SCIENCE, AERONAUTICS, AND TECHNOLOGY
FISCAL YEAR 1998 ESTIMATES
BUDGET SUMMARY

OFFICE OF MISSION TO PLANET EARTH
MISSION TO PLANET EARTH

SUMMARY OF RESOURCES REQUIREMENTS

MISSION TO PLANET EARTH	FY 1996	FY 1997	FY 1998
Earth observing system	554,200	586,700	679,700
Earth observing system data information system	247,200	254,600	244,700
Earth probes	80,100	57,200	40,700
Applied research and data analysis	350,100	373,400	325,300
Global observations to benefit the environment	5,100	5,000	5,000
Launch services	107,100	84,700	121,900
Construction of facilities	17,000	---	---
(Earth system science building)	(17,000)	(---)	(---)
Total	**1,360,800**	**1,361,600**	**1,417,300**

Distribution of Program Amount by Installation	FY 1996	FY 1997	FY 1998
Johnson Space Center	100	---	---
Kennedy Space Center	4,900	4,700	6,600
Marshall Space Flight Center	4,200	5,400	4,000
Stennis Space Center	17,200	66,200	16,200
Ames Research Center	38,100	8,200	5,500
Dryden Flight Research Center	5,100	19,000	18,700
Langley Research Center	27,000	42,500	30,600
Lewis Research Center	68,400	16,300	36,000
Goddard Space Flight Center	922,400	991,300	1,067,600
Jet Propulsion Laboratory	68,600	97,200	103,100
Headquarters	204,800	110,800	129,000
Total	**1,360,800**	**1,361,600**	**1,417,300**

SCIENCE, AERONAUTICS, AND TECHNOLOGY
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PROGRAM GOALS

The pursuit of Earth system science would be impractical without the continuous, global observations provided by satellite-borne instruments. MTPE comprises an integrated slate of spacecraft and *in situ* measurement capabilities; data and information management systems to acquire, process, archive and distribute global data sets; and research and analysis programs to convert data into new knowledge of the Earth system. Numerous users in academia, industry, federal, state and local government tap this knowledge to produce products and services essential to achieving sustainable development. MTPE is NASA's contribution to the U.S. Global Change Research Program(USGCRP), an interagency effort to understand the processes and patterns of global change.

The Earth Observing System(EOS), the centerpiece of MTPE, is a program of multiple spacecraft(the AM, PM, Chemistry series, Landsat-7, and others) and interdisciplinary science investigations to provide a 15 year data set of key parameters needed to understand global climate change. The first EOS satellite launches begin in 1998. Preceding EOS are a number of individual satellite and Shuttle-based missions which are helping to reveal basic processes. The Upper Atmosphere Research Satellite(UARS), launched in 1991, collects data on atmospheric chemistry. The Total Ozone Mapping Spectrometer(TOMS) instrument, launched in 1978 and 1991, measures ozone distribution and depletion. Two TOMS instruments were launched in 1996, one on the Japanese Advanced Earth Observing System(ADEOS) mission and the other on a dedicated U.S. Earth probe. The French and U.S. collaborated on the Ocean Topography Experiment(TOPEX/Poseidon), launched in 1992, to study ocean topography and circulation. The NASA Scatterometer(NSCAT), also launched on the Japanese ADEOS in 1996, maps ocean winds. In 1997 the Tropical Rainfall Measuring Mission(TRMM) will measure tropical precipitation. Complementing EOS will be a series of small, rapid development Earth System Science Pathfinder(ESSP) missions to study emerging science questions and make innovative measurements in parallel with the 15 year mission of EOS. The first ESSP mission should be ready for launch in 2000.

Data from MTPE missions, both current and future, are captured, processed into useful data products, and broadly distributed by the EOS Data and Information System(EOSDIS). EOSDIS will ensure that data from these diverse missions will remain available in active archives for use by current and future scientists. Since these data are useful beyond the Earth system science research community, EOSDIS will be accessible by environmental decision-makers, resource managers, commercial firms, social scientists and the general academic community, educators, state and local government--anyone who wants the information. Following the recommendation of the National Research Council, MTPE is exploring the creation of a federation of Earth science information partners in academia, industry and government to broaden the participation in the creation and distribution of EOSDIS information products.

The intellectual capital for these missions, and the key to generating new knowledge from

them, is vested in an active program of research and analysis. MTPE's research and analysis program funds over 1,700 researchers from nearly every U.S. state. There are also scientists from seventeen other nations, funded by their own countries but, collaborating with U.S. researchers. These researchers develop Earth system models from MTPE data, conduct laboratory experiments, run aircraft campaigns, develop new instruments, and thus expand the frontier of our understanding of our home planet. MTPE-funded scientists are recognized as world leaders in their fields, as exemplified by the awarding of the 1995 Nobel Prize in chemistry to two who identified the threat of cholorflorocarbons to upper atmospheric ozone. The research and analysis program is also the basis for generation of application pilot programs which enable universities, commercial firms, and state and local governments to turn scientific understanding into economically valuable products and services.

In 1996, the first MTPE Science Research Plan was published. The plan lays out a strategy for study in five Earth system science areas of maturing scientific understanding and significant societal importance: land-cover and land use change; seasonal-to-interannual climate variability and prediction; natural hazards research and applications; long-term climate natural variability and change research; and atmospheric ozone research. The plan also outlines some twenty related areas of research which round out the MTPE contribution to Earth system science.

The challenges of Earth system science, sustainable development, and protection of people, property and the environment from natural disasters, require collaborative efforts among a broad range of national and international players. As mentioned above, the USGCRP coordinates research among thirteen U.S. government agencies. MTPE has extensive collaborations with the National Oceanic and Atmospheric Administration(NOAA) on seasonal-to-interannual climate prediction. MTPE is the responsible agent in NASA for managing the development of NOAA's operational environmental satellites. NOAA, NASA, and the Department of Defense(DOD) are collaborating on a convergence of the civilian and military weather systems. MTPE collaborates with the U.S. Geological Survey(USGS) on a range of land surface, solid Earth and hydrology research. NASA, NOAA and USGS collaborate in the Landsat-7 program, and NASA, DOD and USGS are working together on a third flight of the shuttle radar laboratory modified to yield digital terrain data on most of the Earth's surface. MTPE participates in the World Climate Research Program, the International Geosphere/Biosphere Program, and the ozone assessments of the World Meteorological Organization. Most of MTPE's satellite missions have international participation, ranging from simple data sharing agreements to joint missions involving provision of instruments, spacecraft, and launch vehicles.

MTPE has adopted an evolutionary approach to fulfilling its mission and goals. During 1995, NASA conducted a comprehensive review of the entire MTPE Enterprise. The goal was to enable: a focus on near-term science and associated applications; explicit provision for new technology infusion; reduction in life-cycle cost of the EOS program; provision of new science opportunities through smaller, quicker and less expensive missions (the genesis of ESSP); and

closer participation with other Federal agencies (especially NOAA), commercial firms and international partners. The result of this review is an EOS which is lower in life-cycle cost, more flexible in implementation, and of greater utility to the science community and more adaptable to commercial opportunities. Out of this review came planning for MTPE involvement in the new millennium program which conducts the development and flight demonstration of advanced, smaller instruments for the EOS second series. Our basic approach has been endorsed by the National Research Council(NRC) through its Board on Sustainable Development.

We continue to refine this plan and seek the advice of the NRC and other external groups as we progress. In 1997, NASA will conduct the first biennial review of MTPE. The biennial review will examine all aspects of MTPE with a view toward incorporating new scientific understanding, technology development, and expanded collaborations with national and international operational and research satellite systems. The product of the biennial review will be reviewed by an NRC-organized panel of external experts, and will be the basis for MTPE's FY1999 budget request development.

This budget fully supports the baseline program presented in the FY1997 budget. The requested funding provides for a robust science program. MTPE has developed an integrated science plan that relates research plans to space observations, and fully integrates EOS and non-EOS science. The basic themes of this plan are consistent with the USGCRP and contain five areas of emphasis. Three initiatives which will further contribute to a robust science program as well as to technology infusion have been incorporated. These initiatives include an Uncrewed Aerial Vehicle(UAV) scientific research program, an instrument incubator, and an advanced geostationary study.

The UAV-based research program will focus on making *in situ* atmospheric measurements in the tropopause and lower stratosphere. UAV's will measure detailed temporal changes by staying over a target area for an extended period, providing unique views of cloud structure and calibration and verification of MTPE's satellite instrumentation. These UAV-based measurement strategies are based on emerging technology which should increase scientific return at a reduced cost to the government.

The instrument incubator is a technical and managerial approach for enabling rapid deployment of new, less costly, and less resource-intensive (i.e., less power, weight, volume, etc.) scientific instruments. It will focus on ground-based development and testing of instrument system and subsystem technologies by applying the results of the core technology (funded in space science) program to MTPE-specific requirements.

The advanced geostationery study provides for concept studies of the application of the latest technology to the development of small, compact, geostationary satellites that will support research and technology objectives. Data from advanced geostationary studies will be used for

both global climate change and research missions.

These initiatives will be funded out of the savings realized elsewhere in the MTPE program, including the common spacecraft procurement. In addition to these savings, MTPE is committed to continue to look for ways to reduce near-term funding requirements. The Chemistry-1, Laser Altimetry, and AM-2 missions are all under study to determine if cost savings can be achieved through the use of new approaches to these missions such as the utilization of smaller spacecraft.

Two significant changes in the management approach to MTPE were implemented in 1996. The MTPE program office, at the Goddard Space Flight Center(GSFC), assumed a larger role when program management responsibilities migrated from NASA Headquarters to GSFC. Further, the NASA Office of Space Access and Technology was disestablished with advanced technology development to be managed by the enterprises and coordinated by a chief technologist in the Office of the Administrator. With this change, MTPE assumed responsibility for the small spacecraft technology initiative (Lewis & Clark) and the commercial remote sensing program.

Upcoming activities over the next two years in the MTPE program include, in the Earth probes program, launch of the Tropical Rainfall Measuring Mission(TRMM) in late 1997. The Lewis and Clark land imaging spacecraft, developed in partnership with commercial firms, will be launched in 1997. The MTPE mission operations program will begin operations and data processing of the TRMM as well as activities for currently orbiting satellites, including TOPEX/Poseidon, UARS, NSCAT and TOMS. The experiments of opportunity program will be focused on Shuttle Imaging Radar-C(SIR-C) and launch the Measurement of Air Pollution from Satellites(Maps) on MIR, a cooperative commercial venture. Within the EOS, a preliminary design review will be held for PM-1 in 1997. Instruments for AM-1 and Landsat-7 will be delivered in 1997. The EOSDIS will release Version1 in 1997, and prepare for the release of Version2.

The EOSAM-1 will be launched in June1998. This mission will provide key measurements that will significantly contribute to our understanding of the total Earth system. The AM-1 instrument complement will obtain information about the physical and radiative properties of clouds, air-land and air-sea exchanges of energy, carbon, and water, measurements of trace gases, and volcanology.

Landsat-7 will be launched no later than December 1998. Landsat-7 will carry a single instrument, the enhanced thematic mapper plus, which will make high spatial resolution measurements of land surface and surrounding coastal regions. This mission will provide data continuity with previous Landsat measurements. Landsat data is used for global change research, regional environmental change studies, national security and other civil and commercial purposes.

The measurements to be made by these and other future MTPE missions as well as current on-orbit missions provide data products that are used extensively in the MTPE science program. The program encompasses over 1,700scientific activities at universities, research laboratories, and government research organizations. These activities are providing an ever increasing scientific understanding of global environment and the effects of natural and human sources of change.

EARTH OBSERVING SYSTEM

BASIS OF FY1998 FUNDING REQUIREMENT (Thousands of Dollars)	FY 1996	FY 1997	FY 1998
AM series	178,700	82,800	49,100
PM series	103,700	149,700	218,000
Chemistry	27,300	63,300	100,600
Special spacecraft	60,500	83,100	91,700
Landsat-7	85,200	76,200	52,100
Algorithm development	73,300	84,900	102,700
Technology infusion	25,500	46,700	65,500
(New millennium program)	(20,000)	(35,000)	(40,000)
(Sensor & detector technology)	(5,500)	(4,700)	(5,500)
(Instrument incubator)	(--)	(7,000)	(20,000)
Total	**554,200**	**586,700**	**679,700**

PROGRAM GOALS

The overall goal of the Earth Observing System(EOS) is to advance the understanding of the entire Earth system on a global scale by improving our knowledge of the components of the system, the interactions between them, and how the Earth system is changing. The EOS data will be used to study the atmosphere, oceans, cryosphere, biosphere, land surface and solid Earth, particularly as their interrelationships are manifested in the flow of energy and in the cycling of water and other chemicals through the Earth system.

