SCIENCE, AERONAUTICS, AND TECHNOLOGY

FISCAL YEAR 2002 ESTIMATES

BUDGET SUMMARY

OFFICE OF EARTH SCIENCE

SUMMARY OF RESOURCES REQUIREMENTS

	FY 2000 OPLAN REVISED	FY 2001 OPLAN REVISED	FY 2002 PRES BUDGET	Page Number
	(Thousands of Dollars)			
Major Development	921,779	836,914	709,097	
Earth Observing System	479,799	414,286	371,894	SAT 3-11
Earth Observing System Data Information System	278,880	281,391	252,650	SAT 3-26
Earth Explorers	163,100	141,237	84,553	SAT 3-31
Research and Technology	466,314	579,658	516,653	SAT 3-36
Earth Science Program Science	286,399	350,626	357,453	SAT 3-37
Applications, Education and Outreach	84,400	114,081	63,200	SAT 3-59
Technology Infusion	94,515	114,951	96,000	SAT 3-72
Construction of Facilities	1,000	--	--	SAT 3-78
Mission Operations	48,007	57,778	52,250	SAT 3-79
Investments	7,300	10,277	--	SAT 3-83
Minority University Research & Education Program	7,300	8,780	--	
Education	--	1,497	--	
Institutional Support	[246,979]	[231,569]	236,978	SAT 3-85
Total	1,443,400	1,484,627	1,514,978	

Distribution of Program Amount by Installation	FY 2000 OPLAN REVISED	FY 2001 OPLAN REVISED	FY 2002 PRES BUDGET
Johnson Space Center	36,218	33,066	18,552
Kennedy Space Center	60,985	80,798	68,708
Marshall Space Flight Center	17,642	18,478	27,567
Stennis Space Center	49,127	67,290	43,159
Ames Research Center	26,342	19,004	30,273
Dryden Flight Research Center	21,883	20,142	25,317
Langley Research Center	93,179	118,283	143,912
Goddard Space Flight Center	871,371	879,136	895,357
Jet Propulsion Laboratory	230,961	204,394	180,667
Glenn Research Center	1,917	2,707	1,375
Headquarters	33,775	41,329	80,091
Total	1,443,400	1,484,627	1,514,978

PROGRAM GOALS

The mission of NASA's Earth Science Enterprise (ESE) is to develop a scientific understanding of the Earth system and its response to natural and human-induced changes to enable improved prediction of climate, weather, and natural hazards for present and future generations. NASA brings to this endeavor the vantagepoint of space, allowing global views of Earth system change. NASA is a provider of objective scientific information, via observation, research, modeling, and applications demonstration, for use by decision-makers in both the public and private sectors. NASA has been studying the Earth from space from its beginnings as an agency. These efforts have led to our current activity of deploying the first series of Earth Observing System satellites that will concurrently observe the major interactions of the land, oceans, atmosphere, ice, and life that comprise the Earth system. In short, the purpose of the Enterprise is to provide scientific answers to the fundamental question:

How is the Earth changing, and what are the consequences for life on Earth?

A fundamental discovery made during the 20th century, enabled in large part by NASA's global view from space, is the existence of a multiplicity of linkages between diverse natural phenomena and interactions between the individual components of the Earth system. As a result, NASA has worked with other agencies to develop a new, interdisciplinary field of "Earth system science", with the aim of investigating the complex behavior of the total Earth environment in which the global atmosphere, the oceans, the solid Earth and ice-covered regions of the Earth, and the biosphere all function as a single interactive system. Earth system science is an area of research with immense benefits to the nation, yielding new knowledge and tools for weather forecasting, agriculture, water resource management, urban and land use planning, and other areas of economic and environmental importance. In concert

with other agencies and the global research community, ESE is providing the scientific foundation needed for the complex policy choices that lie ahead on the road to sustainable development.

ESE has established three broad goals through which to carry out its mission. 1) Science: Observe, understand, and model the Earth system to learn how it is changing, and the consequences for life on Earth; 2) Applications**:** Expand and accelerate the realization of economic and societal benefits from Earth science, information and technology; 3) Technology**:** Develop and adopt advanced technologies to enable mission success and serve national priorities. These goals are articulated in the Earth Science Enterprise Strategic Plan.

NASA and its partners have already made considerable progress in understanding the Earth system. With satellites launched over the past decade, ESE has charted global ocean circulation including the waxing and waning of El Niño, mapped land cover change over the entire globe, illuminated the 3-D structure of hurricanes, and explored the chemistry of the upper atmosphere and the causes of ozone depletion. With deployment of the Earth Observing System now underway, ESE is opening a new era in Earth observation from space in which the major interactions of the Earth system are studied simultaneously to provide a global view on climate change. With this knowledge, NASA and its partners will develop prediction capabilities to quantify the effects of natural and human-induced changes on the global environment. Operational agencies such as National Oceanic and Atmospheric Administration (NOAA) and United States Geological Survey (USGS), who are partners in this effort, can use these capabilities to improve weather and climate forecasting, natural resource management, and other services on which the Nation relies.

STRATEGY FOR ACHIEVING GOALS

Science

We know that natural and human-induced changes are acting on the Earth system. Natural forces include variation in the Sun's energy output, and volcanic eruptions, which spew dust into the atmosphere and scatter incoming sunlight. Human forces include deforestation, carbon emission from burning of fossil fuels, methane and soil dust production from agriculture, and ozone depletion by various industrial chemicals. Internal climate factors such as atmospheric water vapor and clouds also introduce feedbacks that serve to either dampen or enhance the strength of climate forcing. We also know the climate system exhibits considerable variability in time and space, i.e., both short and long term changes and regionally-specific impacts.

NASA has used the concept of Earth System Science in developing its program. Researchers have constructed computer models to simulate the Earth system, and to explore the possible outcomes of potential changes they introduce in the models. This way of looking at the Earth as a system is a powerful means of understanding changes we see around us. That has two implications for Earth Science. First, we need to ***characterize*** (that is, identify and measure) the forces acting on the Earth system and its responses. Second, we have to peer inside the system to ***understand*** the source of internal variability: the complex interplay among components that comprise the system. By combining observations, research and modeling, we create a capability to ***predict*** Earth system change to help our partners produce better forecasts of change.

