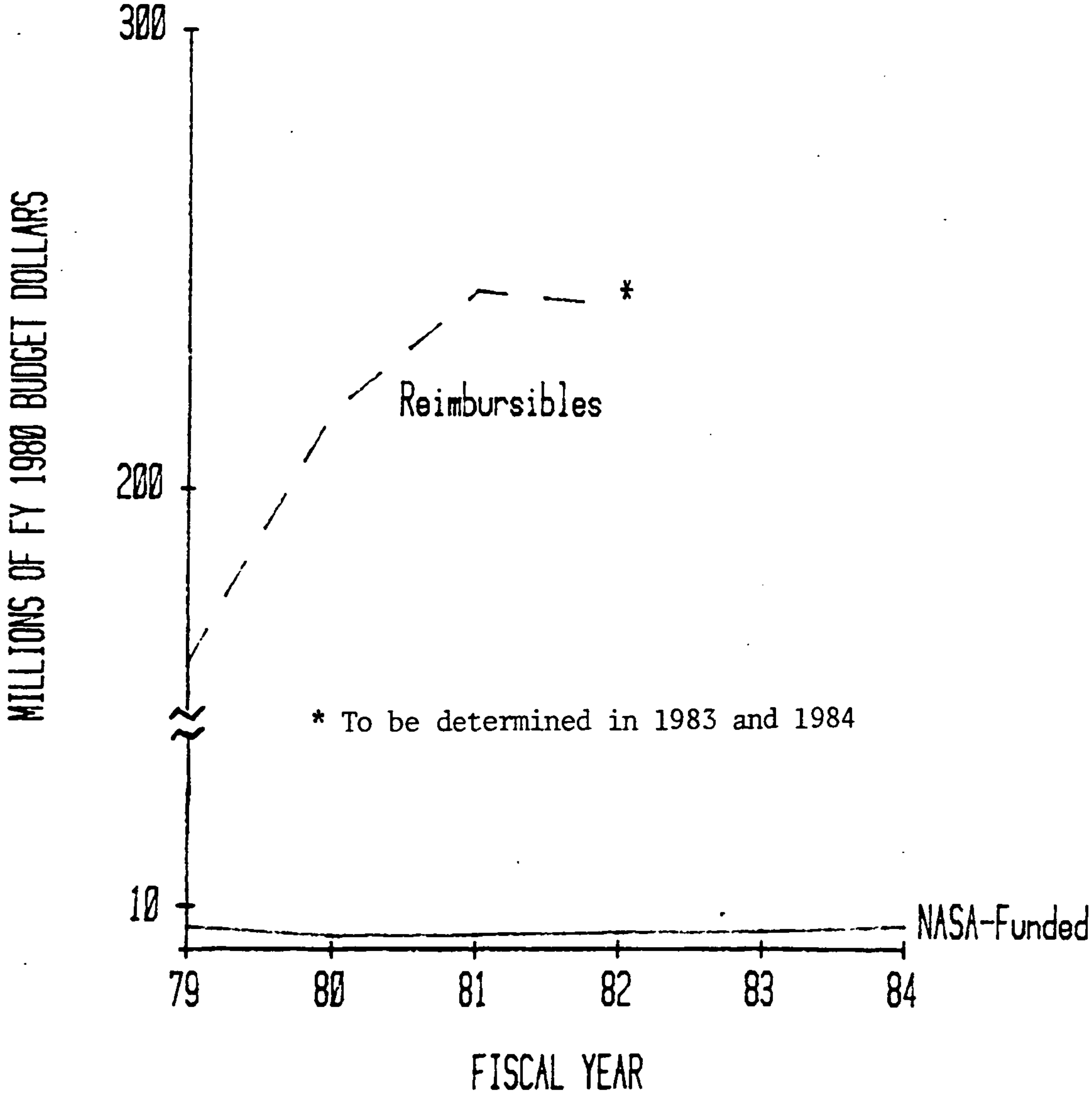
PROGRAM SCHEDULE AND FUNDING

Table 16 shows the phasing of the Energy Systems program and Figure 21 shows the program's funding requirements.

TABLE 16 - ENERGY SYSTEMS PROGRAM SCHEDULE

PROGRAM	PROGRAM PHASE INITIATION	PROGRAM PHASE COMPLETION	ADDITIONAL IMPORTANT DATES
SPACE UTILIZATION			
Nuclear Waste Management Definition	Ongoing	1981	Safety Assessment of Preferred Concept - Complete 1980 NASA-DOE Program Continuation - Decision 1981
Satellite Power Systems Exploratory Research Program	1981	1983	Ongoing System Definition - Complete 1980 Exploratory Research Program - Decision 1980
SOLAR TERRESTRIAL			
Solar Heating and Cooling	Ongoing	1982	Analysis - Complete 1982
Photovoltaic Conversion	Ongoing	-	First Fixed-Price Purchase of an Array - Initiate 1980 Technology for Manufacturing $10/kg Silicon Cells - Ready 1981 Second Fixed-Price Purchase of an Array- Initiate 1982 Third Fixed-Price Purchase of an Array - Initiate 1983 Pilot Plant for Mass Production of Silicon Cells - Operational 1983
Wind Turbo-Generators	Ongoing	1983	Mod-0A (200-kW) On Oahu, Hawaii - Operational 1980 Mod-2 (2,500-kW) - 4 Units Operational 1981 Commercialization - Initiate 1982
Solar Thermal-Electric Conversion	Ongoing	1985	Advanced Technology Systems - Ready for Test 1980 and 1981 1-MW Engineering Experiment - Operational 1982
Energy Storage	1981	-	Program Definition - Complete 1980
CONSERVATION AND FOSSIL ENERGY			
Advanced Propulsion for Ground Vehicles			
Automotive Gas Turbines	Ongoing	1984	Ceramic Components - Demonstration 1982 Advanced Engine - Available 1983
Automotive Stirling Engine	Ongoing	1984	Characterization of Baseline Engine - Complete 1980 Experimental Engine - Available 1982 Advanced Engine - Available 1983
Electric and Hybrid Vehicles	Ongoing	-	Improved Electric Vehicle - Available 1980 Improved Hybrid Vehicle - Available 1981 Advanced Vehicle - Available 1984
Advanced Coal Extraction	Ongoing	1982	Prototype System - Available 1982
Industrial Gas Turbines	Ongoing	1984	Screening of Concepts - Complete 1980 Components - Available 1982 Engine Verification - Complete 1984
Phosphoric Acid Fuel Cell Systems	Ongoing	1982	System Technology - Demonstration 1982

FIGURE 21- ENERGY SYSTEMS PROGRAM FUNDING



CONTENTS

CONTENTS (CONTINUED)

CONTENTS (CONTINUED)

TABLES

FIGURES

SPACE SCIENCE PROGRAM

Our Nation, and indeed all humanity, recently celebrated a major anniversary. Ten years ago, human footprints were firmly implanted on the surface of another celestial body. History will record the advent of our leaving our natal planet as one of the most profound adventures in the history of humanity. It is now time to reflect on the consequences of that adventure, to assess the accomplishments that have accrued as a result of space exploration, and to formulate a strategy for further exploration. As Norman Cousins stated in his testimony to Congress in 1976, "This significance of the adventure in space is that we are positioning ourselves for perceiving larger truths. Such truths can give us an enlarged sense of human purpose."

Space Science deals with exploration and exposition of those "truths." Its goals address some of the most basic questions that have tantalized mankind since the birth of intellectual awareness caused humans to wonder where they fit in the cosmos, how they were created, what their history has been, and what their future is.

PROGRAM ORGANIZATION

The Space Science program consists of the following four major elements:

1. The Astrophysics program, which seeks to understand the origin and evolution of the universe, and to study and test the fundamental laws of physics that govern observed celestial phenomena

2. The Planetary program, which studies the origin, evolution, and current state of the solar system; investigates, by means of comparative study of solar system bodies, the past and present processes that affect the Earth and humanity's environment; and studies the relation of the chemical history of the solar system to the origin and evolution of life

3. The Solar Terrestrial program, which studies the processes that generate energy in the Sun and transform and transport that energy to the Earth, as well as the interactions of that energy with Earth's space environment and magnetic field

4. The Life Sciences program, which seeks to: ensure the health, safety, well-being, and effective performance of humans in space; ultimately break human dependence on Earth's environment; use the space environment to further knowledge in medicine and biology; and understand the origin and distribution of life in the universe.

Preceding page blank

DISCIPLINE BALANCED 5-YEAR PLAN

In response to the Administration's anti-inflation stance, the Office of Space Science has developed a 5-year plan that is constrained but strives to retain a balance in and between the areas of science for which the Office is responsible.

MAJOR PROVISIONS

This discipline-balanced plan provides for:

1. Major steps forward to be taken in high-energy Astrophysics with the development of the Gamma Ray Observatory and the Advanced X-ray Astrophysics Facility

2. Fundamental new testing of the theory of general relativity to be performed with Gravity Probe-B, and additional experiments in relativity, in the vicinity of the strong gravitational field of the Sun, to be carried out with the Solar Probe

3. Programs in ultraviolet and optical astronomy to be conducted with the Space Telescope, a facility of unparalleled sensitivity

4. Important Astrophysics research to be continued with two new satellites in the Explorer program, the Cosmic Background Explorer and the Extreme Ultraviolet Explorer, and in the Spacelab program with both Principal Investigator-class experiments and multiuser instruments such as the Shuttle Infrared Telescope Facility and the Large Area Moderate Angular Resolution X-ray telescope

5. Exploration of the inner planets to be continued with the Venus Orbiting Imaging Radar

6. Data on the outer planets to be acquired from the Saturn and Uranus encounters of the Voyager missions, and from the Galileo mission to orbit Jupiter

7. Reconnaissance of the small bodies of the solar system to be initiated with the Halley Flyby/Tempel 2 Rendezvous mission

8. Our solar physics program to be continued by flying the Solar Maximum Mission, continuing the development of the International Solar Polar mission, incorporating the Solar Optical Telescope in Spacelab, and initiating the Solar Probe

9. Understanding of solar-terrestrial relations to be improved through comprehensive study of space plasmas in the terrestrial environment with the Origins of Plasma in Earth's Neighborhood mission and the Spacelab program's Chemical Release Facility

10. The first dedicated life sciences laboratory to fly on Spacelab in 1982 to begin a program to test hypotheses explaining medical and biological changes observed in previous space flights.

MAJOR COMPROMISES

This constrained program, even though balanced, will materially delay realization of several space exploration objectives and defer several beyond the period of this 5-year plan. For example, we will be able to conduct only parts of the comparative planetology studies of the terrestrial planets that must ultimately be conducted. Specific compromises in relation to previous plans submitted to the Office of Management and Budget are:

1. Loss of the next major step forward in cosmic ray astrophysics. Delay in the Cosmic Ray Observatory means loss of a timely opportunity to perform definitive measurements of cosmic ray particles having the very highest energy and charge. Cosmic rays are samples of stellar matter. They enable us to sample the environment of a supernova and to understand how charged particles can remain intact at energies vastly higher than can be produced on Earth or in the Sun. They are a stabilizing force in our galaxy, whose pressure is comparable to that of starlight and magnetic fields. An understanding of cosmic rays is critical to our understanding of the stability and evolution of our galaxy. The low fluxes and high energies of the particles of principal interest require exposure times of from one to two years with large, massive instruments. While some exploratory work can be done on Spacelab, a free-flying satellite is needed for major steps forward in this field.

2. No Mars Program. The greatest yield from any planetary mission conducted by this country, or any other country, has been obtained at Mars by the Viking mission. We are beginning to understand the evolutionary history of, and reasons for the differences among, the terrestrial planets. The Space Science Board stated in its recently released report, Strategy for Exploration of the Inner Planets: 1977-1987: "The planet Mars displays a host of geological and atmospheric processes and shows a continuing history of surface activity of diverse sorts and on many scales. Fundamental questions about the constitution and history of Mars and about the nature of these planetary processes will remain after all experimental results from the Viking mission have been analyzed. Mars is a key member of the triad Earth-Mars-Venus and is closely linked to the Earth by virtue of the volcanic, erosional, and climate phenomena that it is known to exhibit. The study of Mars is an essential basis for our understanding of the evolution of the Earth and the inner solar system. To accomplish the scientific objectives, we recommend that intensive study of Mars by spacecraft be achieved within the

period 1977-1987." We are not responding to this recommendation because we cannot include a Mars mission in this constrained plan.

3. No outer planets program after Galileo. The Voyager mission will initiate reconnaissance of the outer planets with flybys of Jupiter, Saturn, and possibly Uranus. The exploration of those planets will then be started with Galileo -- an orbiter and entry probe mission to Jupiter that will explore Jupiter's atmosphere and satellites. The logical mission to be accomplished after Galileo is an equivalent mission to explore Saturn, its rings, and its satellites. Saturn's satellite Titan is one of the most fascinating objects in the solar system. It has an atmosphere with a surface pressure comparable to Earth's. We know that Titan generates organic material, and hence that the building blocks of life exist on that satellite. However, we have had to eliminate the Saturn Orbiter Dual Probe (SOP) mission from this plan, thereby disrupting the orderly exploration of the outer solar system. A side effect of this action is inability to use the most economical approach to development. The Saturn probe can be identical to the Galileo program's Jupiter probe, but with less heat shielding. Consequently, the most cost-effective approach for developing the Saturn probe would be to extend the Jupiter probe development. Delay in the SOP program prevents that synergism.

4. No Asteroid Mission. The logical follow-on to the Halley-Flyby Tempel 2 Rendezvous mission in our reconnaissance of the small bodies of the solar system is reconnaissance of asteroids. A reconnaissance mission to several asteroids could enable us to understand why main-belt asteroids have a variety of chemical compositions and would help us to understand better the connection between main-belt asteroids, near-Earth asteroids, and meteorites. Our inability to include this follow-on program in our 5-year plan creates a major delay in our efforts to understand the solar system's evolution.

5. No Solar Cycle and Dynamics Mission (SCADM). The constrained budget has caused the initiation of SCADM to be deferred beyond FY 1984. The result is elimination of SCADM as the means for acquiring in-ecliptic solar optical data to provide a baseline for the polar passage period of the International Solar Polar Mission in 1987. The postponement also delays application of emerging techniques to observations that are fundamental to studies of the solar interior. Those studies will provide information essential for a better understanding of 11- and 22-year periodic phenomena that are believe to originate in the Sun's interior and that may have a profound influence on Earth's environment. Such studies can also address questions of whether the current behavior of the Sun is truly representative of the Sun's long-term behavior.

OTHER PROGRAM OPTIONS

We arrived at the program in our Discipline-Balanced 5-Year Plan only after analyzing a number of possible programs. All the programs we examined were consistent with the President's budget for FY 1980, but followed different funding profiles in the succeeding four years. We selected the Discipline-Balanced plan, despite its limitations, because it allows balanced progress among scientific areas. Of the even more constrained programs we analyzed, three are described below. Those three are the ones we deemed most logical to examine in our search for an even more constrained program. However, each of those three has major deficiencies, and we therefore adopted the Discipline-Balanced plan. The major new initiatives in that plan and in each of the three optional programs are shown in the schedule in Table 17, and the funding requirements of each program are shown in Figure 22.

FIRST OPTION

In the first optional program, the comet mission is delayed to 1983. As a consequence, Halley's comet would not be available as a target for exploration, and we would not be able to meet one of the key exploration objectives established by the summer study organized by the Committee on Planetary Exploration. That objective is to analyze, in a comparable manner, two comets in a different state of evolution; e.g., a young comet like Halley and an old comet like Tempel 2 or Encke. Moreover, loss of scientific data is not the only unfortunate aspect. Public interest in Halley's comet is high. It has been observed since 239 B.C., and many people living today observed the comet during its last appearance in 1910. It would be regrettable if the agency chartered to explore the solar system had to ignore the best known and most spectacular periodic phenomenon in the solar system because of financial constraints. Our failure to undertake a comet mission that includes Halley's comet could be interpreted as a sign that the Agency, and perhaps the Nation, is backing off from the imaginative, pioneering tradition of previous generations that contributed to our Nation's progress by eagerly exploring the unknown.