The EOS program mission goals are: (1)to create an integrated, scientific observing system emphasizing climate change, that will enable multi-disciplinary study of the Earth's critical, life-enabling, interrelated processes; (2)to develop a comprehensive data and information

system, including a data retrieval and processing system; (3)to serve the needs of scientists performing an integrated multi-disciplinary study of planet Earth and to make MTPE data and information publicly available; and, (4)to acquire and assemble a global database for remote sensing measurements from space over a decade or more to enable definitive and conclusive studies of Earth system attributes.

STRATEGY FOR ACHIEVING GOALS

The EOS contributes directly to accomplishing the goal of understanding global climate by providing a combination of observations made by scientific instruments, which will be integrated with the EOS spacecraft, and the data received, archived, processed, and distributed by the EOSDIS. The selection of scientific priorities and data products responds directly to the USGCRP global change science priorities and the assessment by the Intergovernmental Panel on Climate Change of the scientific uncertainty associated with global change.

The three main EOS spacecraft that will support observations by the scientific instruments include the morning(AM), afternoon(PM), and Chemistry series. Beginning in 1998, 2000, and 2002 respectively, the first satellite in each series will be flown for a period of six years in order to obtain, at a minimum, a data set that will span fifteen years. Additional observations will be provided by the Landsat-7 mission beginning in 1998. Data continuity for the Landsat program will be maintained by flying an advanced technology Landsat-like instrument on the AM-2 mission in 2004.

International participation is a highly valued element of the EOS program. Understanding global climate requires a global effort. In addition to the fiscal benefits from integrating our complimentary science programs, it is critical to ensure that the world's decision makers have a common body of information that is credible and well understood. AM-1 includes instruments provided by Canada and Japan. International partners contribute to several other key EOS missions. Within the special spacecraft program, flights of the Radar Altimetry and Laser Altimetry satellites, as well as Stratospheric Gas and Aerosol Experiment-III(SAGE-III), SeaWinds, Active Cavity Radiometer Irradiance Monitor(ACRIM), Solar Stellar Irradiance Comparison Experiment(SOLSTICE), and Clouds and Earth's Radiant Energy System(CERES) instruments will be accomplished with a combination of domestic dedicated spacecraft and international participation by Japan, Russia, France, and potentially other countries.

EOS program planning began in 1983 with the definition of the science and mission requirements by the EOS Science and Mission Requirements Working Group(SMRWG). The SMRWG charter was to examine the major Earth science questions for the 1990's and to define the requirements for low-Earth-orbit observations needed to answer these questions on a comprehensive multi-disciplinary basis. The SMRWG's report, issued in 1984, listed five basic recommendations concerning Earth science in the 1990's:

- A program must be initiated to ensure that the present time series of Earth science data are maintained and continued. Collection of new data sets should be initiated.
- A data system that provides easy, integrated, and complete access to past, present, and future data must be developed as soon as possible.
- A long-term research effort must be sustained to study and understand these time series of Earth observations.
- The EOS program should establish an information system to carry out those aspects of the recommendations that go beyond existing and planned activities.
- The scientific direction of EOS should be established and continued through an International Scientific Steering Committee.

The Earth System Sciences Advisory Committee(ESSAC) was appointed in November 1983 by the NASA Advisory Council to consider directions for NASA's Earth sciences program. The committee's report, issued in May 1986, recognized EOS as the centerpiece of the future Earth sciences implementation strategy. It stated the following goal of Earth system science: "To obtain a scientific understanding of the entire Earth system on a global scale by describing how its component parts and their interactions have evolved, how they function, and how they may be expected to continue to evolve on all time scales." It also identified the following challenge to Earth system science: "To develop the capability to predict those changes that will occur in the next decade to century, both naturally and in response to human activity."

The successor to the SMRWG, the EOS Science Steering Committee(SSC), continued the definition of the EOS program and provided an overall implementation strategy in its report issued in 1987. Concurrent with the SSC work, NASA included the EOS program under a broader Agency initiative termed MTPE, which included other efforts such as the Earth probe missions and NASA's participation in the International Geosphere Biosphere Program(IGBP) and the World Climate Research Program(WCRP). By proceeding to carry out the recommendations of the SMRWG and the ESSC, including EOS, the SSC argued that it would be possible to move from a single-discipline research mission to a comprehensive mission addressing all aspects of the Earth as a system. Thus, the concept of an Earth system was adopted as the EOS scientific thrust.

An announcement of opportunity(AO) to solicit proposals for EOS investigations was issued in January 1988. The EOS program objectives were based on the requirements and goals of the SMRWG, SSC, and ESSAC. In responding to the AO, proposers could offer to do interdisciplinary studies to carry out integrated Earth system research leading to the development of comprehensive Earth system models, to be members of research facility teams (formed to provide scientific guidance for the development of the research Facility Instruments(FI) and to analyze and interpret data from them), or to be Principal Investigators(PI) of proposed instruments and data products. The EOS selection process was completed in February 1989, with the selection of six team leaders and 93 team members for

the six NASA research FI's, 24 instrument PI's, and 29 interdisciplinary team PI leaders to participate in the definition phase of the EOS program.

The EOS Investigators Working Group(IWG), formed in 1989, consists of PI's (instrument and interdisciplinary), and team leaders to provide scientific advice and guidance for the program. The program scientist (from NASA Headquarters) and the senior project scientist (from GSFC) co-chair the IWG. The working bodies of the IWG include twelve science panels. The chairpersons of each of these panels, together with the program scientist and senior project scientist, constitute the Science Executive Committee(SEC) of the IWG. Membership on the panels is generally open to all EOS investigators, including co-investigators on any EOS investigation and members of EOS FI teams. Scientists outside the group of EOS investigators are also included in the various panels.

The IWG plays a leading role in defining the overall science thrust for the EOS program. It coordinates the research efforts and provides guidance and advice to the EOS program and project, as appropriate, concerning all major scientific issues. It will meet regularly throughout the lifetime of the program.

The EOS study project was established at GSFC in 1983. During the PhaseA andB study periods, GSFC and the Jet Propulsion Laboratory(JPL) performed mission, data system and spacecraft studies resulting in a conceptual design of a dual series of spacecraft missions that would satisfy the EOS requirements. The spacecraft were designated EOS-A and EOS-B, with GSFC and JPL having the respective managerial responsibilities. Following the EOS Non-Advocacy Review(NAR), held in June 1989, management responsibilities for the EOS-B series, as well as the project management role for the execution phase of EOS, were transitioned to GSFC. The synthetic aperture radar(SAR), which was an FI to be launched on EOS-B, was identified as an independent mission, to be managed by JPL, and a candidate for separate program approval. In 1990, responsibility for development of the platform was transferred from the space station program to EOS. EOS management became centralized within the EOS project at GSFC.

The EOS program was approved by Congress as an FY1991 budget initiative. The payload for the first flight (EOS-A1) was selected in January 1991, following conceptual design and cost reviews of the selected instruments and IWG Payload Panel recommendations on scientific priorities and synergism. The baseline flight segment consisted of two series of large observatories, EOS-A and-B, in 1:30PM ascending, sun-synchronous orbit, launched by a Titan-IV with solid rocket motor upgrades from the Western Space and Missile Center(WSMC). Each observatory had a five-year life and each was to be replaced twice to provide a 15-year mission. The budget runout through FY2000 was $17billion.

The NRC advises the federal government through reports of reviews it conducts using its various committees, which involve the broad community of science and technology experts.

Prior to the EOS new start approval in FY1991, their report, "The U.S. Global Change Research Program: An Assessment of FY1991 Plans," provided a critical review of the EOS program.

In the July 1991, report, "Assessment of Satellite Earth Observation Programs 1991," the NRC was in general agreement with the EOS plan for the large EOS-A observatory and its selected payloads. It expressed concern that the total EOS budget size could lead to potential delays, noted data gaps in key areas, and endorsed the MTPE Earth probe concept. These reviews were the beginning of a series of reviews and evaluations of the program to ensure the proper scientific return on the EOS investment.

As part of the FY1992 budget process, the Committees on Appropriations directed NASA to restructure the EOS program to:

- Focus the science objectives of EOS on the most important problem of global change (i.e., global climate change).
- Increase the resilience and flexibility of EOS by flying the instruments on multiple, smaller platforms rather than a series of large platforms.
- Reduce the cost of EOS through FY2000 to $11billion.

In the summer and fall of 1991, NASA conducted a restructuring of the program to meet the Congressional mandate. This process included an independent review by the External Engineering Review Committee, which issued its report in September 1991. The process also involved assessment by the scientists who will use the data from EOS, including both the EOS IWG and the EOS Payload Advisory Panel. The EOS project at GSFC conducted studies to determine how the EOS instruments could most effectively be configured on small spacecraft. In December 1991, the NASA Administrator reviewed and approved the restructured EOS program, and in March 1992, NASA submitted its report on the restructured program to Congress. Congress approved the restructured program in 1992.

Recognizing that the subsequent budget environment would not support the complete and timely implementation of the restructured EOS program described in the March 1992, report to Congress, the NASA Administrator directed that the program be rescoped with a goal of further reducing its costs through FY2000 by 30% to $8billion. The EOS rescope was completed in June 1992, satisfying the 30% reduction by capitalizing on efficiencies, reducing at-launch science data products, by rephasing work, by increasing international participation, and by deleting the High-Resolution Imaging Spectrometer(HIRIS) flight instrument. As a result of the rescoping process, EOS became recognized by NASA as a cost-driven program.

In the 1995 Congressional budget cycle, the EOS budget was reduced by $758.5million through FY2000, to $7,243.4million, of which $131.3million was due to a funding responsibility transfer. The EOS rebaselining effort conducted in 1994, with the following

results, was reflected in the FY1996 budget submission.

- Preserve the scientific integrity of EOS and MTPE
- Preserve the measurement complement of the first mission in each series
- Preserve the launch dates for AM-1, PM-1 and Chemistry-1
- Phase EOSDIS development to support missions through FY2000
- Restore reserves to a prudent level
- Incorporate appropriate technology advancements
- Fit within annual funding guidelines for the EOS program
- Replace major spacecraft at six year intervals

Public Law102-555 returned the development, operations and data distribution of the Landsat-7 program to the federal government in 1992. It established the Landsat Program Management(LPM) team comprised of the DOD and NASA. DOD was responsible for the acquisition of the satellite and NASA was responsible for the development of the ground system. In the fall of 1993, DOD withdrew from the program. At the direction of the National Science and Technology Council(NSTC), the Office of Science and Technology(OSTP) initiated a review and restructuring of the Landsat-7 program. Under Presidential Decision Directive(PDD)/NSTC-3, the Land Remote Sensing Strategy was established. This strategy implemented a program management structure for the Landsat-7 program, which made NASA responsible for development of the satellite, instrument and ground system, USGCRP responsible for operations, and the USGS, in conjunction with the EOSDIS Land Process Distributed Active Archive Center(LPDAAC), responsible for data archive and distribution. During the EOS rebaselining process, the Landsat-7 program was integrated with EOS. As another aspect of the rebaselining, the EOS science program was reorganized. The funding to support the activities of the EOS instrument investigators and interdisciplinary science investigators was moved to research and analysis. The science algorithm development and maintenance remains in the EOS budget.

During 1995, NASA conducted a comprehensive review of EOS to reshape mission planning to accomplish a number of interrelated objectives: substantially reduce EOS life-cycle costs while preserving the basic measurement set; provide now for technology infusion so that it will be available in time to be able to lower the cost of the second and third EOS series; provide new science opportunities through small satellites; and, adjust program management to an evolutionary approach.