Earth system changes are global phenomena. Yet the system comprises many micro-scale processes, and the most significant manifestations are regional. Thus, studying such changes requires a global view at regionally discerning resolutions. This is where

NASA comes in, bringing the unique capability to study planet Earth from the vantagepoint of space. To *characterize* the forces acting on the Earth system and its responses, *understand* the source of internal variability and *predict* Earth system change, NASA must observe the Earth, conduct research and analysis of the data, model the data and synthesize the information into new knowledge. Where we are on this knowledge "life cycle" determines the strategy for our investment decisions.

The ESE is pursuing a targeted research program, focused on a set of specific science questions that can be addressed effectively with NASA's capabilities. ESE formulates comprehensive research strategies that can lead to definitive scientific answers and potentially to effective applications by other entities.

The key Earth Science research topics sponsored by NASA follow from this view of the Earth as a system. Thus they are grouped into categories of variability in the Earth System, forces acting on the Earth system, responses of the system to change, consequences of change, and prediction of future changes. Complicating this seemingly linear construct is a set of feedbacks; responses to change often become forces of additional change themselves. This conceptual approach applies in essence to all research areas of NASA's Earth Science program, although it is particularly relevant to the problem of climate change, a major Earth Science-related challenge facing our nation and the rest of the world. The ESE has articulated an overarching question and a set of strategic science questions reflecting this Earth system approach, which its observational programs, research and analysis, modeling, and advanced technology activities are directed at answering**.**

How is the Earth system changing, and what are the consequences for life on Earth?

- *How is the global Earth system changing?*
- *What are the primary causes of change in the Earth system?*
- *How does the Earth system respond to natural and human-induced changes?*
- *What are the consequences of changes in the Earth system for human civilization?*
- *How can we predict future changes in the Earth system?*

ESE's Research Strategy for 2000-2010 describes NASA's approach to answering these questions. The intellectual capital behind Earth science missions, and the key to generating new knowledge from them, is vested in an active program of research and analysis. Over 1,500 scientific research tasks from nearly every state within the U. S. are funded by the Earth science research and analysis program. Scientists from seventeen other nations, funded by their own countries and collaborating with U. S. researchers, are also part of the Earth science program. These researchers develop Earth system models from Earth science data, conduct laboratory and field experiments, run aircraft campaigns, develop new instruments, and thus expand the frontier of our understanding of our planet. ESE-funded scientists are recognized as world leaders in their fields, as exemplified by the award of the 1995 Nobel Prize in chemistry to two scientists who first recognized that cholorflorocarbons provided a threat to upper atmospheric ozone. The research and analysis program is also the basis for generation of application pilot programs that enable

universities, commercial firms, and state and local governments to turn scientific understanding into economically valuable products and services.

Applications

NASA expects that expanded scientific knowledge of Earth processes and the utilization of advanced space-based and airborne observing techniques or facilities developed by NASA will ultimately result in practical applications beneficial to all citizens. Examples of these applications may include: quantitative weather and hydrologic forecasts over an extended range of one to two weeks; prediction of seasonal or longer-range climate variations; the prediction of impacts of environmental changes on fisheries, agriculture, and water resources; global air quality forecasts, and natural hazards risk assessments. NASA ESE has a role in demonstrating the potential applications.

ESE continues to build a viable applications, education and outreach program that bridges our focused Research and Analysis (R&A) and mission science investments towards demonstration of new remote sensing data products for industry and regional and local decision makers. The emphasis is to focus on the dissemination of information to non-traditional Earth science customers, such as States, counties and regional managers and decision-makers. A base program is funded to put the essential tools in place and pilot several key demonstration projects. Eventually we hope that our demonstration of this concept will allow products to reach a much broader user base – practically every state in the Union.

A series of regional workshops have been held around the Nation to enable a wide variety of State and local government users to explain the challenges they face that might be addressed with tools based on satellite remote sensing. One result is the establishment of regular, open, competitively selected opportunities for these organizations to propose partnerships with NASA, academia and industry to demonstrate new applications of Earth science to specific problems. Successful demonstrations are expected to lead to new commercial / state & local government transactions, while ESE moves on to the next new demonstration activity.

Technology

In addition to ensuring a robust science program, this budget contains a vigorous Advanced Technology program that supports development of key technologies to enable our future science missions. In addition to our baseline technology program that includes the New Millennium Program (NMP), Instrument Incubator and High Performance Computing and Communications (HPCC), an Advanced Technology Initiative will identify and invest in critical instrument, spacecraft and information system technologies.

The ESE will lead the way in the development of highly capable, remote and *in situ* instruments and the information system technologies needed to support coupled Earth system models. Together they will enable affordable investigation and broad understanding of the global Earth system. The ESE will emphasize the development of information system architectures to increase the number of users of Enterprise information from hundreds to tens of thousands, with the goal of providing easy access to global information for science, education and applications. Finally, ESE will work in partnership with industry and operational organizations to develop the capabilities and infrastructure to facilitate the transition of sustained measurements and information dissemination to commercial enterprises.

ESE's technology strategy seeks to leverage the entire range of technology development programs offering benefits in cost, performance and timeliness of future Earth science process and monitoring campaigns. ESE's strategy is to establish strong links to other government programs in order to maximize mutual benefit to use open competitions for ESE-sponsored technology programs to attract the best ideas and capabilities from the broad technology community, including industry and academia.

Technology investments will be made in the following areas:

- Advanced instrument and measurement technologies for new and/or lower cost scientific investigations;
- Cutting-edge technologies, processes, techniques and engineering capabilities that reduce development, operations costs, and mission risk and that support rapid implementation of productive, economical, and timely missions;
- Advanced end-to-end mission information system technologies: technologies affecting the data flow from origination at the instrument detector through data archiving, for collecting and disseminating information about the Earth system, and enabling the productive use of Enterprise science and technology in the public and private sectors.

MISSION IMPLEMENTATION

The pursuit of Earth system science would be impractical without the continuous, global observations provided by satellite-borne instruments. NASA's Earth science research program 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 projects to convert data into new knowledge of the Earth system. Numerous users in academia, industry, Federal, State, and local government use this knowledge to produce products and services essential to achieving sustainable development. Enabling us to get at the answers to the science questions, our top priority continues to be our existing near term commitments with the launch of our first series of EOS and selected Earth Explorer missions that are nearing completion. In addition, we are committed to deliver a functioning data and information system to support the processing, archival and distribution of data products for these missions. These satellites will propel the ESE into a new era of data collection, research and analysis for which both the national and international Earth science community has been preparing over the last decade.