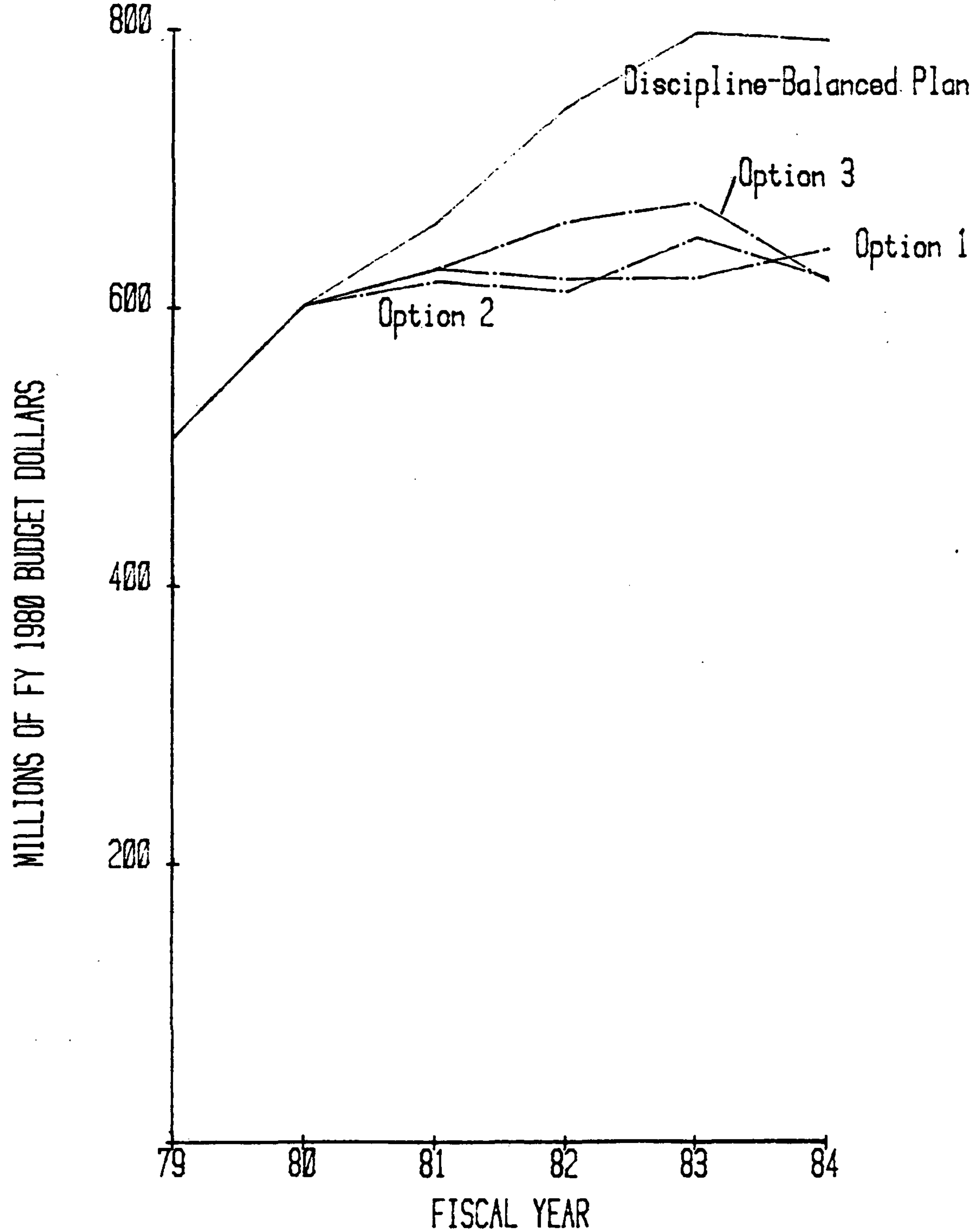
This first option also delays the Origins of Plasma in Earth's Neighborhood (OPEN) program. That delay would seriously jeopardize the opportunity to obtain simultaneous observations of the in-ecliptic heliosphere-magnetosphere system with OPEN and the solar high-latitude heliosphere and corona with the International Solar Polar Mission. Those observations are important because recent data indicate that solar high-latitude phenomena may have a surprisingly significant effect on the heliosphere at Earth's orbit.

This option delays the Advanced X-ray Astrophysics Facility (AXAF) one year, with the general effects described under the heading, Third Option, below.

TABLE 17 - SCHEDULE COMPARISON FOR MAJOR INITIATIVES

NEW INITIATIVE	INITIATION YEAR 1980	1981	1982	1983	1984
ASTROPHYSICS					
Gamma Ray Observatory					
Discipline Balanced		X			
Option 1		X			
Option 2		X			
Option 3		X			
Gravity Probe-B					
Discipline Balanced			X		
Option 1			X		
Option 2	-	-	-	-	-
Option 3	-	-	-	-	-
Advanced X-ray Astrophysics Facility					
Discipline Balanced				X	
Option 1					X
Option 2				X	
Option 3	-	-	-	-	-
PLANETARY					
Venus Orbiting Imaging Radar					
Discipline Balanced		X			
Option 1		X			
Option 2	-	-	-	-	-
Option 3		X			
Halley Flyby/Tempel 2 Rendezvous					
Discipline Balanced			X		
Option 1				X	
Option 2			X		
Option 3			X		
SOLAR TERRESTRIAL					
Origins of Plasma in Earth's Neighborhood					
Discipline Balanced		X			
Option 1				X	
Option 2			X		
Option 3					X
Solar Probe					
Discipline Balanced					X
Option 1					X
Option 2					X
Option 3	-	-	-	-	-

FIGURE 22-FUNDING REQUIREMENTS COMPARISON
SPACE SCIENCE



SECOND OPTION

This optional program eliminates the Venus Orbiting Imaging Radar (VOIR) and, therefore, any mission to the inner planets during the 5-year planning period. The Space Science Board (SSB) has stipulated that comparative analysis of the terrestrial planets -- Earth, Mars, and Venus -- is one of the most significant activities NASA can undertake. Indeed, the SSB deems that this objective has the highest priority in NASA's exploration of the solar system. In any event, it is evident that this objective has great relevance to an understanding of our own planet, the Earth. The exploration potential of VOIR is very high, and discovery of possible volcanoes, canyons, and even tectonic activity on Venus would have major value in enabling us to understand Earth's geological history.

This option also eliminates Gravity Probe-B, causing the loss of a unique opportunity to carry out a fundamental test in general relativity. That test, measurement of the distortion of space produced by a rotating mass, can be carried out in no other way. Work on that test, which requires measurements of unparalleled precision, has been underway for nearly 15 years, during which time extraordinary technical advances have been made.

THIRD OPTION

This optional program makes no provision for X-ray astronomy in the 5-year planning period. During the past decade, X-ray observations have revealed a universe previously unknown to us -- the high-temperature, non-thermal, non-equilibrium universe. We have discovered entirely new classes of objects and phenomena. We also have accumulated evidence for the existence of very compact objects and for the widespread presence of a very hot gas that may, in fact, contain the bulk of the matter in the universe and that is only observable at X-ray wavelengths. We have detected transient events whose time scales range from milliseconds to months and whose characteristics challenge our current concepts of the laws of physics. Even seemingly normal optical objects such as stars and galaxies have been discovered to emit X-rays, and it has become clear that we cannot truly understand those objects without taking into account their high-energy manifestations. Consequently, the absence from the program of a major X-ray astronomy mission such as the AXAF mission would keep our picture of what is going on in the universe fundamentally incomplete, and would drastically retard the entire field of astronomy.

This option also eliminates Gravity Probe-B from the Astrophysics program, with the results described in the discussion under the heading, Second Option, above.

This option defers OPEN and delays the Solar Probe. OPEN's deferral would destroy that program's synergism with the approved International Solar Polar Mission and degrade significantly our ability to analyze the interstellar medium and Earth's plasma environment. Delay of the Solar Probe would hold back our ability to understand solar wind heating and acceleration processes because in-situ observations of them are essential and can only be obtained close to the Sun. Loss of those observations would postpone our understanding of the Sun's mass loss and the implications of that loss for plasma processes generally and for other astrophysical objects, as well.

CONCLUSION

As a result of our analysis of possible programs for the FY 1980 through 1984 period, we concluded that any program less inclusive than our Discipline-Balanced program would not retain balanced progress among scientific areas or pursue crucial science and exploration objectives. The remainder of this description of the Space Science program addresses only the Discipline-Balanced program.

SCHEDULE AND FUNDING

Table 18 shows the phasing of the Discipline-Balanced Space Science program and Figure 23 shows the program's funding requirements.

ASTROPHYSICS PROGRAM

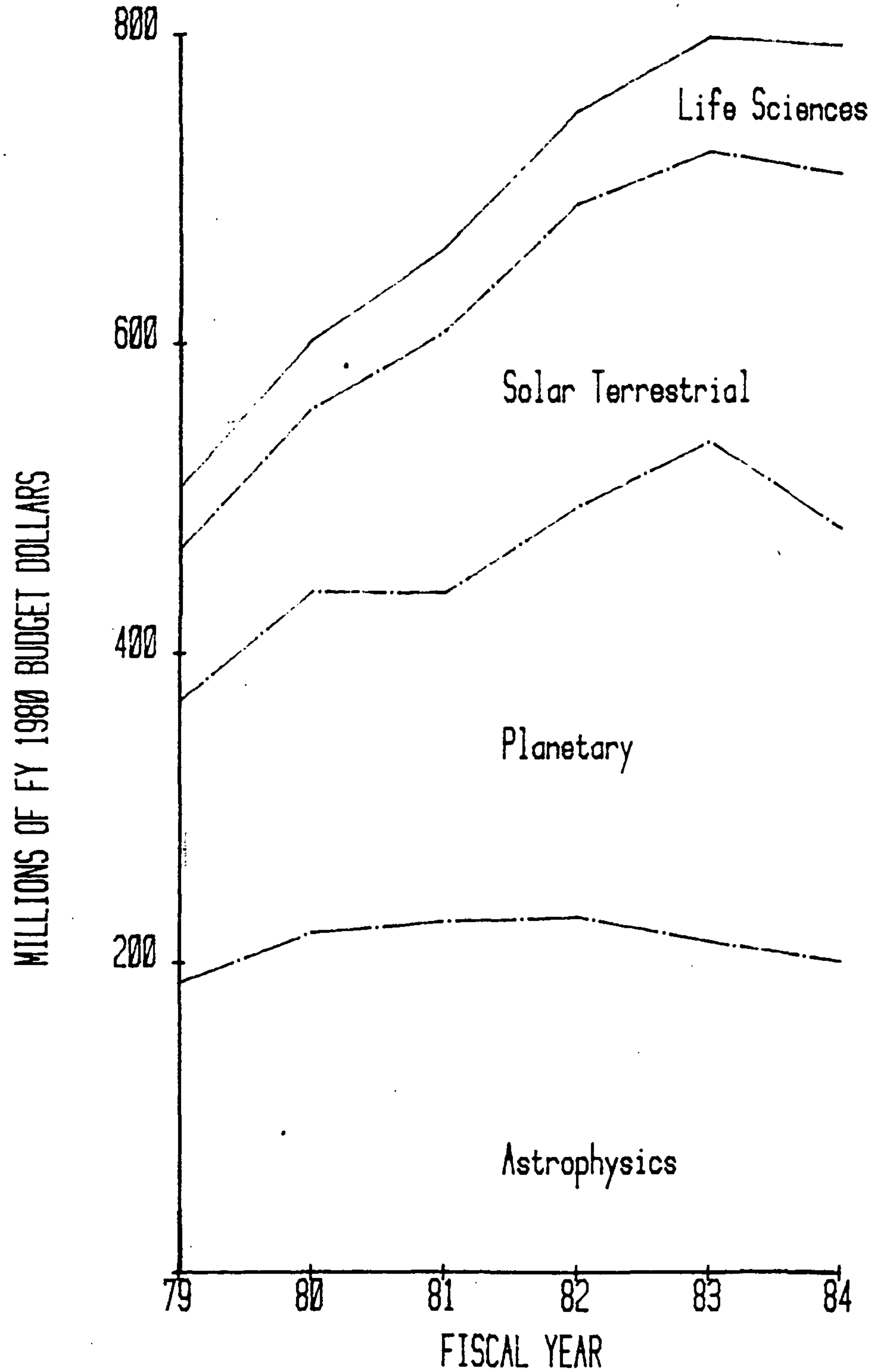
The study of astrophysics involves scientific consideration of fundamental questions that have been at the core of human concern since the most primitive times. What are the size, scope, and structure of the universe? What is our place in it? How did the universe begin? Is it unchanging or does it evolve, and will it have an end? Do we completely understand the physical laws that govern the universe? Can we explain the enormous variety of observed celestial phenomena in terms of known physical laws, or will we have to revise those laws when we consider large-scale natural processes that cannot be duplicated in the laboratory?

For centuries, our limited abilities kept us from obtaining a complete picture of the universe, and we could make little real progress in understanding the universe without that complete picture. Until the space age, we could observe the heavens only through "the dirty basement windows of the atmosphere." Water vapor in the atmosphere blocks much of the infrared spectrum; and celestial radiation in the ultraviolet, X-ray, and gamma-ray frequencies do not penetrate the atmosphere at all. Even at the wavelengths of visible light, atmospheric scintillation limits the performance of the most advanced ground-based telescopes.

TABLE 18 - SPACE SCIENCE PROGRAM SCHEDULE

PROGRAM	PROGRAM PHASE DEFINITION	INITIATION	LAUNCH	ADDITIONAL IMPORTANT DATES
ASTROPHYSICS				
High-Energy Astronomy Observatory-C	Completed	Ongoing	1979	
Infrared Astronomy Satellite	Completed	Ongoing	1981	
Space Telescope	Completed	Ongoing	1983	Relaunch 1990
Cosmic Background Explorer	Ongoing	1980	1984	
Extreme Ultraviolet Explorer	Ongoing	1981	1985	
Shuttle Infrared Telescope Facility	Ongoing	1981	1985	
Gamma Ray Observatory	Ongoing	1981	1985	
Gravity Probe-B	Ongoing	1982	1985	
Advanced X-ray Astrophysics Facility	1980	1983	1987	
PLANETARY				
Galileo	Completed	Ongoing	1982	
Venus Orbiting Imaging Radar	Ongoing	1981	1984	
Halley Flyby/Tempel 2 Rendezvous	1980	1982	1985	
SOLAR TERRESTRIAL				
Solar Maximum Mission	Completed	Ongoing	1979	
Dynamics Explorer	Completed	Ongoing	1981	
International Solar Polar Mission	Completed	Ongoing	1983	2 Spacecraft
Active Magnetospheric Particle Tracer Experiment	Ongoing	1980	1982	
Solar Optical Telescope	Ongoing	1980	1984	
Chemical Release Facility	Ongoing	1980	1983	
Origins of Plasma in Earth's Neighborhood	1979	1981	1985	Second and Third Spacecraft - Launch 1985, Fourth Spacecraft - Launch 1986
Solar Probe	1980	1984	1987	
SPACELAB PAYLOADS				
Orbital Flight Test-4			1980	
Spacelab 1			1981	
Spacelab 2			1982	
Dedicated Life Sciences Module			1982	Subsequent Flights - Every 18 mos.
Dedicated Physics and Astronomy Mission			1982	Subsequent Flights - 1 in 1983 2 or 3 in 1984

FIGURE 23-SPACE SCIENCE PROGRAM FUNDING



As a result of this country's program in space astronomy and astrophysics, a new view of the universe has emerged during the past two decades. Rocket and satellite observations at ultraviolet wavelengths have shown that many types of stars are ejecting significant amounts of material at high velocities. A revolution has occurred in our knowledge of the chemical composition and physical state of the interstellar gas and dust. Discovery of celestial X-ray and gamma-ray sources has revealed the existence of entirely new types of celestial objects and has shown that humanity lives in a universe characterized by the routine occurrence of vast explosive events of unimaginable violence. Evidence is now beginning to accumulate that a large fraction of the matter in the universe may exist in the form of very high temperature gas located between the galaxies. That state of matter is observable only at X-ray wavelengths. These new discoveries have been made at an astonishingly rapid pace. This Astrophysics program is designed to continue that revolution.

PROGRAM GOAL

The goal of the Astrophysics program is to understand the origin and evolution of the universe and the fundamental laws of physics that govern cosmic phenomena.

PROGRAM STRATEGY

Investigation Stages

Five distinct stages can be identified in the strategy used in the Astrophysics program:

1. Preliminary surveys (low-cost first cut) to see if anything is there and to detect gross features

2. Initial all-sky surveys to acquire data on source characteristics, determine approximate source locations, and collect other useful data

3. Detailed studies of individual sources or high-sensitivity surveys

4. Flight of full-scale observatories

5. Flight of specialized follow-on and observatory-support missions.

In addition, we may develop individual missions to study specialized or unique problems requiring use of the space environment.

We make typical "first cuts" using ground-based telescopes, aircraft such as the C-141 Kuiper Observatory, sounding rockets, and balloons. In the future, we will also use Spacelab. We may also use those vehicles to develop and test new types of instrumentation before using the instrumentation on major free-flying satellites. Examples of initial survey missions include those of the UHURU X-ray satellite and the

Infrared Astronomy Satellite (IRAS), which is currently under development. The second High Energy Astronomy Observatory (HEAO-2) is taking X-ray astronomy into the detailed study stage. Building on a long history of ground-based astronomy and on a series of ultraviolet space-astronomy missions, the Space Telescope will move ultraviolet and optical astronomy into the mature observatory stage.