This "reshaping" exercise recognized that the first series already employs or advances the state-of-the-art in spacecraft and instruments. Even so, savings achieved in the EOS Data and Information System(EOSDIS) implementation and other changes enable some savings and improvements in the first series. These include accelerating Laser Altimetry and ACRIM by one year, providing a spacecraft for SOLSTICE (previously awaiting a flight of opportunity), and the explicit provision of funding within the EOS budget for new technology missions.

The second series relies upon technology development to reduce the size of instruments, and therefore, the size of the spacecraft required--cutting the total weight approximately in half for the multi-instrument missions. This should enable movement from Medium Class Expendable Launch Vehicles (MELV's) in the first series to Medium-Light Class ELV's(MLELV's) in the second series, when we expect these launch capabilities to be available. One key to the development of these advanced instruments is NASA's new millennium program, in which NASA's programs for MTPE and Space Science are engaged in demonstration flights of much smaller prototype component technologies.

The reshaped second series also provides for an advanced Landsat-type instrument to be incorporated on EOSAM-2, saving the government the cost of a separate spacecraft and launch (approximately $325 million in the Landsat-7 program). The EOSPM-2 spacecraft can be substantially downsized if the National Polar-Orbiting Operational Environmental Satellite System(NPOESS) can incorporate an infrared sounder with adequate specifications and calibration. The first NPOESS satellite will be ready for launch in 2007 with a probable launch date of 2009. NASA will work with NOAA and the DOD through the NPOESS Integrated Program Office(IPO) over the next three years to find common requirements in sounding as well as other areas. Downsizing the remaining EOSPM-2 instruments enables them to be flown on a small spacecraft. The second EOSChemistry mission is planned to be split into two smaller missions; one for largely stratospheric measurements taken in a monitoring mode and one largely for tropospheric measurements taken in a process study mode. Autonomous operations will be adopted in the second series to further reduce the cost of ground operations.

The third EOS series is left relatively undefined to allow maximum flexibility to accommodate emerging science requirements, technology infusion, and greater international and commercial participation to reduce the cost of completing the basic commitment to the EOS measurement set. By this point in the development program, the process for infusion of new technology from the new millennium program and other sources will be routine. Further advances in computing and network technology should continue to decrease EOSDIS operations costs.

AM Series

The global climate change research emphasized by the AM instrument data set will include cloud physics, atmospheric radiation properties, and terrestrial and oceanic characteristics. Because the AM series primarily observes terrestrial surface features, a morning equatorial crossing time is preferred to minimize cloud cover over land. The primary contractors associated with the program are Lockheed Martin Missiles and Space(LMMS) for the AM-1 spacecraft, Hughes Santa Barbara Remote Sensing(SBRS) for the Moderate Resolution Imaging Spectrometer(MODIS) instrument, TRW for the CERES instrument (the instrument will also be flown on the TRMM in 1997 and PM series spacecraft, and as a flight of opportunity), and Lockheed Martin Commercial Launch Services for the AM-1 Atlas

Centaur/IIAS launch service. The Multi-Angle Imaging Spectro-Radiometer(MISR) instrument is being built in-house at JPL. The Japanese will provide the Advanced Spaceborne Thermal Emission and Reflection Radiometer(ASTER) instrument and the Canadians will provide the Measurement of Pollution in the Troposphere(MOPITT) instrument for the AM-1 spacecraft.

PM Series

The research focus of the PM series is atmospheric temperatures and humidity profiles, clouds, precipitation, and radiative balance; terrestrial snow and sea ice; sea-surface temperature and ocean productivity; soil moisture; and the improvement of numerical weather prediction. With the emphasis of the instrument complement being cloud formation, precipitation, and radiative properties, an afternoon equatorial crossing is more suitable for acquiring the data. The primary contractors associated with the program are TRW for the common spacecraft to be used for PM-1 and Chemistry-1; Lockheed Martin Infrared and Imaging Systems(LMIRIS) and JPL for the Advanced Infrared Sounder(AIRS) instrument; and Aerojet General Corporation for the Advanced Microwave Sounding Unit(AMSU) instrument. Japan will provide the Advanced Microwave Scanner Radiation(AMSR) instrument for the PM-1 spacecraft and Brazil will provide a microwave instrument, the Humidity Sounder from Brazil(HSB).

Chemistry Series

The study area for the Chemistry series will be atmospheric chemical species and their transformations. The Tropospheric Emission Spectrometer(TES) and the Microwave Limb Sounder(MLS) instruments are planned to be built in-house at JPL. The Japanese will provide the Ozone Dynamics Ultraviolet Spectrometer(ODUS) instrument and the University of Colorado and Rutherford Appleton Lab/Oxford University in the United Kingdom will provide the High Resolution Dynamics Limb Sounder(HIRDLS) instrument for the Chemistry-1 spacecraft.

Special Spacecraft

The special spacecraft will be designed to study atmospheric aerosols, ocean circulation, ice-sheet mass balance, cloud physics, atmospheric radiation properties, and solar irradiance. Ball Aerospace is responsible for developing SAGE-III that will fly on a Russian spacecraft in 1998 and on the International Space Station in 2001 and will take advantage of both solar and lunar occulations to measure aerosol and gaseous constituents of the atmosphere. The Japanese will provide the Advanced Earth Observing SystemII(ADEOSII) spacecraft for the SeaWinds instrument to measure ocean surface wind velocity as a follow-on to the NSCAT instrument on ADEOS-I. The first Radar Altimetry mission, Jason-1, will be as a follow-on to the TOPEX/Poseidon as a joint mission with the French Space Agency(CNES), with data

provided to NOAA for operational purposes. The Laser Altimetry mission is presently planned as a dedicated domestic mission. There remain a number of instruments in the program that are also identified as flights of opportunity (i.e., ACRIM, SOLSTICE, and CERES).

Landsat

With the launch of Landsat-7 in 1998, substantially cloud-free, sun-lit land surface imagery for detecting and characterizing regional and global change will continue. The primary contractors are Lockheed Martin Missiles and Space(LMMS) for the Landsat-7 spacecraft, Hughes Santa Barbara Research Sensing(SBRS) for the Enhanced Thematic Mapper Plus(ETM+), and McDonnell Douglas for the Landsat-7 Delta 2 launch service. The Landsat-7 estimate includes funding for ground segment development. NOAA will be responsible for operating the satellite and the USGS will archive the data.

Technology Infusion

This New Millennium Program(NMP) budget reflects a commitment to develop new technology to meet the scientific needs of the next few decades and to reduce future EOS costs through focused technology demonstrations for Earth orbiting missions. Two Headquarters enterprises offices are coordinating their program plans to do these missions. OMTPE has joined the Office of Space Science in the New Millennium Program in order to capitalize on common work from core technology development programs and specific spacecraft and instrument studies. The program will identify and demonstrate advanced technologies that reduce cost or improve performance of all aspects of mission for the next century, (i.e., spacecraft, instruments and operations). The program objectives are to spawn "leap ahead" technology by applying the best capabilities available from several sources within the government, private industries and universities. These low cost, tightly controlled developments will take more risk in order to demonstrate the needed technology breakthroughs and thus reduce the risk of using that technology in future science missions. Missions will be selected based on their ability to meet the science needs of the future by innovative technology that would also decrease the cost and improve the overall efficiency of space flight missions.

Increased technology work will be pursued in the areas of sensor and detector systems. Emphasis is being placed on developing new capabilities for Earth science sensors and integrated, autonomous, self-calibrating instruments. Studies are being conducted in the areas of differential absorption Light Direction and Ranging(LIDAR) and OH(hydroxyl) radiometer.

The instrument incubator initiative is expected to reduce the cost and development time of future scientific instruments for MTPE. The instrument incubator program will aggressively pursue emerging technologies and proactively close the technology transfer gaps that exist in

the instrument development process. The program will take detectors and other instrument components coming from NASA's fundamental technology development programs and other sources and focus on combining them into new instrument systems which are smaller, less costly, less resource intensive, and which can be developed into flight models more quickly for future MTPE missions. This includes the key follow-on instruments for the EOS.

MEASURES OF PERFORMANCE

Preliminary Design Reviews - Confirms that the proposed project baseline is comprehensive (meets all program-level performance requirements), systematic (all subsystem/component allocations are optimally distributed across the system), efficient (all components relate to a parent requirement), and represent acceptable risk.

Performance Milestone	Plan	Actual/Revised	Description/Status
EO-1	February 1997	--	Spacecraft review held November 1996; instrument review to be held in February 1997
PM-1	April 1997	--	--
Chemistry-1	March 1998	March 1999	Rescheduled to accommodate revised instrument schedule

Critical Design Reviews - Confirms that the project system, subsystem, and component designs, derived from the preliminary design, is of sufficient detail to allow for orderly hardware and software manufacturing, integration and testing, and represents acceptable risk. Successful completion of the critical design review freezes the design prior to actual development.

Performance Milestone	Plan	Actual/Revised	Description/Status
SeaWinds	December 1995	January 1996	Minor schedule change
Landsat-7	September 1995	October 1995	Minor schedule change
Aerosol SAGE III (Russian)	August 1996	TBD	--
EO-1	April 1997	July 1997	Schedule changed to accommodate a grating spectrometer, which was recently added to the mission
PM-1	April 1998	August 1998	Revised schedule due to late start
Chemistry-1	June 1999	April 2000	Revised instrument schedule

Instruments Delivered - Confirms that the fabrication, integration, certification, and testing of all system hardware and software conforms with their requirements and is ready for recurring operation. Throughout system development,testing procedures or, as appropriate, engineering analysis have been employed at every level of system synthesis in order to assure that the fabricated system components will meet their requirements.

Performance Milestone	Plan	Actual/Revised	Description/Status
Landsat-7	December 1996	February 1997	Delays due to miscellaneous technical problems and inefficiencies at Santa Barbara Remote Sensing
AM-1 last instrument	February 1997	--	--
Aerosol SAGE-III (Russian)	December 1997	--	--
SeaWinds	March 1998	--	--
EO-1	October 1998	December 1998	Schedule changed to accommodate a grating spectrometer, which was recently added to the mission
PM-1 last instrument	December 1998	June 1999	Instrument deliveries delayed
Chemistry-1 last instrument	June 2001	--	--

Algorithm Development (Version 2) - Confirms that the second version of the science software necessary for the production of the standard data products for each mission has been

Launch Readiness Dates - Verifies that the system elements constructed for use, and the existing support elements, such as launch site, space vehicle and booster, are ready for launch.

Performance Milestone	Plan	Actual/Revised	Description/Status
AM-1	June 1998	--	--
Landsat-7	December 1998	--	--
ACRIM	late 1998	--	-
Aerosol SAGE-III (Russian)	December 1998	--	--
EO-1	1998	May 1999	Schedule changed to accommodate a grating spectrometer, which was recently added to the mission
SeaWinds	August 1999	--	--
Jason 1	December 1999	--	--
PM-1	December 2000	--	--
Chemistry-1	December 2002	--	--
Laser Altimetry-1	July 2002	--	--
SOLSTICE	December 2002	--	--

ACCOMPLISHMENTS AND PLANS

AM Series

Fabrication and assembly of all AM-1 spacecraft subsystems are nearing completion. The project spacecraft effort has been begun the transition from fabrication to integration and test. The propulsion subsystem will be complete in the second quarter of FY1997. Test of the fully integrated ASTER engineering model was completed in the first quarter of FY1996. Fabrication and assembly of all AM-1 instruments (ASTER, CERES, MISR, MODIS, and MOPITT), and integration and test of the instruments is scheduled to begin in the first half of FY1997.

Integration and test of the AM-1 spacecraft will be completed in FY1997. Version 1 of the science software will be delivered in the second quarter of FY1997. The second external independent readiness review will be held prior to the start of environmental testing of AM-1 (with all instruments integrated onto the spacecraft). Environmental testing will begin in mid-FY1997 and continue into FY1998.

The spacecraft will be delivered to Astrotech commercial launch processing facility at the Vandenberg AFB in California where system end-to-end testing will be performed and preparation for launch will be completed. Launch is scheduled for June 1998.