Realizing Scientific Return from Past Investments

Preceding the EOS were a number of individual satellite and Shuttle-based missions that 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) instruments, launched in 1978, 1991, and 1996, measure 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. France and the U. S. collaborated on the Ocean Topography Experiment (TOPEX/Poseidon), launched in 1992, to study ocean topography and circulation. In 1997, the Tropical Rainfall Measuring Mission (TRMM) was launched to provide the first-ever measurements of tropical precipitation. Also in 1997, ESE began purchasing ocean color data from a commercial vendor based on our joint investment in the Sea-viewing Wide Field Scanner (SeaWiFS) instrument.

Opening a New Era in Earth System Science with the Earth Observing System

The Earth Observing System (EOS), the centerpiece of Earth science, is a program of multiple spacecraft (the Terra, Aqua, Aura, Landsat-7, Jason-1, ICEsat, ACRIMSAT, Seawinds, SORCE, SAGE III, QuikSCAT, and follow-on missions) and interdisciplinary science investigations to provide a data set of key parameters needed to understand global climate change

Terra was recently launched on December 18, 1999. Terra is providing key measurements that are significantly contributing to our understanding of the total Earth system. The instrument complement is obtaining 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 was also launched in 1999. Landsat-7's single instrument, the Enhanced Thematic Mapper Plus (ETM+), is making high spatial resolution measurements of land surface and surrounding coastal regions. This mission is successfully providing data continuity with previous Landsat measurements. Landsat data are used for global change research, regional environmental change studies, and other civil and commercial purposes.

The QuikSCAT spacecraft was launched in June 1999. QuikSCAT, carrying instruments to collect sea surface wind data, is filling the gap in such critical data between ADEOS 1, which failed in June 1997 after seven months on-orbit, and ADEOS II. The availability of components of the Seawinds instrument originally planned for launch on Japan's ADEOS II was accelerated to fly on QuikSCAT. Japan has yet to decide on the timing and form of an ADEOS II mission (or missions), but the ESE still intends to fly a Seawinds instrument in that context as the follow-on instrument to QuikSCAT. It now appears that ADEOS-II will be launched no earlier than 2002 with the delay due to a failure of the Japanese H-IIA launch vehicle.

The Active Cavity Radiometer Irradiance Monitor Satellite (ACRIMSat) was launched on December 20, 1999 providing for the continuation of the long-term, quantitative understanding of the solar forcing of Earth's climate.

The Earth Explorers Program contains a series of focused, rapid development missions to study emerging science questions and processes utilizing innovative measurement techniques as a complement to the systematic measurements made through the EOS. The Shuttle Radar Topography Mission (SRTM) flown on STS-99 in February 2000 was a joint NASA and National Imaging and Mapping Agency (NIMA) mission to create a near-global high-resolution digital elevation topographic map of the world. The data from the SRTM will allow scientists in Federal, state and local agencies and academia to study the terrain for basic research in the areas of ecology, geology, geodynamics, hydrology and atmosphere modeling.

Some missions in this category are Earth System Science Pathfinder (ESSP). Four ESSP missions have been selected, Gravity Recovery and Climate Experiment (GRACE) with launch in 2001, Vegetation Canopy Lidar (VCL) with launch TBD (launch date under review), CloudSat with launch in 2003, and the Pathfinder Instruments for Cloud and Aerosol Spaceborne Observations – *Climatologie Etendue des Nuages et des Aerosols* (PICASSO-CENA) with launch TBD (launch date is under review). The Earth Explorers Program also encompasses various missions, which are developed in response to requirements that provide or continue highly focused Earth science process measurements. This currently is QuikTOMS (TOMS FM-5) with launch planned for June 2001. Because the launch date for Triana remains uncertain until the Shuttle manifest becomes definitized, Triana will be placed in storage following completion of spacecraft development. In addition, the University Earth System Science (UnESS) program is being

cancelled to fund immediate priorities in the Earth Science budget. A small amount of funding will be retained for these activities to complete contractual obligations associated with proposal evaluations.

EOS and related missions in development and preparation for launch through 2003 are:

- QuikTOMS (2001) - Atmospheric ozone and aerosols
- SAGE III (2001) - Stratospheric aerosols and gases experiment
- Jason (2001) - ocean topography; successor to TOPEX/Poseidon
- Aqua (2001) - atmospheric temperature and humidity, clouds, sea surface temperature, biosphere
- GRACE (2001) – time variations of Earth's gravity field
- ICEsat (2001/02) - ice sheet topography
- SORCE (2002) – solar irradiance
- SeaWinds (2002) – on Japan's ADEOS II satellite; ocean winds successor to QuikSCAT
- Vegetation Canopy Lidar (TBD) - Forest canopy height
- Aura (2003) - Upper and lower atmospheric chemistry
- Cloudsat (2003) - 3-d cloud profiles
- PICASSO-CENA (TBD) – 3-d aerosol profiles

The EOS Data and Information System (EOSDIS) is operating the EOS satellites now in orbit, and retrieving flight data and converting it into useful scientific information. EOSDIS is nearly complete; remaining segments are timed for release to support the upcoming launches of EOS missions through Aura in 2003. Following the recommendation of the National Research Council, NASA 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. As a federation pilot project, 24 organizations were competitively selected in December 1997 to become Earth Science Information Partners (ESIPs) to develop innovative science and applications products. This is part of a broader analysis of how ESE's approach to data and information systems services should evolve in the future. In addition to the EOSDIS that will produce data products for a wide range of users, NASA is engaging in a variety of activities to extend the utility of Earth Science data to a broader range of users such as regional Earth science applications centers, Earth science information partners, and efforts are under way to fuse science data, socio-economic data and other data sets that can be "geo-referenced" in readily understandable data visualizations.

The measurements to be made by these and other future Earth science missions as well as current on-orbit missions provide data products that are used extensively in the Earth science program. These activities are providing an ever increasing scientific understanding of global environment and the effects of natural and human sources of change.