Status of Astrophysics Disciplines

Different disciplines within astrophysics are at very different stages of development. At the bottom of the ladder of five stages, we have only recently detected the first extreme ultraviolet sources. The next step will be to carry out the initial all-sky survey. At the top of the ladder, X-ray astronomy is ready to move into the mature observatory stage. In general, different wavelengths (or particle-energy ranges) provide information on different physical objects or on different physical processes in a given object. To obtain a complete picture of what is going on in our universe, we must advance all the astrophysics disciplines.

PROGRAM CONTENT

Current Program

The principal element inthe ongoing Astrophysics program is the 2.4-meter diameter Space Telescope, now in development. Its ability to cover a wide range of wavelengths, to provide fine angular resolution, and to detect faint sources will make it the most powerful astronomical telescope ever built. We will use it to attack a wide variety of frontier problems in astrophysics, particularly in the areas of extragalactic astronomy and observational cosmology. The Space Telescope will be a permanent orbital facility launched and serviced by the Space Shuttle, which will change and update the Space Telescope's focal plane instruments as scientific priorities and instrument capabilities evolve.

In high-energy astrophysics, we will launch the last of the HEAO series, HEAO-C, in 1979. HEAO-C will carry two instruments to study the charge composition of heavy cosmic rays and the isotope composition of primary cosmic rays. It will also carry a gamma-ray line spectrometer to carry out the first survey of the sky for gamma-ray lines. An instrument being developed for Spacelab 2 will study the chemical compostion and energy spectra of very-high-energy cosmic rays. Instruments of this type developed for use on the Shuttle will later fly on free-flying satellites in order to measure definitively the cosmic ray particles that have the very highest energies and charges and that are therefore of primary scientific interest.

In infrared astronomy, IRAS will carry out the first comprehensive all-sky survey in the 8- to 120-micron region of the spectrum. It is expected that this survey will detect as many as 10 million infrared sources and obtain sufficient crude spectral information to identify the most interesting of those sources for later intensive study with other instruments. The survey will be complemented by an extended source survey to be carried out with a small telescope on Spacelab 2.

Technological Progression

The current program and the new initiatives in this Astrophysics program plan reflect an integrated, evolutionary approach to achieving the program's goal. New missions build on the scientific accomplishments and technological developments of earlier programs. For example, updated experiments, related hardware, and experience from previous sounding rocket, balloon, Explorer, Orbiting Astronomy Observatory, and HEAO efforts will be used in the Space Telescope, Spacelab, and high-energy follow-on missions, as appropriate. Both the hardware and the scientific experience from IRAS will contribute directly to the Shuttle Infrared Telescope Facility. New generations of large instruments for high-energy physics investigations will be tested and used initially on Spacelab, and then on free-flyers and space platforms. We will use space in developing progressively greater experimental and observing capabilities. Most important of all, we must continuously think in terms of a comprehensive program to plan properly for the future. For that reason, the description of the Astrophysics program that follows describes not only the programs that we will be able to initiate with the funding we will receive during the period of this plan, but also other programs that would contribute significantly to scientific and technological progress. Some of those programs will not get started until after 1984, but consideration of them has helped us to shape the integrated, comprehensive program described.

Major New Initiatives

Gamma Ray Observatory (GRO)

GRO will move gamma-ray astronomy from the initial survey stage to the detailed study stage. Gamma-ray measurements reveal the explosive, high-energy, nuclear and elementary particle processes that occur in the universe. High-sensitivity observations of gamma-ray line emissions in supernovae and their remnants can provide direct evidence of nuclear reactions that we believe lead to synthesis of elements. Gamma rays produced by interactions of cosmic rays with the interstellar medium provide direct information on both the interstellar gas and the cosmic rays. Observations of gamma rays from objects such as pulsars, which also emit radiation in the radio, visible, and X-ray regions, are essential to detailed understanding of the objects. Because of their extreme penetrating power, gamma rays retain the detailed directional and temporal features imprinted on them at their birth, even if that birth was deep in regions opaque to visible light and X-rays, or was early in the history of the universe.

Gravity Probe-B (GP-B)

The orbiting-gyroscope experiment, GP-B, will carry out a fundamental test of the theory of general realtivity by measuring an orbiting gyroscope's geodetic precession from movement through a gravitational field (relativistic spin-orbit coupling) and from the twisting of space due to the rotation of the Earth itself (relativistic spin-spin coupling). High-precision measurement of the magnitude of those two effects will be a fundamental step in evaluating competing theories of gravitation, and the necessary precision can be achieved only in the space environment.

Advanced X-ray Astrophysics Facility (AXAF)

A direct descendent of the HEAO-2 mission, AXAF will take X-ray astronomy into the mature observatory stage. The focal plane of AXAF's grazing incidence X-ray telescope, which will be about 1.2 meters in diameter, will be capable of accommodating a variety of instruments to provide spectral and high-spatial-resolution data on quasars, galaxies, clusters of galaxies, and the intergalactic medium. AXAF will be launched, serviced, and retrieved by the Space Shuttle. With four times the spatial resolution and at least twenty times the sensitivity of HEAO-2, AXAF will be as large an advance in X-ray astronomy as the Space Telescope is in optical astronomy.

Other New Initiatives

Cosmic Background Explorer (COBE)

COBE will measure with high precision the spectrum and directional distribution of the cosmic microwave background radiation. That radiation is believed to be a remnant of the "big bang" explosion that produced the present universe. Measurements made from Earth, balloons, and aircraft are subject to relatively large uncertainties. The satellite experiment will provide the definitive information that measurements from Earth cannot provide on a fundamental theory in cosmology.

Extreme Ultraviolet Explorer (EUVE)

This Explorer satellite will carry out the initial survey of the sky for objects emitting primarily in the 100-900Å region of the spectrum, thereby opening up one of the last remaining unexplored spectral regions. EUV objects discovered to date have all been stars at very advanced stages of their evolution. We believe that discovery of a large number of those objects will lead to new insight on the late stages of stellar evolution, as well as on the energetics of the interstellar medium.

Astrophysics Explorer Continuing Program

We will define and study additional astrophysics Explorers during the next two years. Studies are already underway to look at novel ways, such as in-orbit changeout of experiments, to conduct Explorer missions. We plan to add Explorers to the Astrophysics program starting in 1982 or 1983 at the rate of at least one Explorer every other year.

Shuttle Infrared Telescope Facility (SIRTF)

SIRTF will be a meter-class, cryogenically cooled, infrared telescope designed to study the very cold regions of space where cosmic dust and gas are condensing into stars, cool solar-system objects (such as asteroids), and infrared-emitting extragalactic objects. Because SIRTF will operate above the obscuring and emitting atmosphere and will use cooled optics, it will provide a more than thousand-fold increase in sensitivity even at those wavelengths observable from the ground, and a hundred-fold increase over the sensitivity of a space-based warm optical system like that in the Space Telescope. One major application of SIRTF will be to carry out detailed infrared spectroscopy and spectrometry of the faint infrared sources that IRAS is expected to discover. Detailed observations of those sources will not be possible with any other telescope.

Spacelab Proof of LAMAR Concept

In high energy astrophysics, specialized instrumentation that will ultimately be used on free flyers and space platforms will sometimes be developed for initial use on Shuttle-Spacelab flights. Those flights are well suited for tests of instruments and for conducting investigations of limited, specific problems, but will not provide the long integration times generally required for observations in this field. In particular, we will develop an early version of the Large Area Moderate Angular Resolution (LAMAR) X-ray telescope, which is described later, for use on Spacelab to test the LAMAR concept and to study selected problems requiring LAMAR's planned capability.

Other Scientifically Desirable Programs

Additional programs that are scientifically interesting and technically ready, and that would be initiated in the 1980 through 1984 period if resources permitted, are the Cosmic Ray Observatory and Starlab.

Cosmic Ray Observatory (CRO)

CRO will use large, massive instruments -- initially tested and used on Spacelab flights -- to carry out measurements in cosmic ray physics requiring long observing times and, therefore, free-flying spacecraft or space platforms. We will emphasize measurement of particles of very high energy and low flux. We will make frontier investigations of the charge composition, energy spectra, arrival direction, and isotopic composition of cosmic ray nuclei. We also will search for exotic particles such as superheavy nuclei, magnetic monopoles, and anti-nuclei.

Starlab

We will use this Shuttle-based, meter-class, ultraviolet and optical instrument to carry out, with high angular resolution, imaging investigations of sources that are too large to be observed efficiently with the Space Telescope. Those sources include globular clusters, gas clouds, nearby galaxies, and large clusters of galaxies. We will also use Starlab as a test bed for advanced instrumentation to be used ultimately on the Space Telescope.

Programs for Initiation After 1984

In molding the Astrophysics program to meet its goal and to follow the strategy established for it, we identified, and are continuing to identify, additional activities needed for a comprehensive program in the future. In X-ray astronomy, for example, we have identified a need for two observatory-support types of missions that will complement AXAF's capabilities.

X-Ray Observatory (XRO)

The first of those two missions is one on which XRO will carry a complement of X-ray instruments to make special measurements that do not require focusing optics and that systems such as AXAF cannot accommodate. Examples include iron-line spectrometers, X-ray polarimeters, all-sky monitors, and instruments for studying energy ranges that AXAF cannot study.

Large Area Moderate Angular Resolution (LAMAR)

LAMAR will be an X-ray telescope having a very large area and capable of conducting a deep-space survey to establish the distribution of extragalactic X-ray objects. LAMAR will consist of many small modules, each with its own detector, assembled to form a collector with a large area. Both HEAO-2 and AXAF have sensitivities limited by their collecting areas -- about 150 and 600 cm^2, respectively. In contrast, LAMAR's collecting area can be built up to as much as 10,000 cm^2 to achieve great sensitivity. That sensitivity will be gained at the expense of angular resolution, which will be about 1 arc minute. Thus, LAMAR will be able to perform studies that do not require precise angular resolution but do require great sensitivity, either because the sources are intrinsically faint or because they vary rapidly in intensity.

Interferometry

We are also considering ways to use space to develop new observing capabilities or to dramatically extend existing ones. Three such ways involve measurements with interferometers. The first, very-long-baseline radio interferometry, will use an orbiting radio antenna 10 to 30 meters in diameter in conjunction with existing ground-based radio-astronomy facilities to produce radio "pictures" of unprecedented angular resolution (10^{-3} to 10^{-5} arc second). We need maps with that degree of detail for study of the physics of quasars and galactic cores, of interstellar masers, and of the dynamics of star formation. Use of an antenna in Earth orbit will remove ambiguities that seriously affect interpretation of radio maps, and will permit use of significantly longer baselines (leading to higher angular resolution) than can be used on Earth.

The second interferometry activity relates to detection of gravitational waves, and will require a very large interferometer in space. The history of science provides countless illustrations of the fact that development of a major new technical capability permits exploration of entirely new scientific "territory." In this case, the Shuttle is expected to provide the needed capability for fabricating in space the very large interferometer required for detection of gravitational waves. Relativistic theories of gravitation predict that gravitational radiation is generated by any non-spherical, dynamically changing system of masses. Possible sources of gravitational waves include pulsars, short-period binary stars containing compact objects, and massive rotating stars that are collapsing to form black holes. The possibility of detecting gravity waves raises the fascinating prospect of an era of observational gravitational astronomy.

We will also need large structures for space-based interferometers to be used at ultraviolet, optical, and infrared wavelengths to study features very small in scale, and possibly to resolve the disks of stars and detect planets. Conceivable baselines for the interferometers range from tens of meters to a kilometer or more.

Additional Tests of General Relativity

Tests of general relativity in addition to the one to be performed by Gravity Probe-B are possible using missions in other program elements of the Space Science program. For example, solar missions and planetary missions into deep space can be tracked accurately to detect very small changes in their trajectories that gravitational waves might produce. A mission such as the Solar Probe would provide a valuable opportunity for studying relativity influences in the high gravitational field near the Sun.

Technology Requirements

The success of the Astrophysics program depends partly on progress in several areas of technology. Continuing development of high-sensitivity detectors at all wavelengths is urgently needed. Studies must be made of problems associated with adapting and using on free-flyers and space platforms experiments originally developed for Spacelab. Novel approaches to flight of instruments, such as reuse of spacecraft and in-orbit changeout of experiments, need to be investigated more thoroughly. Very-long-baseline interferometry and astronomy at millimeter and submillimeter wavelengths will require careful development of technology for deployment, construction, and use of large antennas in space, as well as for new types of sensitive radio receivers. Assembly or fabrication in space of large structures will also be needed for the next generation of very large high-energy astrophysics experiments, as well as for the large interferometers mentioned above. Those experiments will also require development of techniques for maintaining, with high precision, the baselines and alignment of large structures. The ability to fly dual-frequency transponders routinely on planetary and solar missions is needed for tests of the theory of relativity involving solar-system dynamics.

The Office of Space Science (OSS) will develop some of those needed technologies, especially if the technologies are related directly to OSS flight programs. Other needed technology will be developed by the other program offices. As an example, the Office of Aeronautics and Space Technology is developing technology for materials and structural designs for large space structures, as well as technology for maintaining the position, orientation, and geometry of the structures in space. The Office of Space Transportation Systems is developing technology for deploying, fabricating, and servicing those structures in space.

SCHEDULE AND FUNDING

The phasing of the initiatives in the Astrophysics program is contained in the schedule for the complete Space Science program in Table 18. Figure 24 shows the Astrophysics program's funding requirements, and Figure 25 illustrates how each of the program's initiatives contributes to achievement of the program's overall strategy.

PLANETARY PROGRAM

The United States program for solar system exploration has benefitted the Nation greatly. From the standpoint of national prestige, our spacecraft were the first to visit Mercury, Venus, and Mars. We were the first to cross the asteroid belt and encounter the giant planet, Jupiter. Our Voyager spacecraft are currently committed to fly to Saturn and possibly to Uranus. We were the first to land and operate an automated vehicle on the surface of Mars and the first to land men on the Moon. However, those highly visible accomplishments are perhaps not as important as the scientific yield from those missions. We are beginning to understand how atmospheres evolve; and, by virtue of studying the dynamics, chemistry, and evolution of the atmospheres of our sister planets, Venus and Mars, we may get an insight as to what the future has in store for our own planet, Earth. We are beginning to understand the origins of Earth and the solar system. Our program will ultimately result in an understanding of the conditions that caused life to develop on Earth and not on any other planet in our solar system. This already large body of knowledge is the profound legacy we have accumulated and will leave to succeeding generations.