PM Series

The Request for Proposals(RFP) for the common spacecraft to provide medium-size platforms for the PM-1 and Chemistry-1 flights was released in September 1994. The planned procurement included two firm-buy and two operational spacecraft. In September 1995, TRW was selected for the common spacecraft contract. After protests were filed with the General Accounting Office, a stop work order was issued to TRW. The spacecraft protest was resolved in NASA's favor. The spacecraft contract has completed PhaseB development including a Spacecraft Configuration Audit(SCA) and Bus Requirements Review(BRR). CERES flight models 3 and 4, and MODIS flight model 1 are proceeding satisfactorily. The Brazilian Space Agency has signed a joint Memorandum of Understanding(MOU) to provide a Brazilian instrument, the HSB, for the PM-1 platform. This instrument has a significant heritage to the Advanced Microwave Sounding Unit-B(AMSU-B), which is being developed for the U.S. meteorological satellites. Japan (NASDA) has agreed to seek funding to provide an AMSR instrument. This instrument is a replacement for the Multi-frequency Imaging Microwave Radiometer(MIMR) instrument which ESA was to provide, but withdrew. PhaseB development of AMSR is on schedule and proceeding satisfactorily. Final commitment by NASDA is subject to the Japanese budget process, with determination expected in April 1997.

The PM-1 spacecraft PDR will be held in the second quarter of 1997. Fabrication and assembly of the AIRS engineering model will continue through FY1997. Assembly of the AIRS protoflight model will begin in late 1997. AMSU, CERES and MODIS will be in various stages of fabrication, test and integration. AMSR PDR and CDR will be completed in 1997. HSB PDR will also be completed in 1997.

The PM-1 spacecraft CDR will be held in the third quarter of 1998. The AIRS, AMSU, CERES and MODIS will complete fabrication, test and assembly and will be delivered in the fourth quarter of 1998. HSB will complete CDR and will be in advanced stages of fabrication, test and assembly along with the AMSR instrument. The EOS common spacecraft design will be completed. The system CDR will be completed. Fabrication of the PM-1 flight subsystems will begin in FY1998.

Chemistry Series

The TES System Concept Review(SCR) was completed in FY1996. The HIRDLS SCR has also been completed. MLS is proceeding satisfactorily during its Phase-B development process. TES, MLS and HIRDLS have shown progress and maturity in their overall design concepts including the infusion of advanced technologies such as Monolithic Microwave Integrated Circuit(MMIC) and laser based local oscillators in tera herz (THz) frequency range. The HIRDLS PhaseC/D RFP was released in the fourth quarter of 1996. The Chemistry-1 mission is scheduled to fly on the second common spacecraft. During the second quarter of 1996, a special assessment study was conducted on the Chemistry-1 mission. It was aimed at reducing cost through aggressive pursuit of new technology and launch configurations. Attempts have been made to streamline each instrument's mass, power and volume without jeopardizing the science requirements. The successful completion of this study allowed the award of three-month cooperative agreement contracts to eight U.S. commercial aerospace companies. The purpose of these agreements is to explore the feasibility of low cost, mid-range spacecraft based upon existing or imminent production line commercial busses.

The HIRDLS PhaseC/D contract is planned for award in the first quarter of 1997. The HIRDLS PDR will be held in June 1997. MLS and ODUS SCR's are also scheduled in 1997. MLS and TES are also planned to be in PhaseC/D by late 1997. In FY1997, the cooperative agreement results will be evaluated and a Chemistry mission decision implementation mode will be made.

During FY1998, the HIRDLS instrument team will procure hardware for the Engineering Model(EM), and complete EM fabrication, integration, test, and calibration. This work will complete the HIRDLS detailed design phase, with culmination to the CDR in December1998. The TES instrument PDR design and brassboard test will be completed with PDR in 1998, followed by fabrication, integration, and test of the EM in preparation for CDR, in 1999. The MLS instrument will complete PDR brassboard test by the end of FY1998. Long-lead procurement of certain parts will be initiated in FY1998 for TES and MLS. In FY1998, the spacecraft for the Chemistry-1 mission will begin.

Special Spacecraft

The FY1995 National Defense Authorization Act asked that NASA and the Navy jointly study the possible convergence of their Radar Altimetry missions (EOS Radar Altimetry program based on TOPEX/Poseidon Follow-On(TPFO) and the Navy's Geosat Follow-On(GFO) program). The final study report recommends that the EOS Radar Altimetry program, based on TPFO, be modified to meet the Navy's operational requirements. This approach would preserve NASA's science objectives, provide a timely follow-on to the TOPEX/Poseidon mission, continue established international collaboration with France, fit within the NASA budget, and satisfy Navy operational requirements with acceptable risk, at the least cost to

DOD. Subsequently, the Navy withdrew from the program.

With Congressional approval to implement the Radar Altimetry mission as a modified follow-on to the successful TOPEX/Poseidon mission, NASA and CNES drafted the initial MOU between the U.S. and France. The MOU has renamed the mission as Jason-1 and divided responsibilities: CNES will provide the spacecraft and altimeter, NASA will provide the radiometer, ground system, and launch. During FY1996, CNES initiated contracts with Aerospatiale and Alcatel for the spacecraft and altimeter, respectively, with the altimeter completing preliminary design in March 1996. The NASA radiometer design is under way at JPL and proceeding normally.

The MOU between the U.S. and France will be signed early this fiscal year. The design for the US-provided radiometer will be complete by the end of FY1997, with both PDR and CDR scheduled to occur this year. The PDR's for the French-provided Jason-1 satellite and the US-provided ground system are scheduled for the second quarter.

During FY1998, the US-provided radiometer will be delivered to CNES for integration with the Jason-1 satellite. The ground system will complete design.

The Laser Altimetry mission, focusing on ice topography and mass balance, continued PhaseA technology development for the Geoscience Laser Altimeter System(GLAS) instrument. New mission implementation studies to reduce mission cost and shorten schedule while still achieving science objectives, were conducted. During FY1997, the Laser Altimetry mission implementation studies will be completed, with a cooperative industry study early in the fiscal year. An approach will be selected for detailed planning, and an acquisition strategy will be developed. The GLAS instrument team will complete the technology development phase. In FY1998, the GLAS instrument will enter PhaseC/D, completing preliminary design before the end of the first quarter. The spacecraft PhaseB/C/D procurement will be concluded with a fourth quarter FY1998 contract award.

The SAGE-III instrument began PhaseC/D development in November 1994. An implementing agreement was signed in December1994 with the Russian Space Agency for flight of the first SAGE-III in a polar orbit on a Russian Meteor-3M(1) spacecraft in late 1998. A second SAGE-III instrument is planned to fly in an inclined orbit on the International Space Station in 2001. Design and development activities have progressed on schedule with the CDR completed in August 1996. Delivery of the first SAGE III instrument is planned for December 1997. A flight opportunity for a third SAGE III Instrument with CNES is under study.

The SeaWinds CDR was completed in January 1996. The SeaWinds instrument will continue to undergo protoflight model fabrication and assembly during FY1997. The first SeaWinds instrument activities will consist of integration and test of the instrument, with the engineering

model being delivered to the Japanese in mid FY1997. The protoflight model, the second SeaWinds instrument, is scheduled for delivery to Tsukuba, Japan in March 1998 for an August 1999 launch on the ADEOS III spacecraft by a NASDA H-II rocket from Tanegashima, Japan.

PhaseB activities for the SOLSTICE instrument continue on schedule with the goal of supporting a flight opportunity in 2002. SOLSTICE PhaseB activities will continue, with a critical design and cost review in early FY1998.

The ACRIM instrument will begin PhaseC/D development in early 1997. A contract was awarded to Orbital Sciences Corporation in late 1996 for a dedicated flight on a small spacecraft as a secondary Pegasus payload in the late 1998. Discussions are under way with the Canadian Space Agency(CSA) regarding a possible flight of a follow-on SOLSTICE instrument, on a CSA small spacecraft in the 2001.

Landsat

The Landsat-7 ETM+ instrument will be delivered in early 1997. The solid state recorder will be ready for integration into the spacecraft by spring of 1997. The ground station and data handling facility will be completed in mid FY1997.

The spacecraft will be delivered to California Space Port commercial launch processing facility at the Vandenberg AFB in California where systems end-to-end testing will be performed and preparation for launch will be completed. Launch is no later than December 1998.

Technology Infusion

In FY1996, a series of workshops were conducted to inform other government agencies, industry, academia and non-profit research and development organizations and to solicit inputs and partnerships for new millennium implementation. Integrated Product Development Teams(IPDT) were established to coordinate a cooperative effort to identify, develop and deliver focused advanced technologies for flight validation. This resulted in formation of the first NMP Earth Observing mission known as EO-1. An Advanced Land Imager(ALI) instrument has been selected to fly on its own dedicated spacecraft. The instrument, to be built by the Massachusetts Institute of Technology's Lincoln Laboratory, is in PhaseB development. The spacecraft has successfully completed the Design Convergence Review(DCR) in the last quarter of 1996.

In FY1997, the NMP IPDT's will establish and maintain phased technology development plans for each technology in priority order and determine the costs. NASA Headquarters will select the additional future mission sets, and contractor teams will be chosen for the design and integration of the demonstration flight. The EO-1 instrument, ALI, and spacecraft CDR's will

be held in 1997. Spacecraft and instrument fabrication, assembly and test will begin in late 1997. The second NMP mission (EO-2), will be selected in FY1997.

Formal definition of EO-2 will be initiated in FY1998. The EO-1 payload and spacecraft will go through integration and test during 1998, with launch planned for May 1999.

During FY1997 and FY1998, specific tests and demonstrations will take place in the sensor and detector technologies as we attempt to reduce existing differential absorption LIDAR systems by at least an order of magnitude in mass, power, and volume. Work will continue in the development of ultra-stable, solid state laser local oscillators for atmospheric and astronomical spectrometers suitable for measurements of atmospheric hydroxyl.

In FY1998, funding for instrument concept exploration, which was stated in FY1997, will continue, These first grants will explore new instrument systems and measurement techniques. The more promising concepts will then be funded to begin development of instrument brassboards or prototypes to further characterize the benefits of each approach. A second round of concept exploration grants will also be funded in FY1998.

EARTH OBSERVING SYSTEM DATA AND INFORMATION SYSTEM

BASIS OF FY1998 FUNDING REQUIREMENT (Thousands of Dollars)	FY 1996	FY 1997	FY 1998
Earth observing system data and information system	247,200	254,600	244,700

PROGRAM GOALS

The goals for the EOS Data and Information System(EOSDIS) are the development and operation of a highly integrated system which can: (1) operate the EOS satellites; (2) acquire instrument data; (3) produce data and information products from the EOS, to preserve these and all other MTPE environmental observations for continuing use; and (4) make all these data and information easily available for use by the research, education, government agencies and all those who can benefit from them in making economic and policy decisions. The EOSDIS facilitates the goals of MTPE by enabling the public to benefit fully from increased understanding and observations of the environment.

STRATEGY FOR ACHIEVING GOALS

The EOSDIS is based on an evolutionary design to develop capabilities with the phased deployment of the EOS satellites and to enable adaptation to changes in user needs and technology. The design is also modular, allowing the replacement of individual components

without costly overall system changes or disruptions in service. NASA is making extensive use of prototypes to assure that EOSDIS will effectively meet the needs of the satellites and users. A limited amount of technology development and adaptation is focused specifically on meeting EOSDIS evolutionary needs while relying on other programs at NASA and other agencies to fund needed technology development efforts of a more generic nature, i.e., communications technology. An initial version of the system, Version 0, implemented at nine Distributed Active Archive Centers(DAAC) and through cooperative efforts with NOAA, the USGS, and international partner space agencies, became operational in 1994. Plans for development of subsequent versions of the system have been redrawn. Unique developmental activity in Version1, ReleaseA, in support of the first flight of two EOS instruments on TRMM in 1997, has been redirected from the EOSDIS Core System(ECS) contractor to the GSFC and LaRC DAAC contractors. The remaining developmental effort previously in ReleaseA and performed by the ECS contractor, has been folded into Version2.0 in support of Landsat-7 and AM-1 in 1998, still to be performed by the ECS contractor.