Preparing for the Next Decade of Scientific Discovery

In parallel with deploying EOS, NASA ESE is looking ahead to determine what will be the important Earth science questions in the next decade, and which require NASA's leadership to be answered. Drawing on existing reports of the National Academy of Sciences and the state of progress in current scientific endeavors, ESE has developed a *Research Strategy for 2000-2010* that articulates a

hierarchy of one overarching question, five broad subordinate questions and twenty-three detailed questions that can and should be tackled over this decade. For each, the Research Strategy defines the observational requirements, which in turn provide the basis for definition of candidate missions to be pursued. An early, high priority in this timeframe is the National Polar-Orbiting Operational Environmental Satellite System (NPOESS) Preparatory Program (NPP), which will serve to provide continuity with the Terra and Aqua missions as well as a demonstration of instruments for the converged weather satellite program. NASA and the Integrated Program Office (IPO) jointly fund the NPP mission. The IPO consists of representative from the three agencies participating in NPOESS – NASA, the National Oceanic and Atmospheric Administration, and the Air Force. Another priority is the Landsat Data Continuity Mission to succeed Landsat 7. As with Landsat 7, this mission is being planned in partnership with the U.S. Geological Survey (USGS). NASA and USGS are also working with industry to explore the potential for a commercial purchase of Landsat-type data to meet this data continuity requirement.

In NASA's FY 2001 appropriation, Congress included funds for concept definition work for potential missions to observe global precipitation, global earthquakes, and global tropospheric winds. Studies are underway, with further definition work anticipated to proceed in FY 2002. Also in FY 2002, ESE plans to begin similar definition activities for observation of global ocean topography and ocean surface winds to succeed Jason and SeaWinds on ADEOS II, respectively. Beginning in FY 2001, NASA is soliciting its third round of ESSP missions, with selection(s) anticipated in FY 2002.

In developing its measurement/mission strategy, the ESE desires to reduce the risk to overall program objectives from any single mission failure by developing smaller, less expensive missions and implementing shorter development cycles from mission definition to launch. Shorter development times will allow more flexible responses to current and evolving scientific priorities and more effective uses of the latest technologies. In accordance with this philosophy, the implementation of each successive future mission in the ESE flight program will be based on specific solicitation alternatives (e.g. Announcement of Opportunity, Request for Proposal, etc.) and competitive selection of instrument payloads and implementation options. In each solicitation, we will ask commercial industry to come forward and offer science-quality data that meet NASA requirements for NASA to purchase. It is important, under this new approach, that instrument technology developments be conducted largely before the relevant mission payload selection. A science and applications-based space-based measurement concept set is indispensable to guide these pre-mission technology developments, particularly the Enterprise's Instrument Incubator Program. Our goal is to reach a mission development cycle of two-three years from the time of selection.

Finally, along with space-based observations, ESE will pursue a guided evolution of data and information system services to support missions and research in the next decade. NASA's FY 2001 appropriation also included funds to develop the "NewDISS" concept for this evolution. Studies in this arena are underway as well.

PARTNERSHIPS ARE ESSENTIAL TO SUCCESS IN EARTH SCIENCE

The challenges of Earth System Science, sustainable development, and mitigation of risks to people, property and the environment from natural disasters, require collaborative efforts among a broad range of national and international partners. NASA's Earth science research program constitutes its contribution to the U.S Global Change Research Program (USGCRP), an interagency effort to understand the processes and patterns of global change. The USGCRP coordinates research among ten U. S. government agencies. NASA is by far the largest partner in the USGCRP, providing the bulk of USGCRP's space-based observational needs.

NASA has extensive collaboration with the NOAA on climate-related issues. The ESE is the responsible managing agent in NASA for the development of NOAA's operational environmental satellites. NOAA, NASA, and the Department of Defense (DoD) jointly work to achieve the convergence of civilian and military weather satellite systems. NASA collaborates with the USGS on a range of land surface, solid Earth and hydrology research projects. NASA 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 a digital terrain map of most of the Earth's surface. NASA participates in the World Climate Research Program, the International Geosphere/Biosphere Program, and the ozone assessments of the World Meteorological Organization.

International cooperation is an essential element in the Earth science program. Earth science addresses global issues and requires international involvement in its implementation and application. Acquiring and analyzing the information necessary to address the science questions is a bigger task than a single nation can undertake. Furthermore, the acceptance and use of the scientific knowledge in policy and resource management decisions around the world require the engagement of the international scientific community. Global data and global participation are needed to devise a global response to environmental change. In addition, integrating our complementary science programs can result in fiscal benefits to the NASA program. For this reason, NASA has sought and nurtured international partnerships spanning science, data and information systems, and flight missions. Most of Earth science's satellite missions have international participation, ranging from simple data sharing agreements to joint missions involving provision of instruments, spacecraft, and launch services. In the past three years over 60 international agreements have been concluded and more than 40 more are pending. In some capacity, Earth science programs involve international partners from over 35 nations, including Argentina, Armenia, Australia, Belgium, Brazil, Canada, Chile, China, Denmark, Egypt, France, Germany, India, Israel, Italy, Japan, Mongolia, Russia, South Africa, Ukraine and others.

BASIS OF FY 2002 FUNDING REQUIREMENT

EARTH OBSERVING SYSTEM

	FY 2000	FY 2001	FY 2002
		(Thousands of Dollars)	
Terra	12,400	3,325	2,370
Aqua (formerly PM-1)	85,900	53,506	14,500
Aura (formerly Chemistry)	112,800	99,467	80,600
Special Spacecraft	121,049	111,195	56,350
QuikSCAT	1,100	1,091	3,303
Landsat-7	9,850	1,397	1,700
Algorithm Development	121,700	89,303	83,449
EOS Follow-on	15,000	55,002	129,622
Total	479,799	414,286	371,894

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 to:

(1) 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) Develop a comprehensive data information system, including data retrieval and processing system.
(3) Serve the needs of scientists performing an integrated multi-disciplinary study of planet Earth and to make Earth science data and information publicly available.
(4) 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 fly aboard the EOS spacecraft. The data are received, archived, processed, and distributed by the EOSDIS.

The three main EOS spacecraft that will support observations by the scientific instruments include the Terra, Aqua, and Aura missions. The Landsat-7 mission, successfully launched on April 15, 1999, provides additional observations.