FIGURE 24-ASTROPHYSICS PROGRAM FUNDING

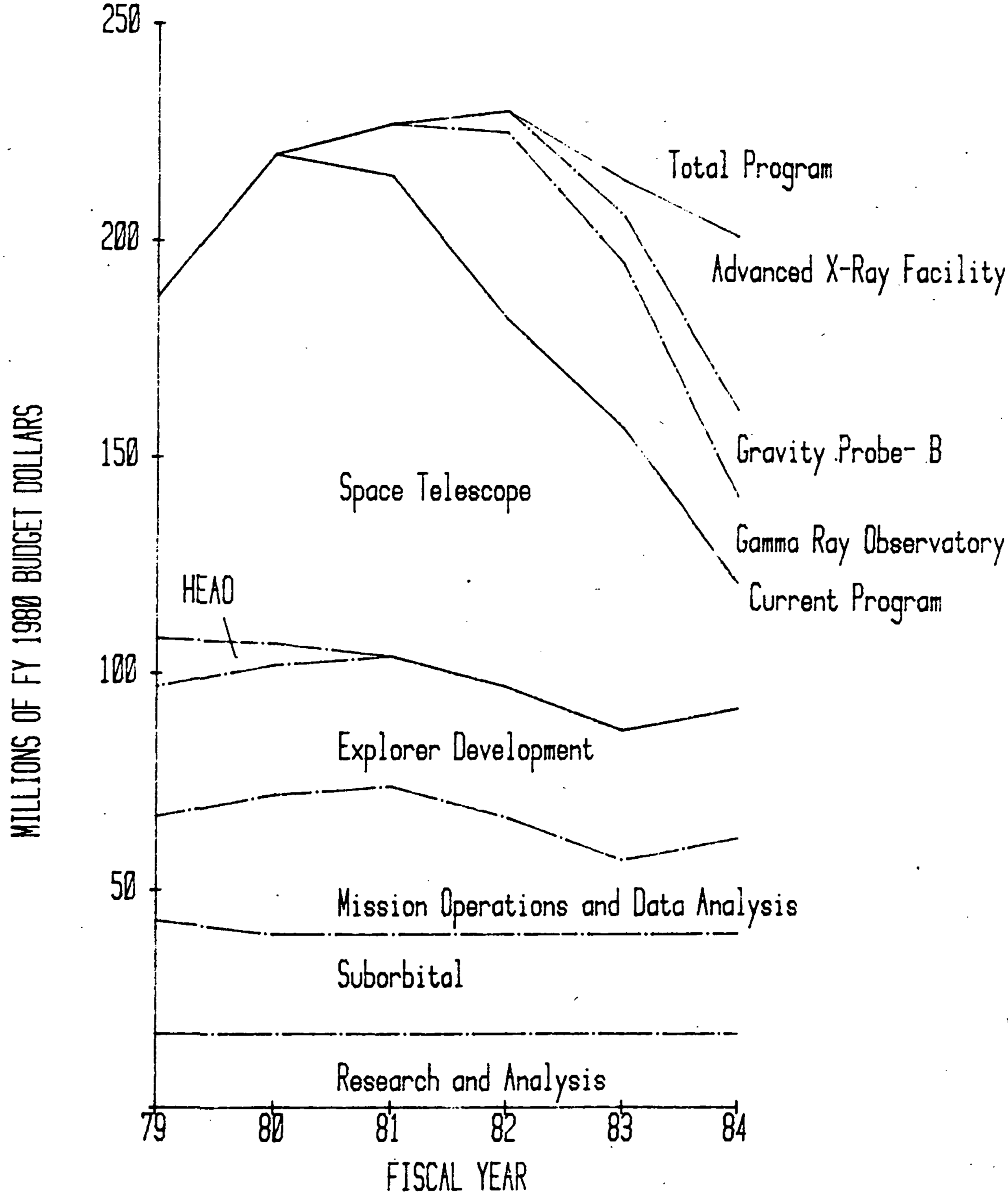


FIGURE 25—ASTROPHYSICS PROGRAM STRATEGY IMPLEMENTATION

DATA BASE	TYPICAL PROBLEMS	FIRST CUT	INITIAL SURVEY	DETAILED STUDY	MATURE OBSERVATORY	OBSERVATORY SUPPORT	SPECIALIZED TECHNIQUES
COSMIC RAYS	FORMATION OF ELEMENTS	BALLOONS	SPACELAB HEAO-C				
GAMMA RAYS	PULSARS INTERSTELLAR GAS (LOCATION)	BALLOONS	SMALL ASTRONOMY SATELLITE-B HEAO-C	GAMMA-RAY OBSERVATORY			
X-RAYS	INTERGALACTIC MATTER	ROCKETS	UHURU; HEAO-1	HEAO-2	AXAF	LAMAR	
SOFT X-RAYS	INTERSTELLAR GAS (COMPOSITION)	ROCKETS	HEAO-1				
EXTREME ULTRAVIOLET	DYING STARS	APOLLO-SOYUZ TEST PROJECT	EUV EXPLORER				
ULTRAVIOLET	HOT STARS	ROCKETS	ORBITING ASTRONOMY OBSERVATORY-2 (OAO-2)	OAO-3 INTERNATIONAL ULTRAVIOLET EXPLORER			
VISIBLE	QUASARS NORMAL STARS				SPACE TELESCOPE		
INFRARED (WARM OPTICS)	IONIZED GAS GALACTIC CENTER	BALLOONS	AIRBORNE	LARGE INFRARED TELESCOPE SYSTEM			
INFRARED (COLD OPTICS)	INTERSTELLAR DUST	BALLOONS ROCKETS	SPACELAB IRAS	SIRTF			
MICROWAVES	BIG BANG	AIRBORNE BALLOONS	COBE				
RADIO	EXPLODING GALAXIES INTERSTELLAR ELECTRONS		RADIO ASTRONOMY EXPLORER-A, B				
RELATIVITY	NATURE OF GRAVITY						GRAVITY PROBE-B

LEGEND:

GROUND-BASED

APPROVED PROGRAMS

NEW EXPLORERS NEW START

SHUTTLE FACILITIES NEW START

FREE FLYER NEW START

NASA HQ P79 1760-1
4 24 79

PROGRAM GOAL

The goal of the Planetary program is to understand the physics, chemistry, and evolution of all the bodies in the solar system and their relationship to the interstellar medium.

PROGRAM STRATEGY

The strategy the program follows for studying each body in order to achieve that goal is to:

1. Obtain an initial reconnaissance of the body

2. Initiate exploration of the body with a focus defined from the initial reconnaissance phase

3. Conduct an intensive study of the body covering very specific and crucial scientific issues identified during the exploratory phase.

STATUS OF SOLAR SYSTEM EXPLORATION

Reconnaissance

Reconnaissance missions are generally accomplished by flyby spacecraft. We have completed reconnaissance of the solar system's inner planets and have initiated reconnaissance of three - Jupiter, Saturn, and Uranus -- of the outer planets with Pioneer 10 and 11 and Voyager 1 and 2. However, our study of primitive bodies -- comets and asteroids -- in the solar system has been restricted to Earth-based observations. Those bodies are unique in spatial and size distribution. They range from very small bodies to bodies nearly 1,000 kilometers in diameter, and they travel in orbits reaching from the stellar interface to catastrophically close to the Sun. Because we expect them to play a key role in our theories about our solar system's evolution, we plan to initiate, in the 1980 through 1984 period, programs for reconnaissance of them with a mission consisting of a flyby of Halley's comet and detailed reconnaissance of the comet, Tempel 2.

Reconnaissance missions to study specific primitive bodies will require propulsion beyond that which the Shuttle and Inertial Upper Stage can provide. The Solar Electric Propulsion System (SEPS) will supply the low-thrust, high-impulse propulsion required. It will be a system whose propulsive medium will be ions energized by electricity from solar power. It will be developed by NASA's Office of Space Transportation Systems for use in the Halley Flyby/Tempel 2 Rendezvous mission, as well as in many other planetary missions starting after 1981.

Exploration

Exploration missions are best accomplished with orbiting spacecraft in combination with entry bodies and landers, the former to determine geological, geophysical, and geochemical properties on a global scale, and the latter to make in-situ measurements of atmospheric or surface characteristics or both.

Venus is the terrestrial planet most like Earth in size and location, but is the least explored and least understood of the terrestrial planets. High-reolution maps of its surface topography are vital to our comparative planetology activities. However, because clouds shroud Venus continuously, we can obtain the maps only with radar. To answer such questions as whether Earth might evolve into a Venus-like planet, we must supplement the information derived from our earlier Mariner and Pioneer reconnaissance and initial exploratory missions. Consequently, we have included in this Planetary program a mission, Venus Orbiting Imaging Radar, to map the surface of Venus with an imaging radar on an orbiting spacecraft.

Jupiter and Saturn, the two giant planets of the solar system, each has ten or more satellites (moons). Three of the moons are about the size of Mercury, with the largest of the three, Saturn's moon, Titan, larger than Mercury. We began reconnoitering Jupiter and Saturn with our Pioneer and Voyager missions. We will obtain more detailed reconnaissance and initial exploration of the Jupiter system with the Galileo (Jupiter Orbiter Probe) mission, which will include an orbiter and an atmospheric probe. The Space Science Board of the National Academy of Sciences has concluded that initiation of exploration of the Saturnian system in the middle 1980s is essential to the Nation's broad plan of space exploration. However, because of budget restraints, we could not include in this 5-year plan an initiative for exploration of the Saturnian system.

Intensive Study

We have completed initial exploration of the Moon and Mars. The yield from the enormously successful Viking mission would enable us to initiate, immediately, a program to conduct intensive study of Mars, the most Earth-like planet in the solar system. However, budget restraints prevent us from including a Mars initiative in this 5-year plan.

PLANNING ASSUMPTION

Our ability to conduct the Planetary program on the schedule planned for it is based on the assumption that SEPS will be flight ready for launch in August 1985.

NEW INITIATIVES

Venus Orbiting Imaging Radar (VOIR)

VOIR will map the entire globe of Venus with a resolution better thar one kilometer, and with a best spot resolution of 100 meters. The equivalent mission at Mars, Mariner 9, detected the existence of volcanoes, huge canyons, and river beds, completely altering our understanding of the geological evolution of Mars. We expect VOIR's contribution to our knowledge of Venus to be as significant as Mariner's was for Mars.

Halley Flyby/Tempel 2 Rendezvous

This mission will yield the first reconnaissance data on the small bodies of the solar system and the first look at the nucleus of a comet. It will detect parent molecules in the inner coma, explore cometary atmospheric dynamics, and measure chemical constituents of the nucleus and dust. It will compare a relatively old comet, Tempel 2, and a young comet, Halley, in order to understand the evolutionary dynamics of cometary behavior.

PROGRAMS FOR INITIATION AFTER 1984

Intensive study of Mars, exploration of Saturn, and reconnaissance of asteroids are vital future initiatives. Consequently, the following endeavors are our highest priority objectives after 1984.

Mars Sample Return Mission

The purpose of this mission is to return soil and rock samples from several distributed locations on Mars selected for their aggregate scientific value. We expect that analysis of those samples in Earth-based laboratories will enable us to determine the age and chemical evolution of Mars, just as our lunar samples have enabled us to understand the Moon's history. Part of our analysis will try to determine whether life could have existed on Mars in an earlier age.

The Mars program will also determine some of the fundamental processes governing that planet's formation. It ultimately will consist of three elements -- global geochemical mapping of elemental abundancies by an orbiter, determination of geological diversity by a rover, and analysis of samples returned to Earth. All three of those elements are considered essential. Return of samples to Earth for analysis is particularly important because testing in Earth-based laboratories can be much more comprehensive and adaptable than remote testing can be. Integration of data from all sources -- geochemical mapper, completed Viking missions, rover, and returned samples -- will guide further development of theories about the formation and nature of Mars.

Saturn Orbiter Dual Probe Mission

The logical mission to follow Galileo in exploration of the outer solar system is the Saturn Orbiter Dual Probe mission. The systems constituting that mission are a Saturn probe, a Titan probe, and a Saturn orbiter. Together, those three systems will yield: in-situ measurements of Saturn's atmosphere, Titan's atmosphere, and possibly Titan's surface; remote observations of Saturn, its rings, and some others of its satellites; and detailed mapping of Saturn's magnetosphere.

Special investigation of Titan is important because Titan is unique in size and appearance. Its unique appearance indicates the presence of an extensive atmosphere and, possibly, of organic materials. This planned Saturn mission will use the same hardware technology that the Galileo mission to Jupiter is using, and it will provide important data for comparative planetology studies of those two complex planetary systems. It will require use of the Solar Electric Propulsion System to be developed for the earlier Halley Flyby/Tempel 2 Rendezvous mission.

Asteroid Multiple Rendezvous

This mission will enable us to understand the nature of the differences among the major classes of asteroids in the main belt. It will consist of sequential rendezvous with one of the major asteroids (Ceres or Vesta), an asteroid we presume is siliceous, one we presume is carbonaceous, and one we presume is metallic.

Other Programs

During the early 1990s, a favorable conjunction of the planets will give us an opportunity for initial reconnaissance of the far outer planets, Neptune and Pluto. Also, at about that time, we hope to conduct a sample return mission to a comet and one to a near-Earth asteroid. Other possibilities for programs to be started after 1984 are: first, exploration of Mercury with a low-altitude orbiter occupying a circular, polar orbit, and possibly augmented with a simple lander; and, second, use of the global data from the VOIR mission to determine optimum locales on Venus for in-situ surface analysis.

SCHEDULE AND FUNDING

The phasing of the initiatives in the Planetary program is contained in the schedule for the complete Space Science program in Table 18. Figure 26 shows the Planetary program's funding requirements, and Figure 27 depicts the progress toward a truly comprehensive understanding of the solar system that will result from the Planetary program proposed in this plan.

FIGURE 26-PLANETARY PROGRAM FUNDING

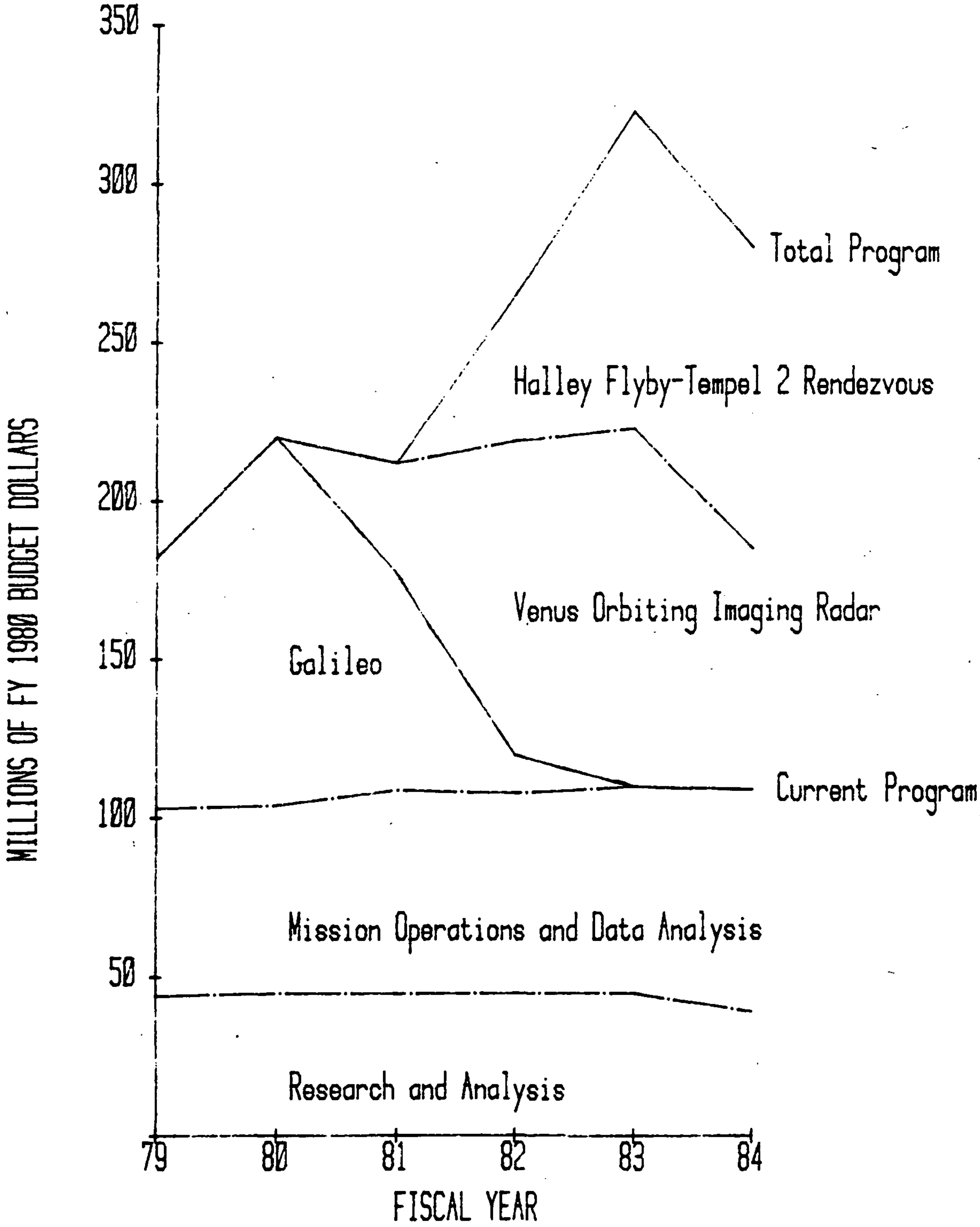
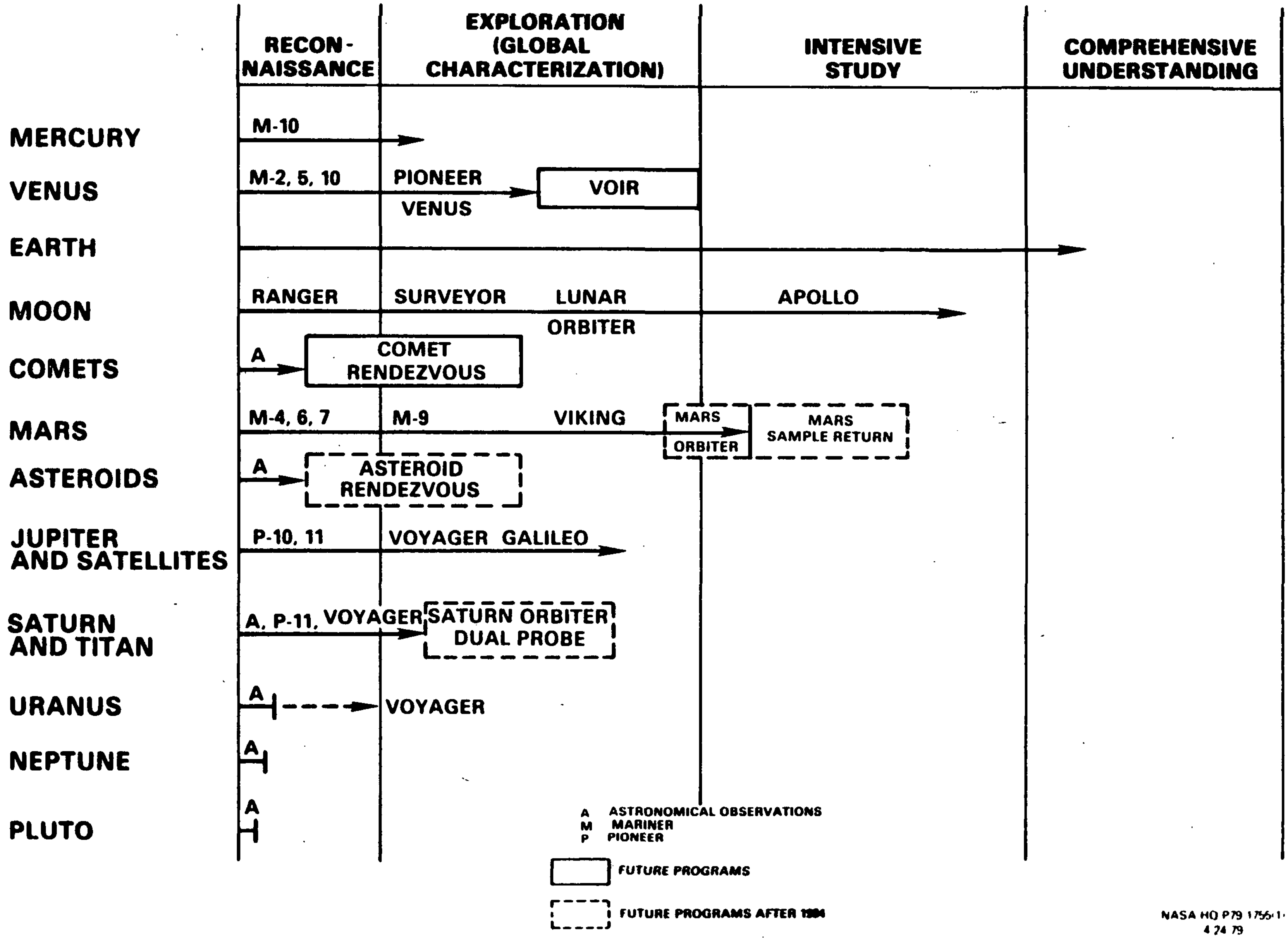