The EOSDIS development has been divided into four major components: the EOS Data Operations System(EDOS) which has been developed by TRW, the EOSDIS Backbone Network(EBNET) which has been developed in-house by GSFC using Computer Sciences Corporation and Allied Signal, the ECS which is under development by Hughes Information Technology Systems, and the DAAC's. The EDOS receives the raw data stream from the satellites, separates the data by instrument, and performs the initial processing and back-up archiving. The EBNET delivers the real-time data to and from the operations control centers and the science data to the DAAC's. The ECS includes the flight operations segment which provides satellite and instrument command and control; the communications and systems management segment which provides data product generation archival, and distribution; and the science data processing segment, which provides the systems to integrate all EOSDIS user functions. The DAAC's currently have a limited operational capability using EOSDIS Version 0. The EOSDIS Independent Verification and Validation(IV&V) contract is with Intermetrics Systems Services Corporation.

The EOS Data and Operations System(EDOS) element of the EOSDIS has been replanned in an effort to reduce cost and improve efficiency. Trade-off studies between the space network and ground stations for EOS data acquisition were performed. These studies resulted in changes to the architecture of EDOS, with some minor architectural implications on other elements of EOSDIS. The previous baseline architecture was to perform Level0 data processing at the White Sands Complex(WSC). The processed data would then be distributed from WSC to the DAAC's. The assumption for that architecture was that all EOS missions would be supported via the space network. The current architecture calls for missions beyond AM-1 to be supported by EOS ground stations(to be built in Alaska and Norway) instead of the space network. The AM-1 mission can use either space network or ground stations. Under this new architecture, Level0 processing will be performed at GSFC and the processed data will be distributed to the DAACs. This architecture saves money in hardware development

costs for EOS spacecraft, reduces risk to PM-1 development, saves money in data transport costs, streamlines data flow, and allows for the potential commercialization of data acquisition.

Using the ECS, the nine DAAC's will process the raw data from the satellites into useful products, handle all user product searches, requests, and orders, and distribute data and information directly to the user community primarily via the national information infrastructure. The DAAC's also permanently archive all MTPE data and information for future use. To serve the user community, each DAAC focuses on the data needs of a specific segment of the user community. Any user may access the entire MTPE data holdings from any DAAC via the Internet/world wide web as well as gaining access to affiliated systems at other agencies nationally and internationally. Each DAAC is guided by a user working group. In response to recommendations by the NRC Board on Sustainable Development, NASA is currently evaluating alternative concepts to perform the DAAC functions.

The nine DAAC's are:

- Alaska Synthetic Aperture Radar(SAR) Facility, University of Alaska Geophysical Institute, Fairbanks, Alaska
- Earth Resources Observation System(EROS) Data Center, U.S. Geological Survey, Sioux Falls, South Dakota
- Goddard Space Flight Center, Greenbelt, Maryland
- Jet Propulsion Laboratory, California Institute of Technology, Pasadena, California
- Langley Research Center, Hampton, Virginia
- Marshall Space Flight Center, University of Alabama at Huntsville, Alabama
- National Snow and Ice Data Center, University of Colorado, Boulder, Colorado
- Oak Ridge National Laboratory, U. S. Department of Energy, Oak Ridge, Tennessee
- Socio-Economic Data and Application Center(SEDAC), Saginaw, Michigan

Currently, EOSDIS Version 0 allows direct access to selected pathfinder data holdings from the USGS and NOAA. Relationships with Canada, Japan, Russia, Israel, Australia and several European countries have been established for the exchange of data for EOSDIS. Many multi-agency efforts, in addition to the NASA EOSDIS, are working to improve environmental data available to the public, especially in the Interagency Working Group on Data Management for Global Change and the Federal Geographic Data Committee.

MEASURES OF PERFORMANCE

Performance Milestone	Plan	Actual/Revised	Description/Status
EOSDIS Version1	January 1997	--	Support the archival and management of data from the two EOS instruments on TRMM. The ECS contractor failed the initial test readiness review of Version1, ReleaseA. NASA issued a stop work order for developing software unique to supporting the two EOS instruments on TRMM. This work will now be performed by contractors at the GSFC and LaRC DAAC's funded by EOSDIS.
EOSDIS Version2 Release V. 2.0 January 1998 V. 2.1 September 1998 Operational V. 2.0 May 1998 V. 2.1 January 1999	October 1997	--	Support the launch of AM-1 and Landsat-7. Version2 will be broken into two incremental deliveries. Version2.0 will provide all mission essential functions to support AM-1 and Landsat-7 launches. Version2.1 will add all the functions needed for long-term data operations to support AM-1 and Landsat-7.
EOSDIS Version3	December 1999	January 2000	Support the launch of the PM-1 mission

ACCOMPLISHMENTS AND PLANS

test version of the EDOS. Another key activity in FY1996 was NASA's response to NRC Board on Sustainable Development's recommendations for EOSDIS. MTPE streamlined the EOSDIS ground and networks segments, achieving significant savings. After careful review by MTPE's science and interagency advisors, NASA formulated plans to evaluate an alternate approach to providing the DAAC functions that begin to shift the responsibility for product generation and publication and user services to a federation of Earth Science Information Partners(ESIP's). EOSDIS Version 0 continued successful operations in FY1996 with the number of user accesses, products delivered, and total volume of data delivered, all showing large increases. April 1996 was the most active month thus far with over 80,000 user accesses and just short of three tera bytes of data delivered. A key milestone for Version 0 was the deployment of a web-based search and order tool that allowed system access to a wider range of users. The EOSDIS ECS development slipped significantly in FY1996. The slip was identified during an ECS Version 1, release A test readiness review. After NASA managers predicted a five-month delay in delivery of EOSDIS Version1, changes to EOSDIS implementation sequence were made to maintain essential data production and distribution systems on a schedule acceptable to the users. The portions of ReleaseA to support the TRMM mission will be implemented by upgrading existing DAAC systems. The remaining non-TRMM unique will be incorporated into Version2, freeing the ECS contractor to focus on the AM-1 and Landsat-7 requirements. Adverse impacts to the TRMM data products are manageable, in part, because of the launch delay due to Japanese launch vehicle scheduling. Termination of EOSDIS activities at the Marshall Space Flight Center(MSFC) DAAC has started, including the transitioning of the MSFC Version 0 data products to other DAACs and federal data centers.

In FY1997, NASA will begin a prototyping phase for formation of the environmental information federation by selecting Working Prototype Earth Science Information Partners(WP-ESIP's) from a variety of industry, research, educational, and government institutions. These WP-ESIP's will develop research data products, provide data products and services having potential commercial value, apply technology to reduce future EOSDIS cost, and collaboratively establish a working prototype federation to begin exploring federation governance and data center inter-operations. In conjunction with the other on-going activities, MTPE will begin a complete peer-review and re-certification of all the current DAACs in FY1997.

In FY1998, EOSDIS will begin routine production and distribution of the first EOS standard data products from the CERES and LIS instruments on the TRMM spacecraft and will provide all mission essential functions to support the AM-1 and Landsat-7 launches. Also during FY1998, the WP-ESIP's will begin to deliver "tailored" information products and services to a broad group of science researchers, state and local agencies, commercial customers, and general interest users, furthering public access to MTPE science products and information.

EARTH PROBES

BASIS OF FY1998 FUNDING REQUIREMENT (Thousands of Dollars)	FY 1996	FY 1997	FY 1998
NASA scatterometer	3,200	---	---
Total ozone mapping spectrometer	3,000	1,000	5,700
Tropical rainfall measuring mission	25,500	17,700	---
Earth system science pathfinders	1,000	19,400	29,400
Lewis & Clark	42,600	5,000	5,000
"LightSAR"	---	12,000	---
Experiments of opportunity	4,800	2,100	600
Total	**80,100**	**57,200**	**40,700**

PROGRAM GOALS

The Earth probes program is the component of MTPE that addresses unique, specific, highly-focused mission requirements in Earth science research. The program was designed to have the flexibility to take advantage of unique opportunities presented by international cooperative efforts or technical innovation, and to complement the Earth Observing System by providing the ability to investigate processes that require special orbits or have unique requirements. The currently approved Earth probes are the Total Ozone Mapping Spectrometer(TOMS), NASA Scatterometer(NSCAT), Tropical Rainfall Measuring Mission(TRMM), Lewis & Clark, and Earth System Science Pathfinders(ESSP).

STRATEGY FOR ACHIEVING GOALS

NSCAT

Because winds are a critical factor in determining regional weather patterns and global climate, NSCAT has been developed to measure near-surface wind speeds and directions over the global oceans every two days, under all weather and cloud conditions. The NSCAT data will be useful for both oceanography and meteorology, and will permit the first global study of the influence of winds on ocean circulation, providing data on the effects of the oceans on the atmosphere and improved marine forecasting on winds and waves. The lead center for this program is JPL, and the main contractor for the instrument development is the Harris Corporation.

The NSCAT was launched in August1996. When NSCAT was first initiated in October 1984, it was planned for launch aboard the Navy Remote Sensing Satellite(N-ROSS). After final cancellation of N-ROSS in March 1988, NSCAT was selected in August 1989, for flight on the Japanese Advanced Earth Observing System(ADEOS). Since a majority of the instrument design had been completed during the period that NSCAT was to fly on N-ROSS, the last few years of the program centered on making design changes to the instrument so that it could be accommodated on the ADEOS spacecraft and completing the instrument. The launch of the Japanese ADEOS spacecraft was slipped from February 1996 when the Japanese experienced anomalies with the spacecraft during integration and test. The ADEOS spacecraft was launched on a NASDA H-II rocket from Tanegashima, Japan on August 17, 1996.

TOMS

The scientific objectives of the TOMS program are to measure the long-term changes in total ozone and to verify the chemical models of the stratosphere used to predict future trends. The TOMS flights build on the experience that began in 1978 with the launch of a TOMS instrument (flight model1) on Nimbus-7 and continued with the TOMS instrument (flight model2) on the Russian Meteor-3, launched in 1991. As with the earlier developments, GSFC has the responsibility for flight project development, and post-launch mission operations and data analysis. Prime contractors are Orbital Sciences Corporation(OSC) for the TOMS instruments and Pegasus launch services, and TRW for the TOMS-EP spacecraft. The TOMS program consists of a set of instruments (flight models3,4,and5, designated FM-3, FM-4, and FM-5) and one spacecraft. Launch of the EP spacecraft by a Pegasus XL launch vehicle occurred on July 2, 1996. The FM-4 launched on the Japanese ADEOS satellite on August17,1996. The FM-5 was completed in 1995 and is planned for a cooperative mission with Russia in 2000.

TRMM

The latent heat released during precipitation is a significant factor in the large-scale computer models used to predict weather and climate change, yet two-thirds of the global rainfall occurs over the tropics where rain measurements are scarce. The TRMM objective is to obtain a minimum of three years of climatologically significant observations of tropical rainfall. In addition, TRMM will provide precise estimates of the vertical distribution of latent heat in the atmosphere. The TRMM data will be used to understand the ocean-atmosphere coupling, especially in the development of ElNiÒo events, which form in the tropics but effects of which are felt globally, causing floods in some areas, yet droughts in others. GSFC has the responsibility for flight project development, and post-launch mission operations and data analysis. The contractors for the instruments are Hughes Santa Barbara Research Center for the Visible and Infrared Scanner(VIRS), and Hughes Space and Communications for the TRMM Microwave Imager(TMI). The TRMM PhaseA study was completed in July 1988, and PhaseB completed in February 1991. Award of major contracts began in May 1992. The

TRMM launch is planned for November1997.

The Japanese space agency (NASDA) is an active partner with three Earth probes, providing the ADEOS spacecraft and H-II launch vehicle for the TOMS(FM-4) and NSCAT, and the Precipitation Radar instrument and H-II launch vehicle for TRMM.

Earth System Science Pathfinder

The Earth System Science Pathfinder(ESSP) is a science-driven program intended to identify and develop short development time, small satellite missions to accomplish scientific objectives in response to national and international research priorities not addressed by current programs. ESSP will provide periodic "windows of opportunity" to accommodate new scientific priorities and infuse new scientific participation into the MTPE program. By launching ESSP missions on a regular basis, NASA will provide a mechanism by which pressing questions in Earth system science may be addressed in a timely fashion, permitting a continual improvement in our understanding of the Earth system and the processes that affect it.