Nearly all-key EOS missions include international contributions. For example, the Terra spacecraft is flying an instrument from Canada the Measurements of Pollution in the Troposphere (MOPITT) and one from Japan, the Advanced Spaceborne Thermal Emission and Reflection Radiometer (ASTER); Aqua will include the Japanese Advanced Microwave Scanning Radiometer (AMSR) for EOS instrument and the Humidity Sounder for Brazil (HSB). Aura will include the Dutch-Finnish Ozone Monitoring Instrument (OMI) as well as the High-Resolution Dynamics Limb Sounder (HRDLS) instrument jointly produced by the U.S. and the United Kingdom. In addition, numerous agreements have been signed for joint data exchange and distribution, including cooperation with the EOSDIS.

The 1997 Biennial Review documented the shift in paradigm for future mission planning vis-a-vis the EOS era. Where EOS mission planning proceeded from science to mission selection to technology development, future mission planning proceeds from science to technology development to mission selection. This has the effect of removing technology development from the critical path of mission implementation, where it introduces added cost and schedule risk. Instead, technologies are matured in the context of a science-driven advanced technology program, and only when they reach a specified level of maturity are they available for use in mission proposals. The result is a more flexible and less expensive approach to acquiring Earth science data.

Terra

A new generation of Earth science began with the launch and checkout on December 18, 1999 of Terra - one that studies the Earth as a global system. Terra's five complementary instruments are designed to obtain information about the physical and radiative properties of clouds and aerosol; the exchanges of energy, carbon and water between the air, land and water; measurements of important trace gases in the atmosphere and volcanology. Terra has a descending equatorial crossing time of about 10:30 AM, typically with minimum cloud cover over land, so surface features can be more readily observed. Terra's orbit places it only 30 to 40 minutes behind Landsat-7 providing good synergy between these spacecraft. Terra's Clouds and Earth's Radiant Energy System (CERES) instrument is performing measurements of the Earth's "radiation budget" or the process by which the Earth's climate system maintains a balance between the energy that reaches the Earth from the Sun, and the energy that radiates from Earth back into space. The components of the Earth system that are important to the radiation budget are the planet's surface, atmosphere, and clouds. Meanwhile, the Moderate-Resolution Imaging Spectroradiometer (MODIS) is measuring clouds, moisture and temperature profiles of the atmosphere, land and ocean temperature, snow cover, and information about the state of the land and ocean portions of the biosphere. CERES and MODIS will also fly on the Aqua spacecraft discussed below. The Multi-angle Imaging Spectroradiometer (MISR) instrument is measuring the variation of the surface, aerosol, and cloud properties with nine different views designed to provide more detailed information about their distribution and structure. The Canadian Measurements of

Pollution in the Troposphere (MOPITT) instrument is an infrared gas-correlation radiometer that is providing global measurements of carbon monoxide and methane concentration and distribution in the troposphere. The Advanced Spaceborne Thermal Emission and Reflection Radiometer (ASTER) instrument, provided by Japan, is the "zoom lens" of Terra, providing the highest resolution measurements from that platform of cloud properties, vegetation, surface mineralogy, soil properties, and surface temperature. ASTER's two visible -near infrared cameras also enable it to produce high quality digital elevation models. The primary contractors associated with the project are Lockheed Martin Missiles and Space (LMMS) for the Terra spacecraft, Raytheon/Santa Barbara Remote Sensing for the MODIS instrument, TRW for the CERES instrument (the instrument has also been flown on the TRMM in 1997), JPL for the MISR instrument, Japan's MITI for ASTER, the Canadian Space Agency for MOPITT, and Lockheed Martin Commercial Launch Services for the Terra Atlas Centaur/IIAS launch services.

Aqua

The Aqua mission is focused on a large variety of measurements related to the Earth/atmosphere system, including atmospheric temperature and humidity profiles, clouds, precipitation, snow cover over the land, sea ice cover over the oceans, sea-surface and land-surface temperatures, land and ocean productivity, soil moisture, and the Earth's radiation budget. The atmospheric temperature and humidity profiles in particular are expected to lead to improvements in weather prediction. The goals of the mission include improved understandings of cloud formation, precipitation, and evapotranspiration. An afternoon equatorial crossing is more suitable for acquiring the data than a morning crossing because in most regions of the Earth there is more cloud coverage in the afternoon than in the morning; hence the 1:30 p.m. equatorial crossing time of the Aqua mission. The primary contractors associated with the project are TRW for the EOS common spacecraft to be used for Aqua and also for Aura; Lockheed Martin Infrared and Imaging Systems (LMIRIS) and JPL for the Advanced Infrared Sounder (AIRS); Aerojet for the Advanced Microwave Sounding Unit-A (AMSU-A); TRW for the Clouds and the Earth's Radiant Energy System (CERES) instrument; and Raytheon/Santa Barbara Remote Sensing for the Moderate Resolution Imaging Spectroradiometer (MODIS). Japan has provided the Advanced Microwave Scanning Radiometer for EOS (AMSR-E), and Brazil has provided a microwave instrument, the Humidity Sounder for Brazil (HSB). All instruments were delivered to TRW by the end of 1999. This mission will be launched no earlier than July 2001. Boeing provides the launch vehicle and services for the EOS Aqua mission.

Aura

The Aura mission will study the chemistry and dynamics of the Earth’s atmosphere with emphasis on the upper troposphere and lower stratosphere (5-20 km). The mission will measure ozone, aerosols, and several key atmospheric constituents that play an important role in atmospheric chemistry, air quality, and climate. Four instruments will fly on Aura: The High Resolution Dynamic Limb Sounder (HIRDLS), being built jointly by NASA and the United Kingdom, is an infrared limb-scanning radiometer designed to sound the upper troposphere, stratosphere and mesosphere; the Microwave Limb Sounder (MLS) will measure the stratospheric temperature and numerous chemical species; the Tropospheric Emission Spectrometer (TES) is a high resolution infrared imaging Fourier transform spectrometer that observes in the limb and nadir; and the Ozone Monitoring Instrument (OMI), being built by the Netherlands Space Agency and the Finnish Meteorological Institute, is an ultraviolet and visible grating spectrometer providing global mapping of the ozone, trace gasses, and aerosols. During FY 2000, the spacecraft successfully completed a delta Preliminary Design Review and a delta Critical Design Review, and began bus integration; and the OMI successfully completed a delta CDR. In FY 2001 the spacecraft bus will complete assembly and test and begin integration. In FY 2002, all of the instruments will be

delivered and integrated onto the spacecraft and observatory level testing will begin. The launch of Aura is scheduled for July 2003. Boeing provides the launch vehicle for the EOS Aura mission.