FIGURE 27—PLANETARY PROGRAM STRATEGY IMPLEMENTATION



SOLAR TERRESTRIAL PROGRAM

In only two decades, this country's space program has made possible great strides in the solar-terrestrial sciences. For example, our earliest spacecraft-borne instruments discovered the terrestrial radiation belts in 1958 and the solar wind in 1960. Since then our space measurements have increased our understanding of Earth's complex space environment to the point where we can resolve ancient problems associated with aurora and solar-terrestrial magnetic activity, and develop models describing the spatial and temporal evolution of the structures of large-scale solar winds. Recently we have learned that the high-speed solar wind associated particularly with geomagnetic effects has as its origin holes in the solar corona. Thus, it is becoming possible to predict periods of geomagnetic disturbances by observing the Sun with newly developed instruments.

We have also learned that our ability to predict the numerical values of weather parameters is correlated with changes in the direction of the solar magnetic field, as measured at Earth, and that even solar high-latitude activity produces effects in the space plasma environment near Earth. During its nine months of operation, Skylab discovered that the Sun's corona is highly active, with major transients occuring almost daily, and that solar flares originate in small loops of plasma confined by intense magnetic fields -- a fact that has had tremendous influence on the theory of solar flares. All this new knowledge has stimulated us to develop a new generation of theory about solar-terrestrial relationships.

We have determined that interaction between spacecraft and Earth's plasma causes differential charging of spacecraft surfaces, and that knowledge has given rise to new considerations in spacecraft design. Satellites have discovered that radio waves emanating from commercial power networks are sufficiently intense to change the natural populations of Earth's radiation belts. That effect creates the possibility of a new form of alteration of our environment, the results of which are poorly understood.

The knowledge we have gained in two decades of space activities enables us to undertake studies not only to obtain better understanding of the individual elements of the solar-terrestrial system, but also to develop understanding of the couplings between them.

PROGRAM GOAL

The goal of the Solar Terrestrial program is a quantitative understanding of the physical processes that determine: the nature and behavior of solar phenomena; how solar activity controls interplanetary processes in the heliosphere; and the structure of the magnetosphere and ionosphere, and their interactions with Earth's atmosphere.

PROGRAM STRATEGY

An understanding of solar-terrestrial processes and, most importantly, of the linkages between them, is fundamental to our ultimate ability to predict the potential effects on Earth's environment of both naturally occurring and human-caused perturbations. That ability is becoming increasingly important to this resource-limited world, whose ability to feed and shelter its inhabitants may be severely reduced by small changes in its climate, and whose environment may be seriously degraded, perhaps irreversibly, by human activities.

Thus, the strategy of the Solar Terrestrial program is to shift emphasis from phenomenological studies to investigations of the physics of cause and effect. That type of investigation requires simultaneous data from several locations in the solar-terrestrial system and involves a variety of instruments making both remote and in situ measurements. It also requires active experiments involving controlled perturbations in the space plasma and the atmosphere.

Our strategy for solar physics research will focus on development of a quantitative understanding of the physical processes that create and control the flow of electromagnetic and particulate energy and mass from the Sun to Earth. Our strategy for space-plasma research will emphasize cause-and-effect relationships between time-dependent solar, magnetospheric, ionospheric, and atmospheric processes. The activities to implement those two strategies will converge, through joint programs involving both theoretical and experimental research, to produce an overall understanding of solar-terrestrial relationships.

STATUS OF SOLAR TERRESTRIAL RESEARCH

Solar Physics Research

Our current solar physics program includes the Solar Maximum Mission (SMM), which is under development for launch in late 1979 and is dedicated to study of solar flares and coronal transients. We have known for some time that those phenomena produce definite perturbations in the space environment near Earth. We have recently discovered that "quiet time" solar phenomena also produce significant perturbations, and will investigate those phenomena with the International Solar Polar Mission. That mission, to be launched in 1983, will study variations in the solar wind and the Sun's magnetic field and energetic particle emission as a function of solar latitude. It will also explore the effects of high-latitude solar features on solar wind conditions in the ecliptic plane, in which the Earth moves.

Space Plasma Physics Research

Our present space-plasma physics program includes the recently launched, 3-element International Sun-Earth Explorer (ISEE), which is investigating the dynamic interactions at the boundary between the solar wind and Earth's magnetosphere. In 1981, we will launch the

2-element Dynamics Explorer (DE) to investigate the processes coupling Earth's polar ionosphere and atmosphere to its magnetosphere and lower-latitude ionosphere.

Synthesis of Results

Correlation of SMM and ISEE data will provide considerable insight into the relationships between solar activity and changes in Earth's magnetosphere. Analysis of DE data will provide similar insight into the processes coupling the elements of the Sun, magnetosphere, and terrestrial atmosphere.

Spacelab Experiments

The Solar Terrestrial program has already scheduled a number of experiments for flight on Spacelab. Those experiments include measurements of airglow, infrared radiation, and winds in the upper atmosphere. They also include instruments to measure the solar constant, solar magnetic and velocity fields, and coronal helium abundances. Of special note is a new class of active space-plasma experiments in which we use known stimuli to study basic interactive processes directly. For example, we will use electron beam injections to stimulate the aurora, thereby providing a calibration relating auroral light to precipitation of magnetospheric electrons.

PLANNING ASSUMPTIONS

This plan assumes the availability of the Space Transportation System, both as a launch vehicle and as a base of operations involving Spacelab and its associated pointing systems. It also assumes the possible development of a Space Science Platform that will provide extended periods of observation with "Spacelab-size" instrumentation.

MAJOR NEW INITIATIVES

Origins of Plasma in Earth's Neighborhood (OPEN)

OPEN's objective is to investigate that portion of Earth's environment where plasma physics determines the behavior of matter. That investigation will involve cosmic magnetohydrodynamic processes that are on spatial and temporal scales far greater than those available in Earth-based laboratories, and that therefore must be studied in the natural environment. Those studies will help us understand the plasma processes that are of interest in our Earth-based activities. They are of interest because, through them, energy and matter expelled by the Sun are fed into Earth's environment, where they constitute a small but highly variable part of our total solar sustenance.

OPEN will seek to: understand how the parts of this closely coupled, highly time-dependent system work together; to trace the flow of matter and energy through the system from input by the solar wind to ultimate deposition into the atmosphere; to understand the physical processes controlling the origin, entry, transport, storage, acceleration, and loss of plasma in Earth's neighborhood; and to determine the role of all those processes in our delicately balanced environment. In doing so, OPEN will place a system of near-Earth satellites in the solar wind, the magnetosphere, the ionosphere, and the magnetotail to make the coordinated, simultaneous measurements relevant to plasma processes.

By studying solar-terrestrial interactions and processes concurrently with the International Solar Polar Mission, OPEN will not only enhance and complement that mission, but will also, in return, benefit from that mission's studies of high solar latitudes, where many solar wind features may originate.

Solar Probe

For a full understanding of the processes that drive and heat the solar wind and that accelerate solar energetic particles, in situ measurements will be required. Consequently, we plan to initiate the Solar Probe, which will approach within four solar radii of the Sun's surface. The Solar Probe will also be able to investigate, indirectly, the distribution of matter in the Sun's interior and to conduct basic physics experiments in relativity and gravitation. It will require technology support in such areas as thermal control (maximum radiation incident on the spacecraft will be equal to 2,500 "Suns"), telecommunications (from within the solar corona), and drag-free systems (needed for measurements of the solar interior and of relativity).

OTHER NEW INITIATIVES

Additional activities, though smaller in scale, will also contribute significantly to the Solar Terrestrial program's accomplishments. One of those activities is an enhanced program of theoretical studies covering most elements of the solar-terrestrial sciences, and complementing both ongoing and future experimental programs. Also included are continuation of our highly successful Explorer and sounding rocket programs, and new initiatives using the capabilities offered by Spacelab.

Explorer-Class Satellites

The two-element Active Magnetosphere Particle Tracer Experiment (AMPTE) will study the dynamic interaction between the solar wind and Earth's magnetosphere by releasing plasma into the solar wind and magnetotail. We are defining, and will initiate during the period of this plan, additional Explorer-class satellites. They are particularly attractive candidates for making remote measurements in conjunction with the active Spacelab experiments we are developing. Also, their relatively low cost may enable us to use them in closely spaced clusters to acquire information on space plasma with a high degree of spatial resolution.

Multiuser Spacelab Facilities

In addition to the principal investigator class of experiments scheduled and planned for Spacelab, a number of major multiuser Spacelab facilities are planned for development during the next five years.

Solar Optical Telescope (SOT)

SOT will be a high-resolution telescope facility covering a broad spectral range from the ultraviolet through the visible wave lengths at angular resolutions down to 0.1 arc second. It will study time-related phenomena of small solar features such as the fine structure of the chromosphere, magnetic flux ropes, spicules, and flare sites -- all of which are considered to be less than 100 kilometers in size.

Chemical Release Facility (CRF)

CRF will be launched by the Shuttle and will make multiple releases of liquids and gases for use as tracers in mapping magnetic and electric fields, tracking motions of neutral atmospheric constituents, displaying plasma instabilities, and serving as test particles for determining particle acceleration, particle entry into specific regions of space, and particle exit from certain trapped regions.

Subsatellites

Maneuverable and recoverable subsatellites equipped with appropriate diagnostic equipment will be essential for use in conjunction with Spacelab. The subsatellites will make remote observations of space plasmas in an environment free of Shuttle-induced electromagnetic and chemical contamination, for comparison with the results of Spacelab's active experiments.

Tether Facility

The Tether Facility will provide a capability for deploying and retrieving an instrument package from the cargo bay of the Shuttle. The instrument package will be fastened to a thin cable (tether), unreeled by gravity gradients to vertical distances toward Earth as great as 100 km from the Shuttle, in order to make measurements in Earth's atmosphere at altitudes as low as 120 km. Multiprobes along the length of the tether will obtain simultaneous measurements from a number of altitudes, thereby providing discrimination between temporal and spatial variations in the measurements of upper atmospheric and space-plasma processes. In addition, use of a conducting tether and measurement of resulting $\underline{V} \times \underline{B}$ potentials and currents will yield information on the electrodynamic characteristics of the space plasma environment near Earth.

Solar Soft X-ray Telescope

This telescope will provide the high resolution needed for studies related to the physics of the Sun's lower corona, active regions, and flares. We will particularly emphasize the evolution and nature of coronal holes and the magnetic loop structure found in and around active regions.

Other Spacelab Programs

We will study and initiate other large-scale Spacelab instruments and facilities during the 5-year period of this plan as they become needed to support the major solar-terrestrial initiatives and in response to new solar-terrestrial knowledge and increased experimental capabilities.

PROGRAMS FOR INITIATION AFTER 1984

Solar Cycle and Dynamics Mission (SCADM)

SCADM is one of the programs we are currently studying for possible initiation after 1984, or sooner if funding becomes available. It will be the first mission to systematically study the solar interior by observing global and local oscillations via the photospheric Doppler fields. It also will use coronal structures as tracers in studying the evolution of large-scale magnetic fields. We are designing SCADM to provide a multi-faceted approach to investigations of those solar phenomena over a large range of space and time.

Pinhole Satellite

We also are studying a "pinhole" satellite system projected for flight in the late 1980s. That system will provide high-resolution studies of energetic events on the Sun and of the detailed structure and nature of the corona. It will consist of a large, Shuttle-borne, occulting disc filled with thousands of pinholes, and a detector package located as far as 1 km from the disc. To provide maximum scientific value, the system should be fully operational by the next solar maximum (1990) and in time to complement the Solar Probe during the Probe's period of encounter.

Solar Terrestrial Observatory (STO)

As our ongoing studies of interactions between individual elements of the Sun-Earth system reach maturity, we should be able to link our knowledge of those interactions into mechanistic "chains." Then, by developing and understanding those chains, we will be able to predict the effects of perturbations on the Earth-space system. The principal means for observing and studying those chains will be extended periods of observation with STO. Our concept is that STO will consist of instrument ensembles that will collect the coordinated data on solar, space-plasma, and atmospheric processes necessary for testing previously identified or hypothesized cause-effect mechanisms and for identifying and developing hypotheses related to new chains. The ensembles for early versions of STO will be built up largely from Spacelab principal investigator and multiuser classes of instruments and from instruments designed initially for satellites and rockets. Later versions of STO will include specially developed instruments. To be able to acquire the complete data set necessary for addressing the complex set of phenomena involved in solar-terrestrial relations, those later versions of STO may grow large enough that the equivalent of several Shuttle payloads will be required to place them in orbit.

Space Science Platform (SSP)

The SSP will be a large structure in space that will serve as a base for experiments that need to remain in space for long periods. The Solar Terrestrial program, the Astrophysics program, and the Life Sciences program will all need the capabilities it will provide. The Office of Space Science is defining the requirements the SSP will have to satisfy, while the Office of Space Transportation Systems will design the platform to satisfy those requirements.

Current studies indicate that the SSP will be able to provide a means for carrying out the advanced type of solar-terrestrial research for which the later versions of STO will be designed. The SSP will provide both the means for emplacment and operation of STO and the capabilities (including power) for long-duration operation of facilities and instruments dedicated to specialized scientific problems.

SCHEDULE AND FUNDING

The phasing of the initiatives in the Solar Terrestrial program is contained in the schedule for the complete Space Science program in Table 18. Figure 28 shows the Solar Terrestrial program's funding requirements, and Figure 29 depicts the program's planned evolution.