The programmatic guidelines for the first ESSP AO were specific. The first two ESSP missions will be focused on high-priority Earth system science research, limited to a total mission life cycle cost from NASA of $60 million and $90 million respectively. They will be managed by the principal investigator as a single point of contact accountable for total mission implementation and success, developed in less than 36 months from development authority to proceed, and compatible with EOSDIS standards, including the immediate release of mission data to the scientific community.

Lewis & Clark

The Lewis and Clark missions will demonstrate different land imaging capabilities and other measurements of scientific interest to MTPE. The Lewis mission is a medium resolution hyperspectral instrument. The Clark mission is a high resolution multispectral imager. Both spacecraft will be launched in FY1997. The "Clark" spacecraft is being built by CTA Incorporated of Rockville, Maryland. The "Lewis" spacecraft is being built by TRW and managed out of their Redondo Beach, CA office. NASA is managing both projects from NASA Headquarters. Lewis will carry 25 new technologies and Clark will carry 36, including composite structures, advanced avionics and high-efficiency power systems. Lewis will also have three advanced sensors to meet the needs of the commercial remote sensing and Earth science communities: a 384-band hyperspectral imager; a Linear Etalon Array to scan the Earth and its horizons; and an instrument to measure the Ultra-Violet UV cosmic background. Clark will have a high-resolution imager capable of 15-meter multi-spectral and 3-meter panchromatic measurements; an instrument to measure pollution in the troposphere; and an x-ray spectrometer to capture bursts from solar flares.

"LightSAR"

The "LightSAR" program is consistent with direction included in House Report 104-812 which stipulates that NASA's FY1998 budget request should include additional funding to accomplish this program. The "LightSAR" program is currently one of the missions competing for possible funding under NASA's Earth Systems Science Pathfinder (ESSP) program and may also compete in the upcoming MTPE Data Purchase solicitation.

Experiments Of Opportunity

This program offers a unique capability to undertake short duration flights of instruments on the Space Shuttle and other platforms. The MTPE program has used the capability of Shuttle/Spacelab development in the important areas of design, early test and checkout of remote sensing instruments for free flying missions, and short term atmospheric and environmental data gathering for scientific analysis. Instrument development activities have supported a wide range of instrumentation, tailored for Space Shuttle and airborne missions.

MEASURES OF PERFORMANCE

Performance Milestone	Plan	Actual/Revised	Description/Status
Launch of TOMS flight model3	March 1996	July 1996	PegasusXL/L1011 launch. Turnover of TOMS to the GSFC mission operations and data analysis team expected thirty days after launch, with data calibration and validation completed successfully. Successfully launched on a Pegasus/L1011 from VAFB on July 2, 1996.
Launch Lewis & Clark	Plan : June 1996 (Clark) and July 1996 (Lewis)	Under review	NASA and industry plan to meet the commitment for a 24-month period between contract initiation and launch of each spacecraft. Planned launch dates are currently under review.

Launch of TOMS flight model4 & NSCAT	August 1996	August 1996	Launched aboard the Japanese ADEOS spacecraft and H-II launch vehicle aboard ADEOS. Turnover of TOMS and NSCAT to the respective mission operations and data analysis teams at GSFC and JPL thirty days after launch, with data calibration and validation completed successfully. The successful launch on a Japanese H-II Rocket from Tanegashima, Japan occurred on August 17, 1996.
Launch of TRMM	August 1997	November 1997	Launch is planned aboard the Japanese H-II launch vehicle, with turnover of TRMM operations and data analysis to TRMM ground system and science data and information system at GSFC thirty days after launch, with data calibration and validation completed. Changes in the Japanese H-II launch vehicle manifest, unrelated to TRMM, have delayed the TRMM launch.
Launch of first ESSP mission	1999	2000	First mission launch and other characteristics will be based on mission selection through the AO. Mission selection currently scheduled for mid FY1997.

ACCOMPLISHMENTS AND PLANS

TOMS EP/flight model 3 was successfully launched on a Pegasus XL from Vandenberg AFB on July 2, 1996. The TOMS flight model-4 and NSCAT instruments on the Japanese ADEOS spacecraft was also successfully launched on a Japanese rocket from Tanegashima, Japan on August 17, 1996.

In FY1997, the interface adapter module for the interface to the Russian Meteor will begin development for the TOMS flight model-5.

the TRMM Science Data and Information System(TSDIS). During FY1997, TRMM will complete its environmental test program and perform the final comprehensive performance tests in preparation for launch from Japan. The observatory will be shipped to Japan in summer 1997 where our Japanese partner, NASDA, will begin integration to the H-II launch vehicle. The ground validation sites will be brought on-line to verify the in-situ products in TSDIS. The TRMM observatory will launch from Japan's Tanegashima Space Center in the fall 1997, and begin normal mission operations two months later. An extensive ground validation program that takes advantage of international field campaigns, as well as the verified ground sites supported by various science team members, is planned. Since the TRMM products will provide the first rainfall/latent heat profiles from space, the validation program is essential to TRMM mission success.

The first ESSPAO was released in FY1996 with selection to occur in mid FY1997. We are currently evaluating the proposals submitted in response to the first AO. The second ESSP AO is currently scheduled for release in FY1998. The ESSP program will emphasize flexible approaches for augmenting the global measurement objectives of the U.S. Global Change Research Program. The recent study by the National Academy of Sciences Board on Sustainable Development (1995) outlines strategic areas for which scientific research is needed in the context of critical Earth system science issues. While these areas do not exclusively define the scientific focus for early ESSP missions, the potential, key measurement needs for which new missions may be required in the next five years are outlined. In the ESSP two-step AO process, forty-four proposals were received in response to the step one request. Thirteen of those were encouraged to respond to the second and final step based on science evaluation. Selection of ESSP teams will be accomplished and design and development of the initial missions will begin in FY1997.

The planned launch dates for Lewis & Clark are currently under review due to the failure of the initial launch of the Lockheed Launch Vehicle (LLV-1) and development delays on Clark. The requirement for an additional LLV-1 test launch prior to launch of the Smallsats would delay their flights.

The second flight of SIR-C as part of the Shuttle Radar Laboratory(SRL-2) mission in October, 1994, was the last MTPE full space shuttle payload. Several smaller payloads were flown on the space shuttle including the Atmospheric Laboratory for Applications and Science(ATLAS-3) mission flown in November, 1994, and the Shuttle Solar Backscatter Ultraviolet(SSBUV) instrument in early FY1996. Funding will allow for wrap-up activities for the SSBUV, ATLAS, and the Measurement of Air Pollution from Satellites(MAPS) instrument. Funding for post flight activities for SRL-1 and SRL-2 missions will continue.

In addition, the experiments of opportunity program supports flight instrument opportunities on foreign spacecraft, such as the cooperative commercial flight of MAPS on the MIR space station in FY1997 and the provision of Global Positioning Satellite(GPS) receivers for the

Satellite de Applicaciones Cientificas-C (SAC-C) satellite with the Argentine Space Agency. Launch of STS 85 is scheduled for July 1997. This mission will include the following instruments: Solar Constant(SOLCON), Shuttle Laser Altimeter #2(SLA-02); and Infrared Spectrol Imaging Radiometer(ISIR).

APPLIED RESEARCH AND DATA ANALYSIS

BASIS OF FY1998 FUNDING REQUIREMENT (Thousands of Dollars)	**FY 1996**	**FY 1997**	**FY 1998**
MTPE Science	276,600	295,400	271,100
Data purchase	(--)	(50,000)	(--)
Research and analysis	(184,800)	(148,700)	(161,800)
EOS science	(16,700)	(22,400)	(30,300)
Mission science teams and guest investigators	(30,800)	(36,300)	(35,800)
Airborne science and applications	(27,300)	(19,000)	(18,700)
Uncrewed aerial vehicles(UAV)	(--)	(2,000)	(5,500)
Advanced geostationery studies	(--)	(1,000)	(3,000)
Commercial remote sensing	(17,000)	(16,000)	(16,000)
Operations, Data Retrieval, and Storage	73,500	78,000	54,200
Mission operations	(37,800)	(41,200)	(31,600)
High performance computing and communications	(26,100)	(28,300)	(18,300)
Information systems	(9,600)	(8,500)	(4,300)
Total	**350,100**	**373,400**	**325,300**

PROGRAM GOALS

The goal of applied research and data analysis is to advance our understanding of the global climate environment, the vulnerability of the environment to human and natural forces of change, and the provision of numerical models and other tools necessary for understanding global climate change.

STRATEGY FOR ACHIEVING GOALS

The applied research and data analysis program is divided into two major components: MTPE science and MTPE operations, data retrieval, and storage. The activities that report MTPE

science include research and analysis, EOS science, airborne science and applications, commercial remote sensing and Uncrewed Aerial Vehicle(UAV) science program. Operations, data retrieval and storage consists of several independent activities responsible for the operation of currently functioning spacecraft and flight instruments, the purchase and management of scientific data, high performance computing and communications, and the provision of computing infrastructure. Each of the major components of applied research and data analysis has its own set of goals, strategies for achieving goals, performance measures, and accomplishments and plans.

MTPE SCIENCE

BASIS OF FY1998 FUNDING REQUIREMENT (Thousands of Dollars)	**FY 1996**	**FY 1997**	**FY 1998**
Data purchase	---	50,000	---
Research and analysis	184,800	148,700	161,800
EOS science	16,700	22,400	30,300
Mission science teams and guest investigators	30,800	36,300	35,800
Airborne science and applications	27,300	19,000	18,700
Uncrewed aerial vehicles(UAV)	---	2,000	5,500
Advanced geostationary studies	---	1,000	3,000
Commercial remote sensing	17,000	16,000	16,000
Total	**276,600**	**295,400**	**271,100**

PROGRAM GOALS

The goal for the MTPE science program is to contribute to the integration of the Earth and environmental sciences into an interdisciplinary scientific understanding of the Earth system and the effects of human-kind on the global environment. Major emphasis is placed on providing early warning and fast response to global environmental changes which pose risks to society. The science program also provides the analysis and integration of critical data and models needed for national and international assessments. An objective of current planning is to achieve the most essential long-term objectives of EOS, and to increase effort on science with near-term payoff, within a sustainable level of funding. The observational program will become resilient, better, and cheaper in the future by (1) taking advantage of the experience being gained in preparation of the first round of EOS flight missions to reduce observing requirements in the future and to simplify the design of instruments for more cost-effective continued operation, (2) finding alternative means to carry out some of the essential

measurements at the same level of quality through cooperation with other agencies and nations, and (3) infusing new ideas and technologies into the EOS program through small satellite missions which have lower infrastructure and flight costs.

STRATEGY FOR ACHIEVING GOALS

The Research and Analysis(R&A) science program is essential to the discovery of new concepts and to the design of future missions. The primary mode of research coordination occurs through the USGCRP, the Committee on the Environment and Natural Resources(CENR) Subcommittee on Global Change Research, and the various boards and committees at the National Academy of Sciences.

The strategy of interdisciplinary research is to increase scientific understanding of the global environment and its vulnerability to both human and natural forces of change (e.g. pollution, climate variability, deforestation). Viewing the Earth from space is essential to comprehending the cumulative influence of human activities on its natural resource base. An important priority is to provide accurate assessment of the extent and health of the world's forest, grassland, and agricultural resources. Observations from space are the only source of objective information on the human use of land in a time of rapid land use change. A related priority is to improve understanding and prediction of seasonal-to-interannual climate variation. Reducing uncertainties in climate predictions to a season or a year in advance will dramatically improve agriculture and energy planning. In addition, the natural hazards research priority places emphasis on the use of remote sensing observations for the characterization and mitigation of drought and flood impacts. There is increasing evidence that predictions of extreme weather events can be improved by understanding their links to interannual climate phenomena like ElNiÒo events. Special attention in measuring and modeling the relative forces like clouds, aerosols and greenhouse gases in long-term climate change, in order to improve our understanding of and prediction of climate on time scales of decades to centuries. A continuing priority is understanding the causes and consequences of changes in atmospheric ozone. Efforts are continuing to make excellent progress on resolving questions related to stratospheric ozone depletion. Emphasis is now being placed on the changing composition of the lower atmosphere, which is sensitive to the unprecedented growth of pollutant emissions in rapidly developing regions throughout the world. Work will continue in the core research programs in MTPE. These programs provide the disciplinary strength that we draw from to solve interdisciplinary priority problems.