Special Spacecraft

The Special spacecraft are designed to study atmospheric aerosols, ocean circulation, and ice-sheet mass balance, cloud physics, atmospheric radiation properties, and solar irradiance. Although there have been delays with the Russian launch vehicle and spacecraft, the joint US/Russian Meteor/SAGE-III mission is presently scheduled for a late May/early June 2001 launch. A second SAGE-III instrument is scheduled to fly aboard the International Space Station in 2005. Planning activities have been initiated for a joint mission with Argentina for flying the third SAGE-III instrument. The SAGE-III takes advantage of both solar and lunar occultation to measure vertical profiles of aerosols, ozone, and other gaseous constituents of the atmosphere and will continue a more than 25 year record of well-calibrated ozone profile data.

The Japanese will provide the Advanced Earth Observing System II (ADEOS II) spacecraft for the Seawinds instrument to measure ocean surface wind velocity as a follow-on to the NASA Scatterometer instrument on ADEOS-I and the Seawinds instrument on QuikSCAT.

The Radar Altimetry mission, Jason, will be a follow-on to the TOPEX/Poseidon as a cooperative joint mission with the French Space Agency (CNES), with data provided to NOAA for operational purposes.

The primary objective of the Ice Cloud and Elevation Satellite (ICESat) mission is to measure ice sheet height and volume change for long-term climate variability studies. The primary contractor associated with the mission is Ball Aerospace for the spacecraft; the GLAS instrument is being built in-house at GSFC. ICESat is co-manifested with the Space Science/CATSAT mission on a Delta II launch vehicle.

The EOS ACRIMSAT will continue the measurement of Total Solar Irradiance (TSI) begun by the ACRIM instruments on the Solar Maximum Mission and UARS.

The Total Solar Irradiance Mission (TSIM) was merged with the Solar Stellar Irradiance Comparison Experiment (SOLSTICE) Mission to form the Solar Radiation and Climate Experiment (SORCE) Mission. SORCE will accomplish all the original science objectives of both TSIM and SOLSTICE including those requirements defined by the National Polar-orbiting Operational Environment Satellite (NPOESS). The SORCE spacecraft will be launched in July 2002.

The ESE is committed to provide a launch vehicle for the Canadian SciSAT mission. The Kennedy Space Center negotiated the launch vehicle contract in FY 2000. The launch vehicle build remains on track for a June 2002 launch.

QuikSCAT

The QuikSCAT mission, which is filling the ocean vector wind data gap created by the loss of the NASA Scatterometer (NSCAT) on the Japanese ADEOS I spacecraft, was launched from Vandenberg Air Force Base in June 1999. The Scatterometer data was

released to the general science community on January 31, 2000. The reprocessing of all the data from the beginning of the mission, with improved rain flag and model function, was completed in July 2000. The Scatterometer has been operating for 19 months (as of January 2001), which is longer than any previous scatterometer. The prime mission will end on June 19, 2001. A continuation mission has been approved until September 30, 2002.

Landsat-7

The Landsat-7 satellite was launched on April 15, 1999, and declared operational in July 1999. The satellite continues to return excellent images, which meet or exceed NASA's expectations. First data was available to the public mid-August 1999. By agreement with the United States Geological Survey (USGS), NASA operated and funded operations in FY 2000. Landsat-7 is producing 150 Terabytes of data per day. Beginning in FY 2001, the USGS is operating and funding the Landsat-7 system.

EOS Follow-On

The next generation of EOS missions will provide new technology and space systems to meet the scientific needs for the NASA Earth science projects. NASA ESE has identified a mission architecture over the mid-term that will help achieve the specific scientific goals using a combination of systematic and exploratory missions. The new missions selected will capitalize on our investments in advanced technologies to reduce lifecycle time/cost and relate to longer-term scientific questions and practical applications. This architecture is directly related to the science priorities as outlined in the Science Implementation Plan. The approach to mission selection and implementation will assure maturity of key and essential technology during mission definition and formulation for both exploratory and systematic missions (i.e. no missions will go into implementation until key technologies are ready).
In FY 2001, new Follow On studies were initiated in the following areas: Landsat Continuity; Global Precipitation; Global Winds; Global Earthquake; and New Data and Information Systems and Services (New DISS).

As it deploys EOS, ESE is also planning for the future. For example, a Landsat Data Continuity Mission is being formulated in partnership with USGS, and will be implemented as a commercial data purchase if possible. ESE is also planning for the transition of several of its key research observations to the Nation's weather satellite system. The DoD, NOAA and NASA have established an Integrated Program Office (IPO) to create a converged civilian and military weather satellite system called the National Polar-orbiting Operational Environmental Satellite System (NPOESS) to replace the present generation of separate systems. NASA and the IPO are jointly funding the NPOESS Preparatory Project (NPP) that will simultaneously continue key measurements begun by EOS and demonstrate instruments for NPOESS. The NPP will save money for both organizations by combining essential atmospheric and Earth surface observations on a single platform, and by seeking to meet both climate science and operational weather requirements with the same advanced instruments.

The first set of <u>systematic</u> missions has been under formulation and study during the past year. These missions are:

- NPP "Bridge mission": Continues fulfilling our commitment to the science community for a 15-year data set for fundamental global climate change observations started by MODIS, AIRS, and a combination of AMSU/MHS/HSB, which are the primary instruments on the EOS Terra and Aqua satellites. This is also a shared cost precursor mission to the next generation of operational polar weather satellites being developed by the National Polar-Orbiting Operational Environmental Satellite

System (NPOESS) Integrated Program Office (IPO), a joint NASA, NOAA, DoD effort. This arrangement assures NASA's long-term science observational needs are met by the operational system.

- Landsat follow-on: Continues the basic global land cover change data set. We are hopeful this can be accomplished with a commercial data purchase or a government-industrial partnership, and released a Request for Information as a first step in exploring this avenue. We are in the process of developing a data specification and other formulation activities leading to a decision to proceed with solicitation development at the end of this year.