FIGURE 28-SOLAR TERRRESTRIAL PROGRAM FUNDING

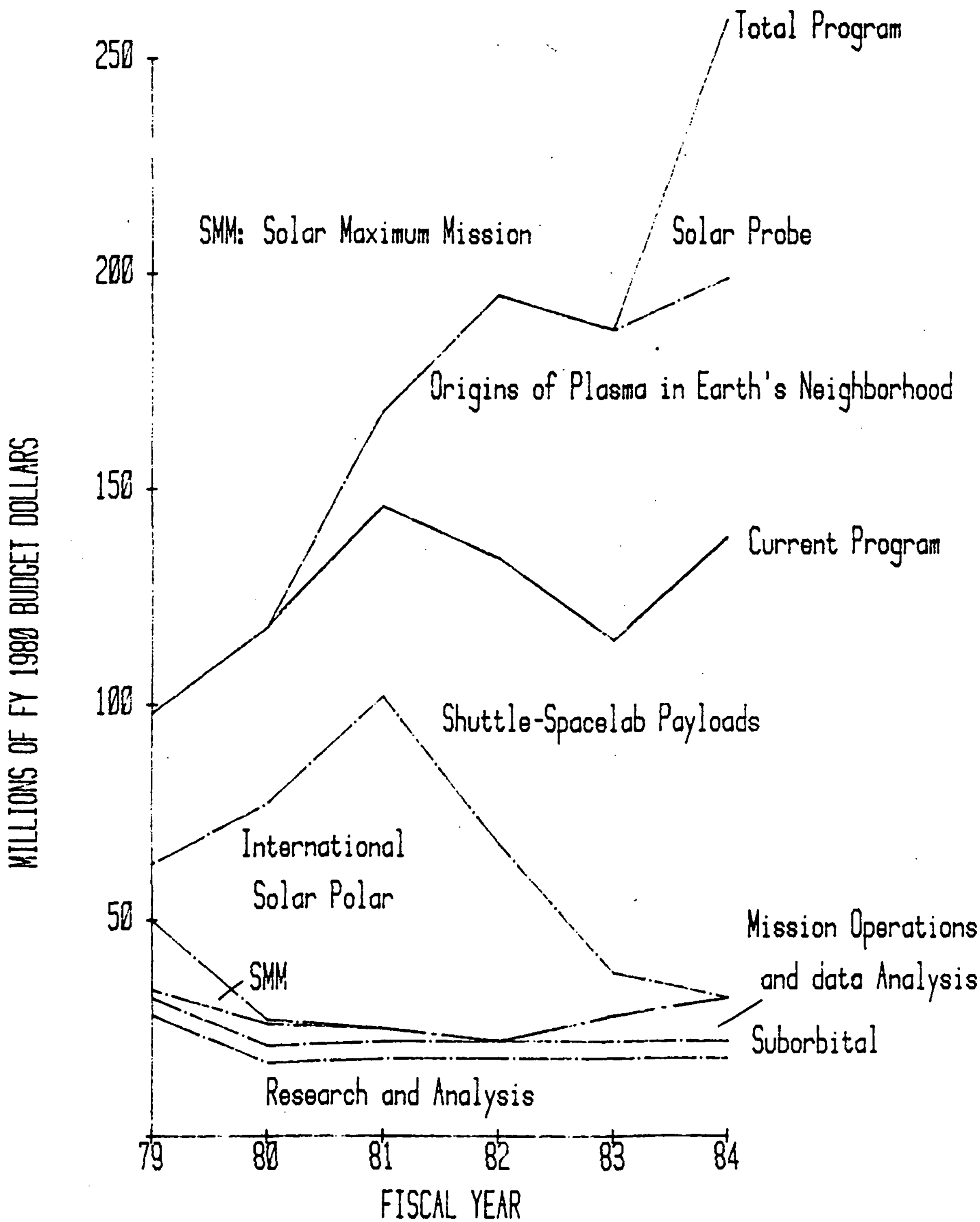
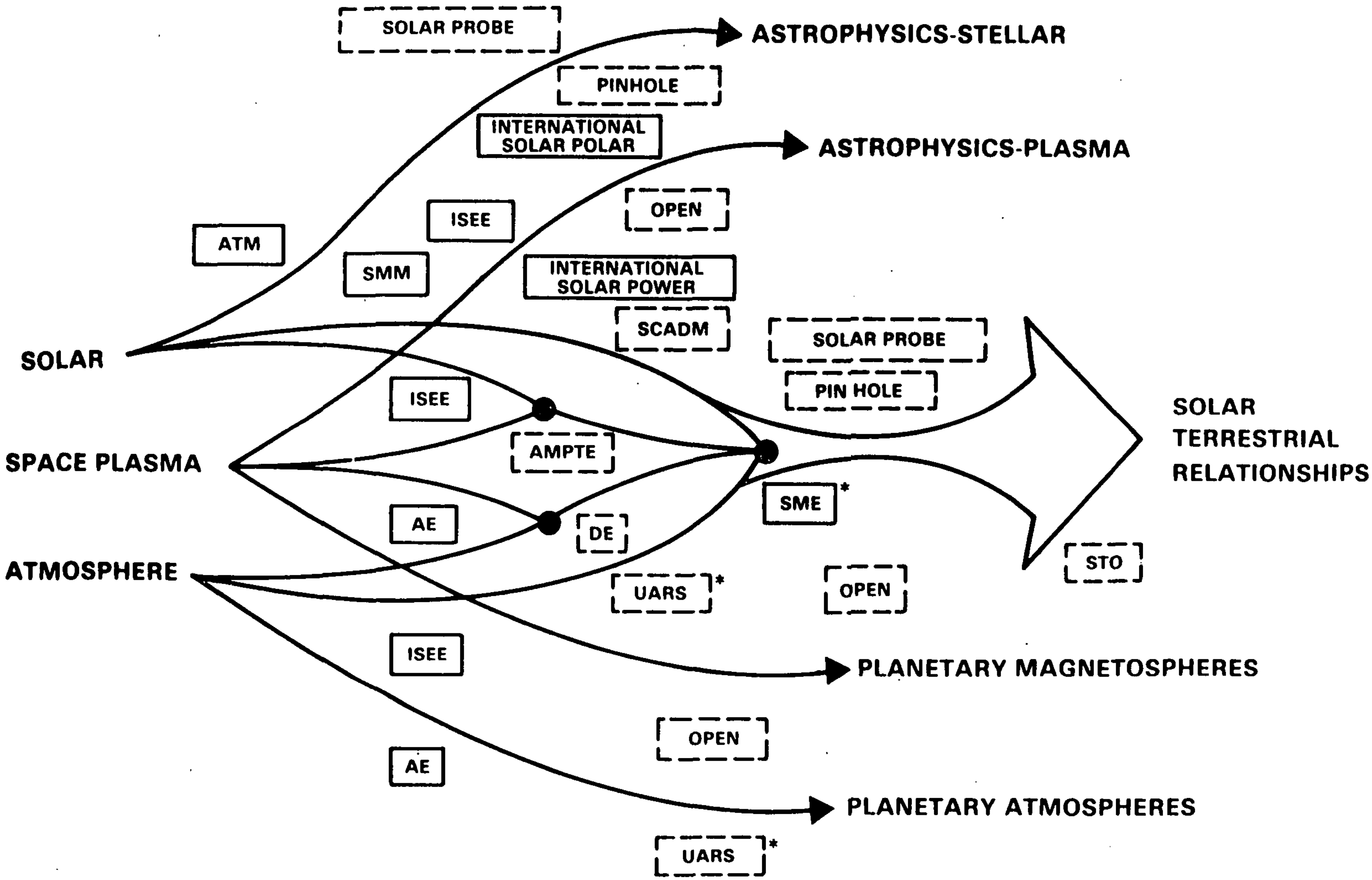


FIGURE 29—SOLAR TERRESTRIAL PROGRAM EVOLUTION



NOTE: SOME PROGRAMS ARE SHOWN MORE THAN ONCE

CURRENT PROGRAMS

FUTURE PROGRAMS

*PROGRAM RESPONSIBILITY IN OFFICE OF SPACE AND TERRESTRIAL APPLICATOINS

AE = APPLICATIONS EXPLORER
ATM = APOLLO TELESCOPE MOUNT
SME = SOLAR MESOSPHERE EXPLORER
UARS = UPPER ATMOSPHERIC RESEARCH SATELLITE

NASA HQ P79 1759(1)
4 24 79

LIFE SCIENCES PROGRAM

The Life Sciences program seeks to understand the aspects of the biological sciences that are relevant to the science and exploration of space. There are two major aspects of the study of life in space.

The first aspect deals with the effects on biological systems, especially humans, of the new environment of space. For three and a half billion years, living organisms have evolved in, and adapted to, environmental conditions on Earth. Consequently, it is not surprising that terrestrial species react in new and complex ways to the unique physical characteristics of space, particularly weightlessness and levels of ionizing radiation higher than those on Earth. One part of the Life Sciences program is concerned with the medical, physiological, behavioral, and life support problems engendered by the exposure of humans to that environment. The other part deals with the effects of the space environment on lower animals and on plants, and with that environment's utility as a research tool. In both parts, there are significant fundamental and applied research problems.

The second major aspect is Planetary Biology -- study of the precursors of life, the origin of life, and the development of complex life forms elsewhere in the universe. Because life is believed to be widespread in the universe, the Planetary Biology program studies chemical and biological evolution in the solar system and the galaxy. In doing so, it draws heavily on research into the origin and evolution of life on Earth, where detailed evidence of the story of life is at hand.

PROGRAM GOALS

The major goals of the Life Sciences program are:

1. To understand and mediate the effects of the space environment on humans so that a varied segment of the population can participate directly in space flight, and to develop the foundation for the extended presence of, and extended operations by, humans in space

2. To increase our understanding of the effects of the unique environment of space on biological processes

3. To understand the origin and early evolution of life in the universe and the role of biological processes in planetary evolution

4. To understand the evolution, nature, and distribution of complex life in the universe.

Each goal is embodied in a program with specific objectives and with specific plans for space flight missions and complementary ground-based research.

The first goal deals with biomedical aspects of the Life Sciences program, and is focused on physiological changes that may adversely affect the performance and health of individuals during space flight or after return from space. One major biomedical aspect involves the changes that occur rapidly after entry into the space environment: motion sickness, fluid redistribution within the body, cardiovascular deconditioning, and associated hormonal and biochemical changes. A second major aspect becomes significant for exposure to space over a period of time: demineralization of bones, loss of body nitrogen and phosphorus, potential changes from the cumulative effects of ionizing radiation, and changes related to the behavioral sciences. A third major aspect addresses the development of life support systems for short-term and long-term exposure of humans to the space environment.

The second goal focuses on fundamental problems of space biology, and its major objectives are subsumed under the discipline of gravitational biology. Weightlessness offers a unique opportunity to explore the response of animals and plants to the absence of gravity. To some degree, all living systems are influenced by gravity at subcellular, cellular, organ, or whole body levels. So, changes in biochemical and biological functions revealed during space biology flight experiments will lead to a better fundamental understanding of the degree to which gravity is important in the terrestrial environment, and of gravity's role in biological evolution. That knowledge will, in turn, contribute significantly to an understanding of the important practical problems of human physiology and controlled ecosystems in space, since the mechanisms by which living systems change in weightlessness will progressively be uncovered.

The third goal deals with the origin and early evolution of life, and seeks an understanding of how biology fits into the larger question of cosmic evolution. It begins with the formation of the planets, then progresses to the formation of organic compounds, the process of biogenesis, the evolution of self-replicating systems, and finally the formation of living cells and the earliest multicellular organisms. Of profound importance, also, is the interaction between an evolving planet and its evolving biota. For example, how do biological processes (human-induced and natural) alter the very nature and evolution of a planet, and vice versa? A small additional part of the program deals with planetary protection.

The last goal addresses the nature and distribution of complex life in the universe. It excites the curiosity, the imagination, and the exploratory spirit of many scientists of all persuasions -- indeed of people from all walks of life. Significant deliberations over the past two decades have developed an increasingly serious debate about the existence of extraterrestrial life in general, and of intelligent extraterrestrial life in particular.

PROGRAM STRATEGY

Our strategy for meeting the four goals of the Life Sciences program includes flight and ground activities, fundamental and applied science, and near-term and long-term objectives.

Flight and Ground Activities

The Life Sciences program focuses primarily on experiments and observations carried out in space, but also conducts a substantial supporting program of ground-based research. That terrestrially based component is comparatively large because the effects of the space environment on biological systems can be simulated to some extent on the ground, and because planetary biology research can draw heavily on studies of biological evolution on Earth. However, all ground-based research is structured either to lead to flight experiments or to uncover mechanisms that might be responsible for changes that occur during flight. The ground-based research also adds to our knowledge of possibilities for the existence and detection of life in the universe.

Fundamental and Applied Science

Changes in human physiology and behavior during flight in space are large enough to lead to real, immediate problems and to potential future problems. Before flight of humans in space can increase significantly,those problems must be resolved because they could limit the ability of humans to live and work in space and will help to determine the design of space systems and space missions. This biomedicine and life support systems work receives the largest share of the Life Sciences funding.

In contrast to the relatively applied nature of that work, space biology and planetary biology concentrate on scientific questions of fundamental importance. By what mechanisms does gravity affect living systems? What are the effects of high-energy cosmic particles on living systems? How did life begin? Why did it evolve as it did on Earth? Has it evolved elsewhere? To what degree of complexity? Can we detect it? Is there intelligent life elsewhere? Can we detect it? The fundamental importance of those questions is so great that the search for answers to them is a central and exciting component of the Life Sciences program. They are intrinsically interesting. In addition, they promise to help us understand the practical problems humans face in space and the interactions between biology and our planet, Earth.

Near- and Long-Term Objectives

The Life Sciences program embraces both near-term and longer-term objectives related to all four of the program's goals. The near-term objectives are clear and occupy a significant part of the program. The longer-term objectives are equally important, dealing as they do with the conditions under which humans can remain in space for long periods of time and with the story of life in the universe.

CURRENT PROGRAM

The Life Sciences program currently is divided into two major categories: Research and Analysis, which deals primarily with ground-based supporting research and technology, and Flight Experiments. For FY 1979, the funding in those two areas is about $24 million and $16 million, respectively.

Flight Experiments

The most important single event during the 5-year period of this plan will be the flight in 1982 of SL-4, the first Spacelab dedicated to the life sciences. Subsequent life sciences Spacelab missions will be flown every eighteen months.

Our cooperative ventures with Soviet life scientists have been very successful in the past and are expected to continue. We anticipate that our cooperative program with the Soviets in space biology flight experiments under the Cosmos Project will continue and may, indeed, expand in scope. In further cooperation, Soviet biomedical scientists may participate in our life sciences Spacelab missions.

Research and Analysis

Bed-rest studies provide a good simulation of weightlessness and are being used by both this country and the USSR. To permit better comparison of results, the U.S. and USSR biomedical teams are conducting the studies according to a strictly standardized protocol. In addition, NASA biomedical scientists will be in attendance for a study to be done in 1979 in the USSR, and Soviet investigators will be in attendance during a second study, in this country, the same year. The studies will try to analyze two different ways for simulating weightlessness by bed rest. Success in applying the standardized protocol is expected to result in improved statistics and, therefore, in research that is more cost-effective for both countries. Standardization in other areas may be achieved in the future, with further benefits to both countries. Those areas might include, for example, test procedures on the ground and space motion sickness in flight.

Experiments in the vestibular physiology of both animals and humans occupy an important place in ground research and in flight experiments. Consequently, we are designing, for use on Spacelab, a multipurpose vestibular research facility for animal experiments. We expect to complete our definition studies for the facility in 1980.

Our research related to intelligent life elsewhere in the universe has included workshops to identify astronomy activities that could contribute to our search, estimation of the probability that intelligent life does exist elsewhere, discussion of systematic methods for conducting a search, and assessment of the national, international, social, and philosophical significance of success and failure of a search. In any event, we believe that any knowledge we can acquire will give us some insight into what the future may hold for life on Earth.

NEW INITIATIVES

Our planned new initiatives for the FY 1980 through 1984 period constitute a program focused on the particular areas in flight experiments and ground-based research that will move the life sciences forward on a broad front in an integrated fashion.

History of Carbon

Our existing planetary biology program does not address some fundamental questions relating to the history of prebiotic elements, especially carbon, before those elements were incorporated into organic compounds destined to be part of living systems. This 1981 initiative will trace the history of these elements back through time to explore their origin, distribution, and fractionation into isotopes. It will also compare that history with the history of elements not found in living systems. It will explore the relationships between organic chemistry and a number of other disciplines -- astrophysics, planetology, inorganic chemistry, geology, and the solar-terrestrial physics that existed when Earth was primitive. We expect it to give us a better understanding of the origin and evolution of organic compounds and of life.

Life in the Universe

Up to now, studies of the origin and evolution of life in space have considered only the development of early life. To complete the story of the biological aspects of cosmic evolution, we must examine the evolution, nature, and distribution of complex life forms, including intelligent life, against the background of the physical characteristics of the galaxy, the stars, and the planets. We have done extensive preparatory work toward the goal of starting in 1981 a well formulated program for making that examination.

Biological Flight Experiments

This 1981 initiative in direct support of biological flight experiments aboard Spacelab will develop plant and animal facilities necessary for those experiments.

Gas Chromatograph (GC) and Mass Spectrometer (MS) for Planetary and Comet Atmospheres

Two 1981 development initiatives, the GC and the MS, will provide a marked improvement in our ability to analyze the atmospheres of planets and comets to detect molecular organic precursors to life. The miniaturization, combination, and flight qualification of those two instruments is a high-priority requirement.

Advanced Studies

A logical sequence of program planning for future efforts ensures that crucial information will be available for sound and cost-effective progression in the Life Sciences program. This 1981 augmentation will provide for exploration, on a small scale, of challenging new concepts and for advanced studies of possible new experiments, missions, facilities, and technology in the Life Sciences.