EOS interdisciplinary science consists of focused research centered around a specific Earth science data set and interdisciplinary research geared toward a broader probe into Earth science systemic functions. The quality of data utilized is monitored by the scientists at interdisciplinary instrument computing facilities and the research is supplemented by graduate student participation in the EOS science fellowship program.

There are currently over 1,700 scientific activities being funded under the research and analysis program. Approximately 900 are carried out by universities, 100 by national research laboratories, and 700 by the federal government. The distribution of the activities encompasses forty-five of the fifty states. A policy change has been implemented where support contractors will no longer perform in-house science and research.

The airborne science program funds operations of two ER-2's and a DC-8 aircraft. A C-130Q is needed to support selected Earth science investigations. The program also funds operation and support of a core of remote sensing instruments and a facility for analyzing and calibrating data from those instruments. The specifically modified aircraft serve as test beds for newly developed instrumentation and their algorithms prior to spaceflight. The instrumented aircraft provide remote sensing and *in situ* measurements for many Earth science research and analysis field campaigns, including stratospheric ozone, tropospheric chemistry, and ecological studies throughout the world. The ER-2 aircraft, in particular, are unique in that they are the highest flying subsonic civilian research aircraft and were key in collecting *in situ* data for our understanding of ozone depletion and stratospheric transport mechanisms.

The Commercial Remote Sensing Program(CRSP), transferred from the Office of Space Access and Technology, will continue to fund cooperative efforts with industrial partners aimed at enabling development of a viable commercial remote sensing industry. The cooperative effort will work to apply space-based data and instrument technology in the development of usable, customer-defined information products. Industry will make significant co-investments, funding the CRSP at about an equal level with NASA.

The Uncrewed Aerial Vehicle(UAV) science program, a new initiative beginning in FY1997, will augment the MTPE airborne program by making *in situ* and remote sensing measurements initially focused on the atmosphere; staying over a target for extended periods to measure detailed temporal changes, provide unique views of cloud structures and provide calibration and verification of MTPE's satellite instrumentation. During FY1997 an AO will be initiated for the selection of three or four scientific investigations carried out using commercially available UAV flight time.

The advanced geostationary studies will investigate the application of the latest technology in developing small compact geostationary satellites that will support both research and operational objectives. For example, one candidate under consideration has the capability to provide the first adequately calibrated observations from geostationary orbit that support climate research. The satellite and instrument would be developed over a four year time period. The first spacecraft would carry an imager and a second spacecraft would carry a sounder. The imager has spectral bands which provide data on cloud albedo, vegetation, cirrus clouds, cloud ice, limited ozone, and both high-level and low-level water vapor along with total water vapor. This would provide stable measurements for MTPE research that have previously been unattainable from geostationary orbit.

MEASURES OF PERFORMANCE

The scientific issues of concern to MTPE are among the most complex and most policy relevant of any major scientific research program. The results of MTPE science are critical to the development of sound U.S. and global environmental policy, necessary for the long-term sustainable development.

Land Cover/Land Use Change	**FY 1996**	**FY 1997**	**FY 1998**
Last Year:	Evaluate hyperspectral remote sensing of land ecosystems	Tropical rain forest-climate: international field campaign	--
This Year:	Evaluated hyperspectral remote sensing of land ecosystems.	Participate in International Field campaign on tropical rain forest climate.	Use satellite methods determined deforestation rate in South America.

Seasonal-to-Interannual Climate Variability	**FY 1996**	**FY 1997**	**FY 1998**
Last Year:	Evaluate role of El NiÒo in tropical droughts.	Provide improved sea surface winds to prediction models.	--
This Year:	Evaluated role of El NiÒo in tropical droughts.	Provide improved sea surface winds for prediction models.	Improve prediction with coupled ocean-atmosphere models.
Long-Term Climate System Variability			
Last Year:	Role of total aerosol burden in climate.	Tropospheric ozone as a climate driver	--

This Year:	Studied role of total aerosol burden in climate.	Evaluate tropospheric ozone as a climate driver.	Determine role of volcanic aerosols in climate.
Natural Hazards			
Last Year:	Strategic plan for remote sensing of flooding/droughts.	Initiate program on flood/drought assessment.	--
This Year:	Completed strategic plan for remote sensing of flooding and droughts.	Initiate program on flood/drought assessment.	Utilize dense array GPS for earthquake studies in southern California.
Atmospheric Ozone			
Last Year:	Ozone transport field campaign.	Establish role of Asian emissions in ozone levels.	--
This Year:	Deployed an ozone transport field campaign.	Establish role of Asian emissions in ozone levels.	Complete assessment of stratospheric chlorine sources.

ACCOMPLISHMENTS AND PLANS

In FY1997, NASA will initiate a data purchase program designed to acquire from commercial sources data sets not otherwise available that are necessary to accomplish broad research goals of Earth system science. The budget authority will be liquidated only as acceptable data is delivered and the proposed contract(s) will be executed with FY1997 funds only after a broad, agency competition. The purchase will be managed by the Stennis Space Center. A RFP will be issued in FY1997 to solicit data purchase proposals. It is anticipated that selection of more than one activity will occur. Such innovative methods of procurement were suggested in the Vice President's National Performance Review. Data product generation, data archival, science analysis, and all other NASA requirements are included in other elements of the MTPE budget.

In FY1996, continuing into FY1997 and FY1998, the following are significant accomplishments in the five priority areas MTPE science is focusing: land cover/land use change, seasonal-to-interannual climate variability, long-term climate system variability, natural hazards, and atmospheric ozone.

Land Cover/Land Use	Major progress was made in characterizing the role of the northern forests as a control on water, heat, and momentum transfers between the surface and the lower atmosphere during the Boreal Ecosystem-Atmosphere Study(BOREAS). Data has since been introduced into experimental weather prediction models significantly improving skill in predicting regional weather.
Seasonal-to-Interannual Climate Variability	Progress continues on forecasting of ElNiÒo events. A study was completed in FY1996 at GSFC that documented the critical importance of accurate characterization of soil moisture for accurate predictions of global precipitation patterns.
Long-Term Climate System Variability	Global observations by the SAGE and the ERBE provided a unique understanding of the climate effects of the Mount Pinatubo volcanic eruption. The NASA-Goddard Institute for Space Studies(GISS) climate model produced a prediction of effects of Mount Pinatubo aerosols on surface temperature which showed excellent agreement with subsequent observations. Analysis of data obtained on the LIDAR In-Space Technology Experiment(LITE), using the Shuttle, demonstrated the capability of space-based LIDAR to improve significantly global measurements of both natural and anthropogenic aerosols. A national network, the Solar Irradiance Research Network, of aerosol measurements has been initiated at ten secondary schools nationwide.
Natural Hazards	Recent research has demonstrated the utility of SAR for accurately documenting changes in topographic features of the earth's surface. MTPE is implementing with other government agencies a high density global positioning system geodetic array in southern California to measure surface deformation produced by underlying geological faults. Preliminary design research for a "lightSAR" is investigating optimal mission characteristics for supporting the science of SAR interferometry as a method of surface change detection.

Atmospheric Ozone	Analysis of global data from the UARS confirmed that ozone depleting chemicals reaching the stratosphere are primarily of industrial origin. New analysis techniques developed for the TOMS provided the first global data set on surface UV radiation. These results provided the first confirmation of global trends in increasing UV radiation related to ozone depletion. The two TOMS that were launched in FY1996 (TOMS-EP and TOMS-ADEOS) will provide data for continued ozone and UV trends determination with improved resolution and precision.

OPERATIONS, DATA RETRIEVAL AND STORAGE

BASIS OF FY1998 FUNDING REQUIREMENT (Thousands of Dollars)	**FY 1996**	**FY 1997**	**FY 1998**
Mission operations	37,800	41,200	31,600
(Upper atmosphere research satellite)	(2,900)	(5,300)	(4,800)
(Total ozone mapping spectrometer)	(1,300)	(1,000)	(2,800)
(Ocean topography experiment)	(14,400)	(12,600)	(11,500)
(NASA scatterometer)	(2,400)	(4,200)	(4,200)
(Tropical rainfall measuring mission)	(--)	(800)	(7,900)
(Earth science)	(16,800)	(17,300)	(400)
High performance computing and communications- Earth and space sciences	26,100	28,300	18,300
Information systems	9,600	8,500	4,300
Total	**73,500**	**78,000**	**54,200**

PROGRAM GOALS

The Operations, Data Retrieval and Storage(ODRS) program provides the data and data

STRATEGY FOR ACHIEVING GOALS

This program supports the observations and data management portion of the activities including process research, integrated modeling and prediction, and assessments that together produce a predictive understanding of the Earth system. The program will achieve its goals through the following: mission operations, high performance computing and communications, and information systems. The data and data products from this program have or will migrate to the EOSDIS.

Mission Operations

The objectives of the mission operations program are to acquire, process, and archive long-term data sets and validated data products. These data sets support global climate change research in atmospheric ozone and trace chemical species, the Earth's radiation budget, aerosols, sea ice, land surface properties, and ocean circulation and biology. Funding provides for operating spacecraft such as UARS, TOPEX, ERBS, SBUV/2, NSCAT, TOMS, TRMM and processing of acquired data.

Key users of UARS data include NOAA, the Naval Research Laboratory, GSFC, JPL, Canada, the United Kingdom, and a number of universities including the University of Michigan, the Georgia Institute of Technology, the University of Washington, the State University of New York, and the University of Colorado. Key TOMS and SBUV/2 proponents include NOAA, Russia (manifested a TOMS on their Meteor3 satellite launched in 1991), Japan (manifested a TOMS on their ADEOS satellite launched in 1996). Key ERBS users include a diverse set of institutions including NOAA (manifested ERBE sensors on NOAA-9and-10 launched in the 1980's), GSFC, LaRC, the State University of New York, Oregon State University, and the Scripps Institution of Oceanography.

The TOPEX users include France (shared in development of the mission), Japan, Australia, the United Kingdom, the Netherlands, Germany, Norway, and South Africa as well as JPL, GSFC, Columbia University, the University of Hawaii, the University of Texas, the University of Colorado, Oregon State University, Ohio State University, and the Massachusetts Institute of Technology. SeaStar principal users include the GSFC, the European community, Japan, Canada, and Australia and a diverse group of universities in Florida, Washington, California, Texas, Maryland, and Rhode Island. At present, the largest demand for ocean color data arises from the Joint Global Ocean Flux Study(JGOFS), an international program under the auspices of the Scientific Committee for Oceanographic Research(SCOR), which is a core program of the International Geosphere-Biosphere Program(IGBP). The NSCAT participants include JPL, NOAA, and Japan (manifested the NSCAT for flight on their ADEOS spacecraft launched in 1996), and universities in New York, Washington, Oregon, and Florida. TRMM is a joint mission with the Japanese to

measure tropical precipitation from a low inclination orbit. Key participants involved in the Alaska SAR Facility(ASF) include the European Space Agency(ERS-1 and -2), Japan(JERS-1 and ADEOS), Canada(RadarSat), GSFC, JPL, and the University of Alaska which hosts the ASF. Participants in the analysis of SIR-C/X-SAR data, in addition to JPL, represent nations in almost every continent including Italy, Saudi Arabia, China, Australia, France, Canada, Brazil, the United Kingdom, and Germany.

High Performance Computing and Communications(HPCC) - Earth and Space Sciences

The NASA HPCC program consists of four vertically integrated projects. These projects are: Computational Aeroscience(CAS), Earth and Space Sciences(ESS), Remote Exploration and Experimentation(REE), and Information Infrastructure Technology and Applications(IITA). The IITA project focuses on providing the technology base and applications to accelerate the implementation of the national information infrastructure.

The implementation of the NASA HPCC program is mainly through coordinated activities at NASA field centers. The ESS project, led by GSFC, will work in close partnership with industry, academia and government. The project used the NASA research announcement process to select eight principal investigator teams and twenty-one grand challenge investigations. The IITA Remote Sensing Databases(RSD) project uses remote sensing databases developed by NASA and other federally funded agencies to expand the application outreach of its programs to traditionally unserved communities. The Internet is used as the primary means of providing access to and distribution of science data and images as well as value-added products of the data and images.