Other systematic missions that are currently being studied are:

- Global Precipitation: Observations from the Tropical Rainfall Measuring Mission have demonstrated the value of these data in modeling the global water and energy cycle, which is an emerging science theme for both the Enterprise and the U.S. Global Change Research Program. We are currently examining options for this mission. We are proposing to begin the formulation of this as the highest priority mission in FY 2002, and begin the international coordination with Japan and Europe.
- Ocean Altimeter: These data sets will lead to the next significant improvement in seasonal climate forecasts. One additional mission beyond Jason is required to ensure continuity before a transition to an operational satellite program is possible. We have the commitments from CNES and EUMETSAT in Europe and NOAA to carry on a transition mission from scientific research into a US/European constellation of polar orbiting satellites. The other three organizations have currently requested the required funds as part of their FY 2002 budget request to support this arrangement.
- Ocean Wind Vector: This mission is needed to provide continuity beyond Seawinds on ADEOS II (to be launched in 2002). Japan is offering a spacecraft and launch vehicle and the IPO has expressed interest in cost-sharing the instrument development and accommodation on behalf of the U.S. Navy and NOAA. We have commissioned a study to develop details to be completed by the end of the year. NASA considers this also to be a transition arrangement from scientific research into operations because NOAA, the Navy and EUMETSAT all have expressed interest in this data set based on QuikSCAT as part of their operational requirement.
- Solar Irradiance Monitor: These data provide the means to distinguish the external (solar) from internal sources of change in the Earth system. A follow-on mission is required to bridge the gap between the SORCE mission (2002) and NPOESS. Discussion with the NPOESS IPO will explore the potential for a shared mission or other mutually beneficial arrangement to meet this common requirement. Formulation activities for this mission concept will include exploration of such a partnership.
- Ozone/Aerosol Total Column: Total ozone measurements are required to assess the anticipated recovery of the ozone layer as a result of the Montreal Protocol. Aerosols are the largest source of uncertainty in efforts to quantify the forces acting on climate. TOMS currently provides the former (with Aura picking it up in 2003), and SAGE the latter. This combined mission is required to fill the gap between Aura & SAGE, and NPOESS.

SCHEDULE AND OUTPUTS

Preliminary Design Reviews - Confirms that the proposed project baseline is comprehensive (meets all project 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.

Seawinds
Plan: May 1995
Actual: May 1995

Meteor-3M Stratospheric Aerosol & Gas Experiment (SAGE III)
Plan: July 1995
Actual: July 1995

Aqua (formerly PM-1)
Plan: April 1997
Actual: April 1997

Jason
Plan: June 1997
Actual: June 1997

ACRIM
Plan: March 1998
Actual: March 1998

ICESat (GLAS Instrument)
Plan: June 1998
Actual: June 1998

Aura (formerly Chemistry)
Plan: March 1998
Actual: October 1999

Rescheduled following completion of alternative configuration studies.

SORCE
Plan: May 1999
Actual: May 1999

SOLSTICE and TSIM were combined in FY 1999 to make the SORCE mission. The Mission Design Review and the Preliminary Design Review were combined and successfully conducted in May 1999.

NPP Project in formulation. Revised due to schedule maturity.
Plan: December 2002
Revised: February 2002

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.

ACRIM:
Plan: January 1998
Actual: January 1998

Aqua (formerly PM-1) Revised schedule due to late start following resolution of spacecraft award protest first reported in the 1998 budget
Plan: April 1998
Revised: June 1998

ICESat (GLAS Instrument)
Plan: March 1999
Actual: March 1999

Jason:
Plan: November 1998
Actual: November 1998

SORCE Revised due to schedule conflicts.
Plan: October 2000
Actual: November 2000

Aura (formerly Chemistry)
Plan: August 2000
Actual: August 2000

NPP Project in formulation. Revised due to schedule maturity.
Plan: December 2003
Revised: January 2003

Instruments Delivered - Confirms that the fabrication, integration, certification, and testing of all system hardware and software conforms to 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.

Landsat-7 Plan: December 1996 Actual: September 1998	ETM+ Instrument technical problems.
Terra last instrument Plan: February 1997 Actual: August 1997	Test anomalies occurred on the MOPITT instrument; which required rework by Canadians.
SAGE-III (Russian) Plan: December 1997 Actual: September 1998	Due to instrument and detector testing problems.
Seawinds Plan: March 1998 Actual: March 1999	Delayed due to launch slip by Japan.
Aqua (formerly PM-1) last instrument Plan: September 1999 Actual: December 1999	Instrument deliveries delayed, first reported in the 1998 budget
ICESat Plan: October 2000 Revised: June/July 2001	GLAS instrument delayed due to late vendor deliveries and development challenges.
Aura (formerly Chemistry) last instrument Plan: January 2002 Revised: July 2002	Rescheduled due to technical problems and 6-month launch delay.
QuikSCAT Plan: May 1998 Actual: May 1998	
ACRIM Plan: October 1998 Actual: June 1999	Instrument delivery changed to fit new launch schedule after selection of launch vehicle and spacecraft vendors.

Jason-1 Revised due to CNES spacecraft need date.
Plan: March 1999
Actual: September 1999

SORCE: TSIM and SOLSTICE were combined in FY 1999 to create the SORCE mission.
Plan: August 2001

NPP
Plan: October 2004

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 developed and is ready to support launch.

Terra
Plan: February 1998
Actual: February 1998

Aerosol SAGE-III (Russian) Commensurate with the delay in instrument delivery.
Plan: June 1999
Actual: March 2000

Seawinds
Plan: September 1998
Actual: September 1998

Jason-1 Revised due to delayed selection of science team and revised launch date.
Plan: October 1999
Actual: December 1999

Aqua (formerly PM-1)
Plan: July 2000
Actual: July 2000

Aura (formerly Chemistry) Revised to reflect change in LRD to 6/03.
Plan: December 2001
Revised: June 2002

ICESat
Plan: January 2001
Revised: May 2001

Revised due to launch delay.

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.

Terra
Plan: July 1999
Actual: December 1999

Due to RL10-11 A3 engine stand down, the Terra launch was delayed until the launch vehicles using RL-10-A3 engines were returned to a flight readiness status. Terra was successfully launched on December 18, 1999.