Space Science Platform (SSP) Use by Life Sciences

We are assessing the SSP described in the Solar Terrestrial section of this report as a potential carrier for long-duration flight experiments in the Life Sciences. If our assessment indicates that use of the SSP will be cost-effective and desirable, we will initiate in 1982 development of experiments to fly on the SSP in order to achieve one of our high-priority objectives -- long-duration, human-tended research in space.

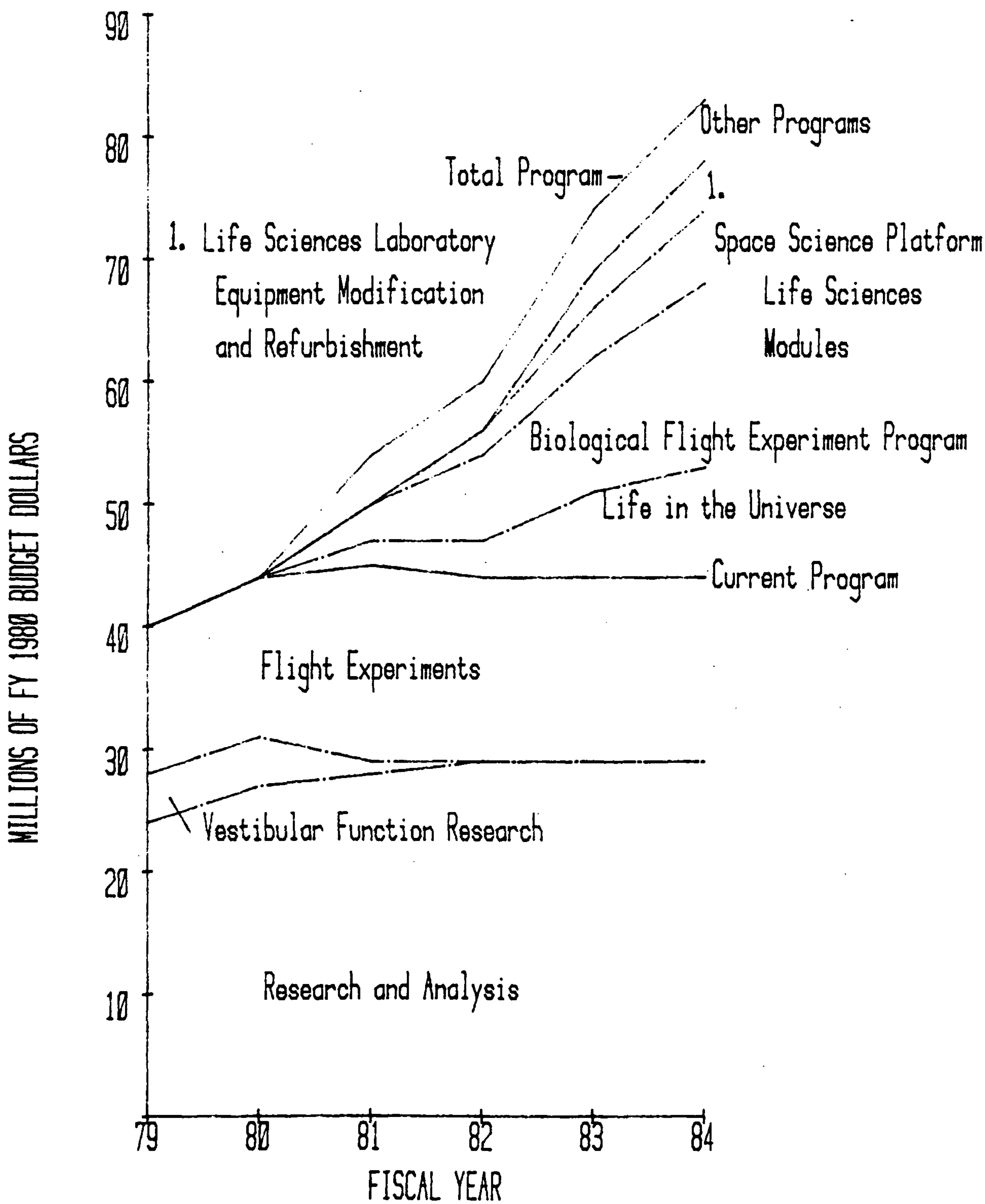
Life Sciences Laboratory Equipment Modifications and Refurbishment

In developing our low-cost approach to the Life Sciences Flight Experiment Program, we have emphasized use of off-the-shelf instruments and reflight of instruments. To continue this low-cost approach, we must initiate by 1983 a program to upgrade or refurbish those instruments for further reflight.

FUNDING

Figure 30 shows the funding requirements for the Life Sciences program.

FIGURE-30 LIFE SCIENCES PROGRAM FUNDING



CONTENTS

Tables

Figures

SPACE TRACKING AND DATA SYSTEMS PROGRAM

Today's space tracking and data systems facilities are the result of a complex, interrelated technological and programmatic evolution.

SPACE TRACKING AND DATA NETWORKS

We developed our first network to track the first U.S. satellite, as part of the Vanguard program. That network was a north-south geographical distribution of 11 ground stations with fixed antennas. From that original trunk, specialized network facilities branched to meet new challenges.

SPACE TRACKING AND DATA ACQUISITION NETWORK

Major new programs, rapid development of technology, and increasing numbers and capabilities of spacecraft soon required expansion and specialization. Communications with the spacecraft required larger, steerable antennas at new locations throughout the world. To meet those requirements, we developed the Space Tracking and Data Acquisition Network (STADAN).

MANNED SPACE FLIGHT NETWORK

The decision to put a man on the Moon before the end of the 1960s led to development of the specialized Manned Space Flight Network (MSFN) to support that national effort. The specialized trajectories of the manned space program required a unique geographical distribution of stations, data systems to handle the complexities of monitoring life support systems, precision tracking for critical reentry trajectories, and provisions for establishing communications in remote recovery areas on short notice and under emergency conditions.

DEEP SPACE NETWORK

Another entirely different network became necessary when we started sending automated spacecraft beyond Earth orbit -- first to the Moon, then to Mars and Venus. The Deep Space Network (DSN) was developed under the management of the Jet Propulsion Laboratory (JPL) to handle the special problems associated with interplanetary navigation and tracking, as well as with the acquisition of data from remote distances that give meaning to the modifier "astronomical." Facilities located in California, Australia, and Spain use giant 64-meter antennas to provide tracking, navigation, and data services to flight missions billions of kilometers from Earth.

SPACE FLIGHT TRACKING AND DATA NETWORK

STADAN and MSFN were consolidated to form today's Space Flight Tracking and Data Network (STDN). STDN incorporates many technological advances; and, although considerably smaller in geographic distribution than its predecessors, it has the ability to handle communications for all Earth-orbiting missions, both manned and automated. Goddard Space Flight Center (GSFC) manages STDN.

The DSN retains its specialized role in support of interplanetary missions and continues to be managed by JPL.

NASA COMMUNICATIONS SYSTEM

The specially engineered NASA Communications System (NASCOM) unites all network stations by use of telephone, undersea cable, microwave, and communication-satellite links leased from both domestic and foreign common carriers. NASCOM provides instantaneous transmission of data and critical commands among spacecraft, tracking stations, and the control centers that direct the missions.

DATA SYSTEMS

A large portion of our data systems are housed at GSFC. There, our large-scale, general-purpose data processing complex for Earth-orbiting missions improves the signal-to-noise ratios of telemetered signals and annotates universal time and spacecraft orientation on flight records. Also housed at GSFC are: a complex of seven control centers that control Earth-orbiting automated spacecraft; in all-digital image processing facility for Earth-viewing satellites; the control center that controls and coordinates the entire STDN network; and the Test and Training Center, which provides not only equipment testing and personnel training, but also operational support to a selected group of special missions.

GROUND STATIONS

Thirteen ground stations located around the world are the major remote components of both the STDN and the DSN. Portable equipment provides special support for unique launch trajectories and atmospheric soundings that the fixed sites cannot cover. Chief among the portable systems are mobile laser stations newly developed to provide special support for missions requiring precise calibration of instruments or determination of orbits for special geodetic, oceanic, and tectonic applications. Instrumentation systems located at Dryden Flight Research Center and Wallops Flight Center support aeronautical and sounding rocket research. GSFC and JPL conduct research, development, and studies on concepts and techniques to ensure that advanced systems required for tomorrow's missions will be ready.

PROGRAM STRATEGY

The size and content of the Space Tracking and Data Systems program are directly related to the activities in NASA's space and aeronautics programs. While the services supplied are vital to all flight programs, there are many ways to provide them, many alternative systems from which to choose, and many performance criteria to apply. An integrated approach to managing tracking and data systems requires effective selection of the mode, cost, and implications -- the "how" and "how much" -- of the delivery of the tracking and data services.

Our strategy is to balance the unique needs of each flight mission with the efficiencies achieved by use of multimission, general purpose systems and facilities.

GOALS AND OBJECTIVES

Our goal is to develop, implement, and operate the tracking and data systems required for the successful, efficient accomplishment of flight missions of orbital spacecraft, both manned and automated, deep space probes, sounding rockets, balloons, and research aircraft.

Our objectives are to:

1. Conduct missions in a wide variety of operational modes

2. Track with higher precision, and improve deep-space navigation

3. Provide improved data acquisition and transfer

4. Maximize the science return from flight missions, while reducing cost

5. Provide rapid delivery of data for analysis

6. Process large volumes of data

7. Evaluate techniques and technologies for future systems.

GROWTH OF REQUIRED CAPABILITIES

To meet our goals and satisfy our objectives, we will have to increase the capabilities of our tracking and data systems. The most evident characteristic that all programs will have in the Space Shuttle era is a large volume of data. The regular, low-cost opportunities the Shuttle will provide coupled with the increasing capabilities and complexity of sensors, will create a veritable deluge of data. New facilities, techniques, and systems will be required to cope with that growth.

DATA ACQUISITION AND TRACKING

Initiation of Tracking and Data Relay Satellite System (TDRSS) services in 1981 will usher in a new era in data acquisition. Two satellites in synchronous orbit and a single ground terminal will take over the tracking and data acquisition functions for all satellites in low Earth orbit, including the Shuttle. While increasing mission coverage sixfold, the system will minimize costs by allowing phasedown of a majority of the ground-network stations.

The mobile laser tracking stations mentioned earlier will provide tracking for Earth- and ocean-dynamics programs, allowing instrument calibration and orbit determination to an accuracy of about five centimeters. To improve deep-space navigation, additional precision will be incorporated into the DSN by modifications to increase the sensitivity of existing antennas and movement to higher frequencies. For example, conversion of one 26-meter subnet to 34-meter, dual-frequency S- and X-band capability will provide more precision in navigating and higher data rates at increasingly greater distances.

DATA TRANSMISSION AND PROCESSING

Modernization and adaptation of existing data transmission and processing systems have already begun. The Telemetry On-Line Processing System (TELOPS) recently became operational, and the GSFC Image Processing Facility has recently been converted to a completely digital system. In addition, planning is continuing for a new system for processing Spacelab data. The data output from Spacelab will equal that from all non-imaging free-flying spacecraft.

Changes in traditional techniques are also occurring in real-time transfer and processing of data. To provide adaptive mission operations and control, the Space Telescope Control Center will use distributive data processing; that is, a sharing of computer resources. That technique allows highly efficient use of a central network of equipment. Also, increasing use of wideband communications via satellites will be a hallmark of the program in the 1980s. Real-time transfer of data through satellite communications will become standard practice for the Shuttle, its complex payloads, and the new generation of deep-space missions.

All of the above techniques and improved systems will enable us to process larger volumes of data, give greater operating flexibility to mission control functions, speed up the transfer of real-time data, and get processed data to investigators more rapidly.

SUBSPACE SUPPORT

A phased program to upgrade and replace equipment will ensure that flights of sounding rockets, balloons, and research aircraft will continue to receive adequate support. We will investigate promising new technologies and techniques that could help us maintain our record of high reliability and low costs in supporting those multifaceted missions. We will study and evaluate for future application such items as ultraprecise time standards and synchronization, fiber-optics communications, and data preprocessing aboard spacecraft.

NEW INITIATIVES

LARGE ADVANCED ANTENNA SYSTEM (LAAS)

LAAS is one of the products of our studies and evaluations. Exploration and detailed study of our solar system requires both indepth study of our terrestrial neighbors by orbiting spacecraft and flights to the outer planets that are of long duration but result in brief, intensive encounters. Both of those types of missions emphasize radar mapping and imaging, which require high data rates. In the 1980s and later, LAAS will help us obtain maximum science return from both of those types of missions by providing a quantum jump in achievable data rates by virtue of the large effective aperture of its antenna.

ORBITING DEEP SPACE RELAY STATION

Planned studies will prepare us for deep-space missions in the 1990s by identifying necessary technologies for, assessing the feasibility of, and examining other parameters relative to an Orbiting Deep Space Relay Station that could conceivably perform a function for deep space missions like the function that the TDRSS will perform for Earth-orbiting missions.

TECHNICAL DATA PROCESSING FACILITY (SPACELAB)

Spacelab will create an immense growth in the volume of data requiring general purpose processing. By placing constraints on Spacelab's data rates and by special augmentation of the current data processing system, we can make the system able to support early Spacelab flights. However, we will even then be able to process data from those early flights in a timely manner only at the expense of not processing data from free-flying spacecraft. Even that procedure will become less and less effective as the data rates from planned experiments rise and the frequency of Spacelab missions increases. Thus, an important initiative is to provide a new facility to process the greater and greater amounts of Spacelab data without neglecting to process data from free-flying spacecraft, without imposing increasingly more stringent constraints on data rates, and without further increasing the delay in the availability of data for analysis.

X-BAND COMMAND SYSTEM

Another initiative currently planned is addition of a high-frequency X-band command system to the DSN. That modification will be applied to the 34-meter subnet currently under conversion. It will reduce the time required to track distant spacecraft and transmit long-range, high-power command signals during spacecraft emergencies. Studies of promising concepts and development of new technology will provide confidence that tomorrow's missions will receive timely, accurate, and reliable support at the lowest possible cost.

SCHEDULE AND FUNDING

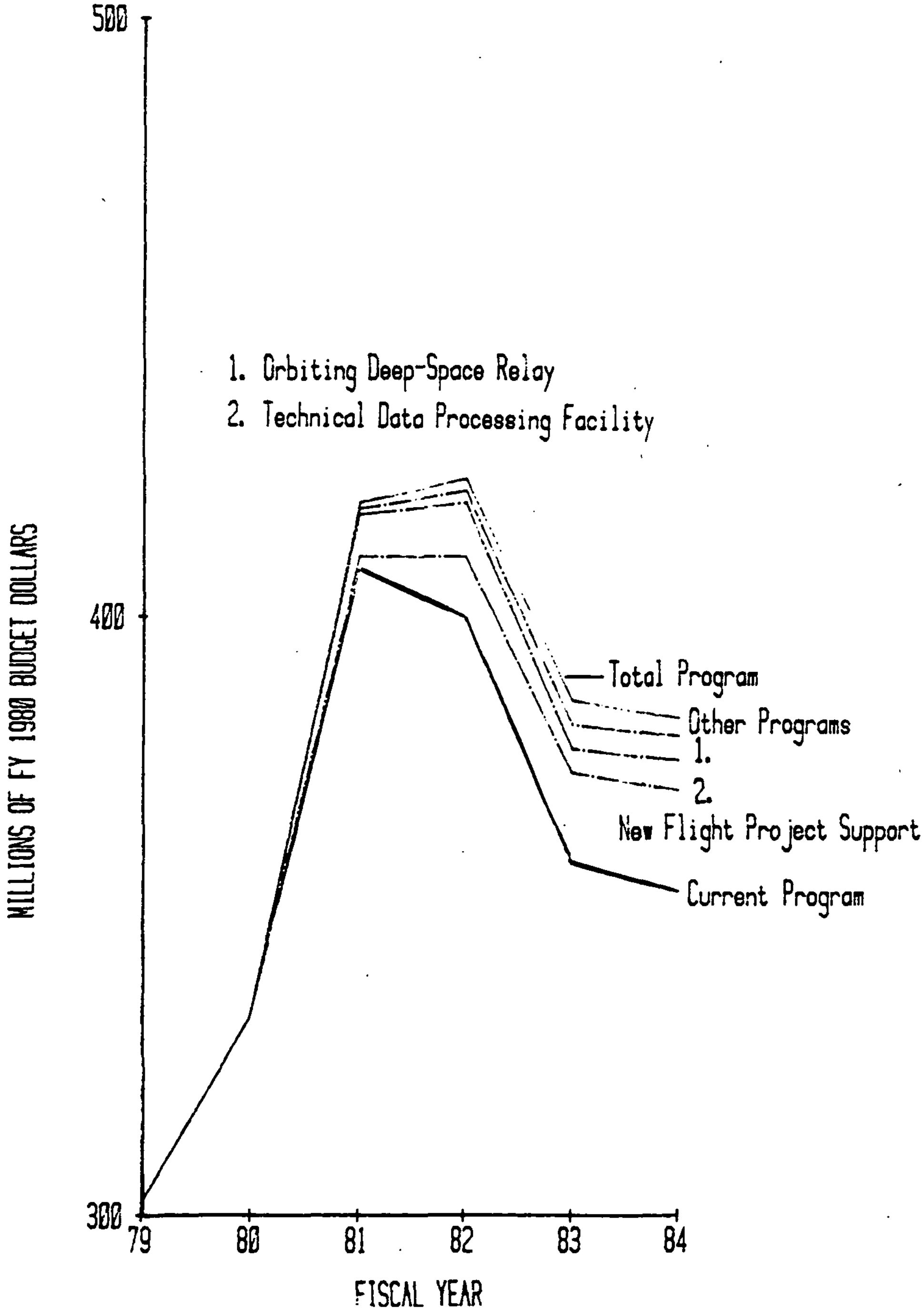
Table 19 shows the phasing of the Space Tracking and Data Systems program and Figure 31 shows the program's funding requirements.