Information Systems

The MTPE information system program has been structured to provide a balanced system of high performance computers, mass storage systems, workstations, and appropriate network connectivity between researchers and components of the system. A major portion of the program funding supports operations of a supercomputing center (the NASA Center for Computational Sciences) at GSFC. A full range of computational services are provided to a community of approximately 1,400 users representing all disciplines of Earth and space sciences. Users of the supercomputer complex select representatives to an advisory committee who are integrally involved in strategic planning for the evolution of the complex. They provide feedback on user satisfaction with services provided and help establish priorities for service and capacity upgrades. Offsite NASA-sponsored users comprise 25% of the total. The program monitors and participates in advanced technology programs, such as the HPCC program and National Science Foundation's gigabit testbed programs. Program elements at GSFC and the JPL are focused on providing early access to emerging technologies for the Earth and space science communities. The early access to new technology provides the

program with the opportunity to influence vendors and system developers on issues unique to the Earth and space science researchers such as data intensive computation and algorithm development. Early access also prepares a subset of the research community to make changes in research methodology to exploit the new technologies and to champion promising technologies to their colleagues and peers.

MEASURES OF PERFORMANCE

OPERATIONAL SPACECRAFT / INSTRUMENTS

Common to all missions: Archive 95% of planned data acquisition	The primary criteria for success of an operational spacecraft is to obtain 95% of the planned data acquisition.
Mission Specific:	
UARS (launched September 1991) continuing operations	The success of UARS operations is judged on providing data to support improvement in monitoring the processes that control upper atmospheric structure and variability, the response of the upper atmosphere to natural and human-induced changes, and the role of the upper atmosphere in climate variability.
TOPEX/Poseidon (launched August 1992) continuing operations	10-cm surface height is required of the spacecraft's radar altimetry instruments in determinations of speed and direction of surface currents, oceanic heat transport, and ocean topography in support of climate change monitoring.
ERBS/ERBE/SAGE II (launched Oct. 1984, December1984 and September1986) continuing operations	Data from the ERBE and SAGE II must continue to be of sufficient accuracy to (1) illuminate the temporal and spatial variations in the Earth's radiation budget which drive the Earth's climate and (2) provide global data for aerosols, ozone, water vapor and nitrogen dioxide altitude profiles.
SBUV/2-SSBUV (launched Dec.1984 and Sept.1988) continuing operations	Data from the Solar Backscatter Ultraviolet/2 (SBUV/2) instruments provide column abundances and vertical profiles of atmospheric ozone. A carefully calibrated version of the same instrument, called Shuttle SBUV (SSBUV) provides correlative measurements so that the TOMS and SBUV instruments flying on other spacecraft can be more accurately calibrated, and provides information on the diurnal variability of stratospheric ozone in low latitudes.

Alaska SAR Facility Missions: ERS-1 (launched 1991) JERS-1 (launched 1992) ERS-2 (launched 1995) RadarSat (launched 1995) ADEOS (launched 1996)	Data received at the ASF must support determination of the properties and dynamics of sea ice and other land and sea processes in the polar regions.
OTD (launched 1995) continuing operations	The Optical Transient Detector(OTD) provides early acquisition of science data to support research in determining global distribution of lightning and its effects on climate change. It allows for an early engineering flight model of the Earth Observing System Lightning Imaging Sensor(LIS) instrument and concept validation, including the high speed solid-state camera system and real-time event processor, and will be a pathfinder for commercial remote sensing applications of lightning data.
TOMS FM-3 and FM-4 (launched July 1996, August 1996) continuing operations	Ozone monitoring systems. The first global ozone image was produced and released September 13, 1996. Automated processing and distribution of science products began September 20, 1996 and Internet distribution started on October 7, 1996.
NSCAT (launched August 1996) continuing operations	NSCAT will measure surface wind speeds and directions over at least 90% of the oceans every two days in all weather and cloud conditions.

SPACECRAFT TO BE LAUNCHED

Performance Milestone	Plan	Actual/Revised	Description/Status
SeaStar/Ocean Color	1996	1997	Measurements will be made of up-welling radiance at eight spectral bands in the visible and near infrared portions of the spectrum at a spatial resolution of 1- kilometer. The entire cloud-free globe will be imaged once per day. Data products will include daily global maps of oceanic pigment concentration; optical attenuation length scales; and visible, water-leaving radiance. The data delivered to NASA shall meet radiometric performance specifications set forth in the contract with Orbital Sciences Corporation. These include specifications for the instrument data bands, signal-to-noise ratio, and radiance levels. The data streams will also contain all necessary information required for processing the radiance data, including predicted ephemerides and calibrations, spacecraft attitude, time, tilt, gain, and other necessary spacecraft and sensor information.
TRMM	November 1997	--	TRMM is a joint United States-Japanese observatory program that will conduct systematic observations of tropical rainfall required for major strides in weather and climate research. TRMM is a U.S. spacecraft with both U.S. and Japanese instruments and will be launched on a Japanese H-II rocket.

ACCOMPLISHMENTS AND PLANS

Data has been acquired, processed, disseminated, and archived to meet mission requirements for user availability of timely and accurate data products for global and/or regional monitoring

to consolidate supercomputer-based information systems.

In the mission operations program, responsibility for assigned missions is assumed 30 days after launch. Data are acquired, processed, disseminated, and archived to meet mission requirements for user availability of timely and accurate data products. The MTPE information systems program will continue to provide a balanced computational environment for NASA science researchers primarily through facilities housed at GSFC and the JPL.

User requirements will be met in 1997 and 1998 by continuing operations of on-orbit spacecraft and instruments including the UARS, TOPEX, and ERBS missions; continuing support of the SBUV/2 sensor and processing of data from the SSBUV, and continuing receipt of ERS-1 and JERS-1 data at the Alaska SAR Facility. In addition, NSCAT, TOMS on ADEOS, and TOMS Earth probe are operational.

The MTPE information systems program will continue to provide a balanced computational environment for NASA science researchers primarily through facilities housed at GSFC and the JPL. Partnerships with industry and other federal agencies will be used to assure the presence of the program's requirements in the strategic planning of new computational technologies. Recently initiated cooperative agreements will allow the development of supercomputer applications 10 times faster than today, providing the computational studies necessary to mesh with NASA's observational and theoretical programs.

GLOBAL OBSERVATIONS TO BENEFIT THE ENVIRONMENT (GLOBE)

BASIS OF FY1998 FUNDING REQUIREMENT (Thousands of Dollars)	FY 1996	FY 1997	FY 1998
Global observations to benefit the environment	5,100	5,000	5,000

PROGRAM GOALS

The goal of the Global Observations to Benefit the Environment(GLOBE) program is to link scientific discovery with the education process in the study of the Earth as an integrated system. The objective is to bring school children, teachers, and scientists together to: (1) enhance environmental awareness of individuals throughout the world; (2) contribute to scientific understanding of the Earth; and (3) help all students reach higher levels of achievement in science and mathematics.

STRATEGY FOR ACHIEVING GOALS

The GLOBE program involves students (kindergarten through twelfth grade or equivalent) in

schools throughout the world, their teachers and the research community. Participating schools are making core sets of GLOBE measurements using GLOBE instruments and procedures under the guidance of GLOBE-trained teachers. The results from all over the world are reported into a central data processing facility. The students then receive feedback and use GLOBE educational materials to understand the compiled results and do their own analyses of the data.

In order to meet the first objective of increasing international environmental awareness, the program has been designed to be international in scope, involving students, educators and researchers from all over the world. By using the Internet to link the schools together, a sharing of discoveries and analysis is encouraged that should result in awareness beyond just the local community.

The second objective to contribute to the scientific understanding of the Earth, is achievable due to the expansive data sets that result from long term, repeated measurements made in areas where data has in some cases been extrapolated in the past. To ensure the greatest possible accuracy of the data, international environmental scientists have been involved from the beginning of the program to select a set of significant scientific measurements that can be made by students and define the experimental procedures and data reporting protocols for each.

MEASURES OF PERFORMANCE

Performance Milestone	Plan	Actual/Revised	Description/Status
Double the number of participating schools	September 1996	September 1996	--
Achieve participation of at least 4,000 schools	September 1997	--	--
Achieve participation of at least 6,000 schools	September 1998	---	--

ACCOMPLISHMENTS AND PLANS

By the end of FY1996, 2,950 schools around the world had joined GLOBE. This is nearly double the number of schools participating at the end of FY1995. During this year, GLOBE also published a second edition of the GLOBE Teacher's Guide with updates to the GLOBE Measurement protocols and dozens of additional learning activities for GLOBE schools.

In FY1997, GLOBE will seek to continue to increase the number of partnerships with organizations, such as universities and school districts, to help achieve program growth goals.

GLOBE will also work to expand participation in the program, including the possible addition of more student measurement areas.

During FY1998, the program will seek to continue to train an increasing number of teachers, thus facilitating the rapid growth in the number of schools participating in the program.

LAUNCH SERVICES

BASIS OF FY1998 FUNDING REQUIREMENT (Thousands of Dollars)	FY 1996	FY 1997	FY 1998
Launch services	107,100	84,700	121,900

PROGRAM GOALS

The goal of the launch services within the MTPE program is to provide the flight programs with cost-effective, on-time Expendable Launch Vehicle(ELV) launch services.

STRATEGY FOR ACHIEVING GOALS

Funding for mission unique launch services is included under the budget for the benefiting program. While funding for the ELV's is found within the MTPE budget, program management for the ELV's rests with the Launch Vehicles Office(LVO) within NASA. The LVO aggregates NASA, NOAA, and international cooperative ELV mission requirements, establishes appropriate acquisition strategies for purchasing firm, fixed priced launch services from the U.S. industry, and imposes the scope and level of technical oversight of the commercial ELV operators' delivery of service that reflects the criticality of the mission and the level of government resources at risk. The objective is to provide affordable, 100% successful delivery to space.

Since 1987, the LVO has been employing a national mixed fleet strategy, with 100% successful launch services to MTPE payloads. The administration, procurement, and technical oversight of launch service delivery in the small and medium performance classes is managed by the Goddard Space Flight Center (Atlas-E, Titan II, Pegasus XL, and Delta II, Ultra-Lite and Med-Lite.) The intermediate and large performance class launch services (AtlasI/IIAS and Titan IV/Centaur) are managed by the Lewis Research Center. The Kennedy Space Center is delegated responsibility for technical oversight of vehicle assembly and testing at the launch site and is responsible for launch site the spacecraft processing. The current corporate participants include Lockheed Martin for AM-1 and McDonnellDouglas for Landsat-7 and RadarSat.

MEASURES OF PERFORMANCE

Performance Milestone	Plan	Actual/Revised	Description/Status
Launch of TOMS-EP	July 1995	July1996	Successfully launched aboard the Pegasus XL/L1011.
EOS AM-1	June 1998	--	To be launched on an Atlas IIAS from Vandenberg AFB.
Landsat-7	December 1998	--	To be launched on a Delta II from Vandenberg AFB.
EO-1/SAC-C	May 1999	--	Med-lite class launch services.
JASON-1	December 1999	--	Med-lite class launch services; co-manifest on Delta under review.

ACCOMPLISHMENTS AND PLANS

Funding will continue in support of the EOS AM-1 and Landsat-7 launches in 1998. FY1998 funding will be used to provide launch services for Earth Observer1(EO 1) with *Satellite de Applicaciones Cientificas-C* (SAC-C), EO 2, Earth System Science Pathfinder1(ESSP 1), ESSP 2, ESSP 3, JASON 1, EOSPM 1, and RadaRSAT 2.

CONSTRUCTION OF FACILITIES

BASIS OF FY1998 FUNDING REQUIREMENT (Thousands of Dollars)	FY 1996	FY 1997	FY 1998
Earth system science building	17,000	--	--
Total	17,000	--	--

PROGRAM GOALS

The goal of the Earth System Science Building(ESSB) project is to construct a facility that will house civil service, contractor, and visiting scientists conducting global climate change and Earth system science research using the Earth Observation System(EOS).

STRATEGY FOR ACHIEVING GOALS

Facility design and initial construction began in FY1994 for the ESSB at the Goddard Space

Flight Center. A second increment of funding was provided in FY1995 for continuation of construction with completion funded by the FY1996 Construction of Facilities request.