TABLE 19 - SPACE TRACKING AND DATA SYSTEMS PROGRAM SCHEDULE

PROGRAM	PROGRAM PHASE		
	DEFINITION	INITIATION	LAUNCH OR INITIAL OPERATION
Tracking and Data Relay Satellite System	Completed	1976	1981
Technical Data Processing Facility (Spacelab)	Ongoing	1980	1983
Large Advanced Antenna System	1980	1982	1985
X-Band Command System	Ongoing	1982	1984
Orbiting Deep Space Relay Station	1981	*	*

*To be determined.

FIGURE 31-SPACE TRACKING AND DATA SYSTEMS PROGRAM FUNDING



CONTENTS

FIGURES

CONSTRUCTION OF FACILITIES PROGRAM

NASA's research and development capabilities depend on a sensitive balance of qualified and dedicated people, sufficient funds, and adequate facilities. The objectives of the Construction of Facilities (CoF) program is to ensure the adequacy of NASA's existing facilities, to upgrade and modify those facilities to meet new requirements, and to acquire new facilities when necessary. The program must provide timely, effective, and economical support to all of NASA's activities by:

1. Participating in the development of facility requirements
2. Analyzing facility needs and exploring alternative methods for reducing facility costs
3. Repairing and rehabilitating existing facilities clearly needed in the future
4. Modifying existing facilities, when possible, to meet new requirements while minimizing the need for new facilities
5. Constructing new facilities when other alternatives are less cost effective.

The CoF program provides facilities to the "supporting" programs (Space Transportation Systems, Space Tracking and Data Systems, and Space Technology) as well as to the "primary" programs (Space Science, Space and Terrestrial Applications, Aeronautics, and Energy Systems). It stems from earlier and continuing efforts to anticipate major project needs, and mainly reflects requirements for preserving and enhancing existing facilities. Few new facilities are generally involved because NASA's planned research activiteis have generated only a few requirements for facilities.

MAJOR NEW INITIATIVES

Most of the approximately 160 projects in the CoF 5-year program will cost $1- to $10-million each, but the following two projects will cost considerably more.

SPECIAL COMPUTER FACILITY

A special computer facility will be constructed at Ames Research Center for numerical simulation of the complex flow of fluids not only in aerodynamics, but also in related areas of current national interest such as weather and climate. Simulation will reduce the time, energy, and dollar costs of testing, but will require very fast computation speeds -- about forty times the speeds of current supercomputers. This construction project will start in 1982, and the facility will be ready for operation in late 1985.

Preceding page blank

LARGE ADVANCED ANTENNA SYSTEM

The Large Advanced Antenna System will be constructed for the Office of Space Tracking and Data Systems to provide improved communications links for all NASA deep-space programs. The antenna will provide gain equivalent to that of a 100-meter, 75-percent efficient aperture at 8,450 MHz in the most cost-effective manner. The proposed location for the antenna is the Jet Propulsion Laboratory's Goldstone tracking and communications center. This one-of-a-kind antenna will supplement NASA's current 64-meter antennas, which even now are overloaded. In addition, it will provide greater capabilities than the smaller 64-meter antennas can furnish with respect to such characteristics as bandwidth, channel capacity, and signal power required for reception. Construction will start in 1982 and the facility will be ready for operation in late 1985.

REMAINING PROJECTS

Each remaining project consists of construction, rehabilitation, or modification of one of the following categories of facilities.

ENERGY FACILITIES

Modifications to facilities, buildings, and utility systems to conserve energy. In many of these projects, combined energy and manpower savings result in simple payback of the capital investment in approximately five years or less.

LARGE AERONAUTICAL FACILITIES

Completion of construction of the National Transonic Facility (NTF) at Langley Research Center, and modification of the 40-foot by 80-foot Subsonic Wind Tunnel at Ames Research Center.

AERONAUTICAL SUPPORT FACILITIES

Construction and modification of aeronautical research facilities, including computer and model-making facilities directly supporting aeronautical research, but excluding the NTF and 40-foot by 80-foot Subsonic Wind Tunnel.

SPACE TRANSPORTATION SYSTEM FACILITIES

Necessary modifications for launching and servicing the Space Shuttle and facilities required for manufacturing and refurbishing Shuttle components.

SPACE SHUTTLE PAYLOADS FACILITIES

Facilities for: Inertial Upper Stage and Spinning Solid Upper Stages, as well as for other scientific experiments and payloads; integrating payloads with the launch vehicle; servicing payloads; and processing data from Spacelab and Landsat projects.

SPACE SUPPORT FACILITIES

Launch facilities, Earth-based laboratories and computer areas for analysis of experiments and samples from spacecraft, and test stands for spacecraft and propulsion systems. This category directly supports the space programs of the Offices of Space Science, Space and Terrestrial Applications, Space Transportation Systems, and Space Technology.

TRACKING AND DATA ACQUISITION FACILITIES

Construction of antennas, and rehabilitation and modification of the ground-based antenna network.

OTHER FACILITIES

Institutional facilities that, typically, support a variety of research programs and are not dedicated to any specific program; for example, roads, parking lots, warehouses, offices, laboratories, shops, and rooms or buildings for computers.

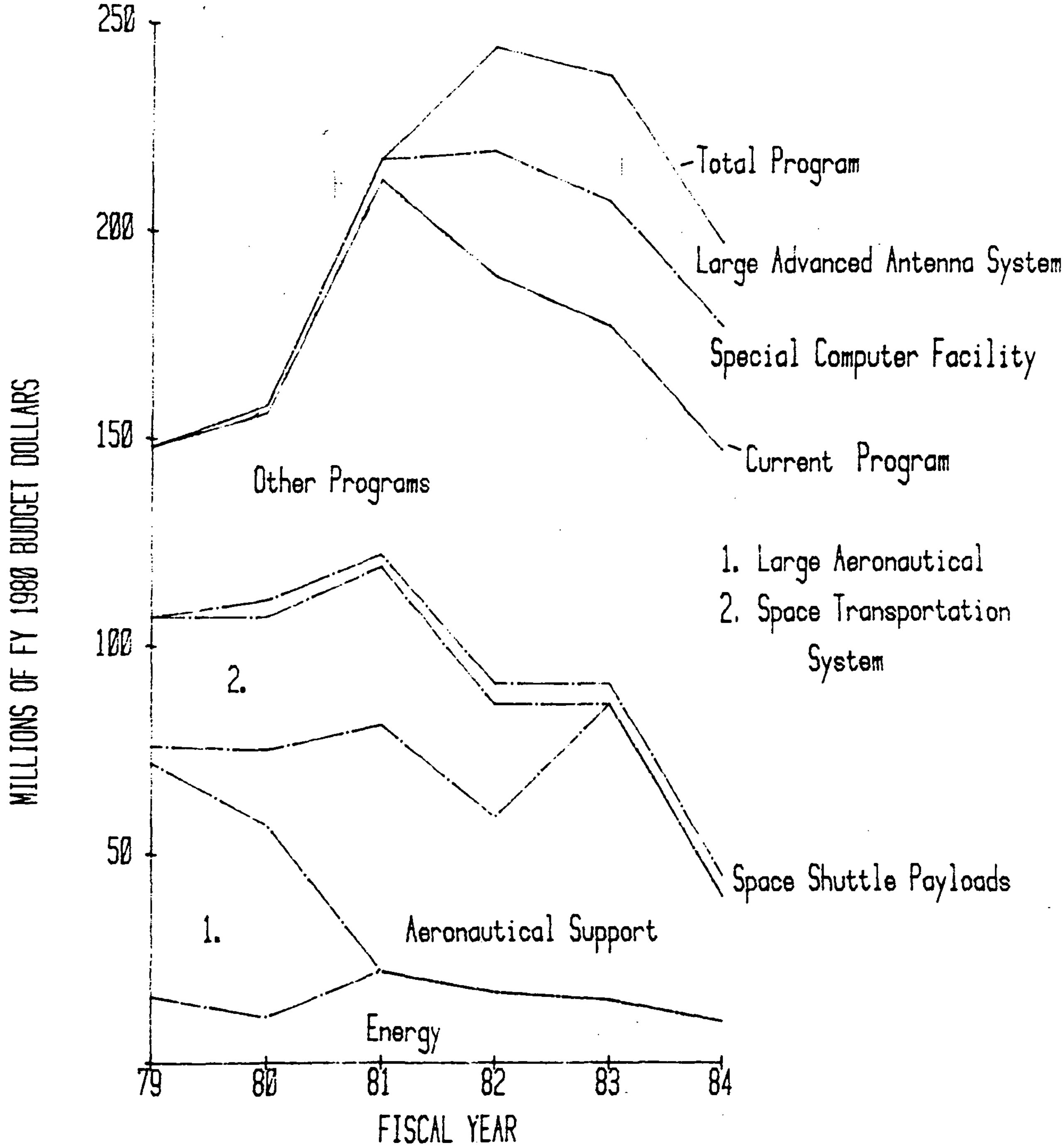
LEVEL-OF-EFFORT FACILITIES WORK

Minor construction, rehabilitation and modification, and repair of existing facilities to preserve their efficient and productive operation, as well as facility planning and design for advanced facilities or for proposed major modifications of existing facilities.

PROGRAM FUNDING

Figure 32 shows CoF funding projected through FY 1984. Construction starting dates are the latest dates that will meet the requirements of the programs the facilities will support, and the dates for institutional projects are based on "good business judgment" to provide overall cost-effective use of resources. The entire scheduling sequence is, of course, regularly confirmed or revised in the CoF program review cycle.

FIGURE-32 CONSTRUCTION OF FACILITIES PROGRAM FUNDING



ABBREVIATIONS AND ACRONYMS

ACEE	Aircraft Energy Efficiency
ACPL	Atmospheric Cloud Physics Laboratory
ADS	Applications Data Service
AE	Applications Explorer
AGRISTARS	Agriculture and Resource Inventory Surveys Through Aerospace Remote Sensing
ARC	Ames Research Center
AR&DA	Applied Research and Data Analysis
ASVT	Applications Systems Verification and Transfer
ATM	Apollo Telescope Mount
ATS	Advanced Technology Satellite
A.U.	Astronomical Unit (Sun-Earth Mean Distance)
AXAF	Advanced X-ray Astrophysics Facility
b/s	Bits Per Second
COBE	Cosmic Background Explorer
CoF	Construction of Facilities
COTV	Cargo Orbital Transfer Vehicle
CRF	Chemical Release Facility
CRO	Cosmic Ray Observatory
CTOL	Conventional Takeoff and Landing
CTS	Communications Technology Satellite
DE	Dynamics Explorer
DFRC	Dryden Flight Research Center
DMA	Defense Mapping Agency
DOD	Department of Defense
DOE	Department of Energy
DOT	Department of Transportation
DSN	Deep Space Network
ELV	Expendable Launch Vehicle
EPA	Environmental Protection Agency
ERBS	Earth Radiation Budget Satellite
ERSAR	Earth Resources Synthetic Aperture Radar
EUVE	Extreme Ultraviolet Explorer
FY	Fiscal Year
GARP	Global Atmospheric Research Program
GC	Gas Chromatograph
GEO	Geostationary Orbit
GEOS	Geodynamic Experimental Ocean Satellite
GHz	Gigahertz (10^9 Hertz)
GOES	Geostationary Orbit Environment Satellite
GP	Large Geostationary Platform
GP-B	Gravity Probe-B
GRO	Gamma Ray Observatory
GSFC	Goddard Space Flight Center
GWE	GARP Global Weather Experiment
HALOE	Halogen Occultation Experiment
HCMM	Heat Capacity Mapping Mission
HEAO	High Energy Astronomy Observatory

HiMAT	Highly Maneuverable Aircraft Technology
HLLV	Heavy-Lift Launch Vehicle
IAC	Industrial Application Center
IFOV	Instantaneous Field of View
IFR	Instrument Flight Rules
IOTV	Interim Orbital Transfer Vehicle
IRAS	Infrared Astronomy Satellite
ISEE	International Sun-Earth Explorer
IUE	International Ultraviolet Explorer
IUS	Inertial Upper Stage
JPL	Jet Propulsion Laboratory
JSC	Johnson Space Center
KSC	Kennedy Space Center
LAAS	Large Advanced Antenna System
LAMAR	Large Area Moderate Angular Resolution
LaRC	Langley Research Center
LDEF	Long Duration Exposure Facility
LEO	Low Earth Orbit
LeRC	Lewis Research Center
LFC	Laminar Flow Control
LFC	Large Format Camera
LRB	Liquid Rocket Booster
MAPS	Measurement of Air Pollution From Shuttle
MEC	Materials Experimentation Carrier
MEM	Materials Experimentation Module
MOTV	Manned Orbital Transfer Vehicle
MPS	Materials Processing in Space
MRS	Multispectral Resource Sampler
MS	Mass Spectrometer
MSFC	Marshall Space Flight Center
MSFN	Manned Space Flight Network
MSS	Multi-Spectral Scanner
NAC	NASA Advisory Council
NASCOM	NASA Communications System
NEEDS	NASA End-to-End Data Systems
NGS	National Geodetic Survey
NOAA	National Oceanic and Atmospheric Administration
NOSS	National Oceanic Satellite System
NSF	National Science Foundation
NSTL	National Space Technology Laboratories
NTIS	National Technical Information Service
OAO	Orbiting Astronomy Observatory
OAST	Office of Aeronautics and Space Technology
OCE	Ocean Color Experiment
OERS	Operational Earth Resources System
OFT	Orbital Flight Test
OPEN	Origins of Plasma in Earth's Neighborhood
OSIP	Operational Satellite Improvement Program
OSS	Office of Space Science
OSTA	Office of Space and Terrestrial Applications
OSTDS	Office of Space Tracking and Data Systems

ABBREVIATIONS AND ACRONYMS (CONTINUED)

OSTS	Office of Space Transportation Systems
PEP	Power Extension Package
PI	Principal Investigator
RAE	Radio Astronomy Explorer
R&D	Research and Development
RD&D	Research, Development, and Design
RMS	Remote Manipulator System
R&T	Research and Technology
SAGE	Stratospheric Aerosol and Gas Experiment
SAS	Small Astronomy Satellite
SCADM	Solar Cycle and Dynamics Mission
SEPS	Solar Electric Propulsion System
SGRS	Spaceborne Geodynamics Ranging System
SIR-A	Shuttle Imaging Radar-A
SIRTF	Shuttle Infrared Telescope Facility
SME	Solar Mesosphere Explorer
SMIRR	Shuttle Multispectral Infrared Radiometer
SOP	Saturn Orbiter Dual Probe
SOT	Solar Optical Telescope
SPS	Satellite Power System
SSP	Space Science Platform
SSUS	Spinning Solid Upper Stage
STADAN	Space Tracking and Data Acquisition Network
STAMPS	Scientific and Technological Aspects of Materials Processing in Space
STDN	Space Flight Tracking and Data Network
STO	Solar Terrestrial Observatory
STOL	Short Takeoff and Landing
STS	Space Transportation System
TDRSS	Tracking and Data Relay Satellite System
TELOPS	Telemetry On-Line Processing System
TM	Thematic Mapper
UAR(S)	Upper Atmospheric Research (Satellite)
USDA	U.S. Department of Agriculture
USGS	U.S. Geological Survey
VLBI	Very Long Baseline Interferometer
VOIR	Venus Orbiting Imaging Radar
V/STOL	Vertical and Short Takeoff and Landing
VTOL	Vertical Takeoff and Landing
WFC	Wallops Flight Center
WTG	Wind Turbo-Generator
XRO	X-Ray Observatory

INDEX

Preceding page blank