QuikSCAT
Plan: April 1999
Actual: June 1999

Delayed due to USAF Titan IV failure investigations and launch site availability conflicts. QuikSCAT was successfully launched on June 19, 1999

Landsat-7
Plan: April 1999
Actual: April 1999

Landsat-7 was successfully launched on April 15, 1999.

ACRIMSAT
Plan: November 1999
Actual: December 1999

ACRIMSAT was successfully launched on December 20, 1999.

Aerosol SAGE-III (Russian)
Plan: September 1999
Revised: June 2001

Instrument integrated on the spacecraft and proceeding toward the scheduled launch date.

Seawinds (ADEOS-II)
Plan: November 2000
Revised: TBD

Instrument delivered and integrated onto the spacecraft. Delay due to Japanese launch vehicle problem.

Jason 1
Plan: May 2000
Revised: NET June 2001

All NASA instruments were delivered to CNES in 1999. Delayed to accommodate satellite development by French Space Agency (CNES) partner.

Aqua (formerly PM-1)
Plan: December 2000
Revised: NET July 2001

Launch delay caused by hardware failures during observatory integration and test.

Aura Plan: December 2002 Revised: July 2003	Directed launch slip to provide funding relief to other Earth Science Programs.
ICESat Plan: July 2001 Revised: December 2001	Budget cuts in early FY99 resulted in a launch delay to January 2002. The project continued to work toward an accelerated launch date of December 2001 due to the acquisition of the spacecraft bus through the RSDO development procurement mechanism. a
SORCE: Plan: July 2002	TSIM and SOLSTICE were combined in FY 1999 to the SORCE mission.
NPP Plan: December 2005	

ACCOMPLISHMENTS AND PROPOSED RESULTS

Terra

The Terra spacecraft opened its aperture doors on February 24, 2000 beginning its science operations. Terra Level-1 data products from MODIS and CERES were released 4 months after launch with spacecraft checkout completed by April 2000. Terra collects 200 gigabytes (200,000 megabytes) of data per day over the entire globe. Among the first operational uses of Terra was imagery from the MODIS instrument in support of the U.S. Forest Service to combat the western U.S. forest fires this past summer. The images from MODIS assisted fire fighters in identifying the active locations of the fire(s) itself instead of through smoke-filled images, and allowed them to control the rapidly spreading fires. MODIS imagery was also used by the Geography Department at Dartmouth College in New Hampshire to assist in flood hazard reduction programs. MODIS data also supports geographic information that Dartmouth converts and distributes to disaster relief agencies through the World Wide Web.

In January 2001, Popular Science Magazine voted Terra to receive the "Best of What's New" Award in its Aviation and Space Category as being best in innovation for the year 2000.

In FY 2001 Terra Level-2 and above products will be released as the first round of product validation efforts completed by instrument science teams. In FY 2002 Terra will continue its mission operations and continue to provide state of the art imagery to the science community to help in the evaluating and analysis of changing Earth.

Aqua

During FY 2000, integration and test of the observatory continued with successful dynamic tests. Failures in the Formatter Multiplexor Unit (FMU)/Solid State Recorder (SSR), and problems with the Transponder and Transponder Interface Electronics (TIE) have delayed the launch readiness to no earlier than July 2001. All instruments have been integrated with the spacecraft.

Observatory and instrument checkout will occur for approximately 120 days after launch after which nominal mission operations will commence.

Aura

The Aura mission focuses on the impact of greenhouse gases on the global climate. In FY 2000, the Aura Project successfully completed a delta Preliminary Design Review and a delta Critical Design Review of the EOS common spacecraft design to verify the Aura unique aspects of the spacecraft development. Also, the spacecraft began bus level integration. In addition, the Ozone Monitoring Instrument successfully completed their delta CDR. Assembly and test of the spacecraft bus units will be completed and bus integration will begin in FY 2001. In FY 2002, all of the instruments will be delivered and integrated onto the spacecraft, and observatory level testing will begin. The launch of Aura is scheduled for no earlier than June 2003.

Special Spacecraft

Jason

The Jason MOU between NASA and CNES was signed in December 1996. CNES will provide the spacecraft, solid-state altimeter, and Doppler Orbitography and Radiopositioning Integrated by Satellite (DORIS) positioning system. NASA will provide the microwave radiometer, Global Positioning System (GPS) and laser retroreflector array. The ground system and mission operations will be shared. NASA will also provide the launch services. Delays in the CNES satellite development program have caused the launch of Jason to be rescheduled. NASA supported a Jason-1 PDR in June 1997 and initiated the Boeing Delta II launch vehicle contract in September 1997.

CNES held the system-level CDR for the Jason mission with NASA support in the fall of 1998. Simulators or engineering models of all the instruments were delivered to CNES, who will perform platform and payload integration and test as separate activities. The flight models of all the instruments were delivered by September 1999. Satellite-level integration and test began in late 1999 with significant portions of system-level testing completed in FY 2000. A Satellite Qualification Review was conducted in November 2000 with participation by the NASA independent review team (Red Team). CNES will ship the integrated satellite for Jason to the Western test range and launch is co-manifested with NASA's TIMED space science satellite. Launch was initially scheduled for May 2000 on the Delta Launch vehicle but is being rescheduled for no earlier than June 2001 due to continuing CNES satellite development problems. After launch and a 60-day checkout, normal mission operations are scheduled to begin, including formation flying with the TOPEX/Poseidon satellite, to provide cross correlation for scientific trend analysis of the sea-surface height.

ICESat

The ICESat team successfully completed the Mission Design Review (MDR) in March 2000 and the vehicle Dual Payload Attached Fitting (DPAF) Critical Design Review (CDR) in July 2000. Critical activities for FY 2001 include integration and test of the GLAS instrument with the spacecraft and launch vehicle integration in preparation for launch. ICESat will launch in early FY 2002 with a 120-day calibration/validation period; generation of data products will also begin in FY 2002.

SORCE

The SORCE team successfully completed both the PDR and the CDR for the spacecraft bus in FY 2000. Additionally, the Mission CDR was successfully completed in November 2000. The SORCE instruments completed their development and design phase in FY 2000 and have transitioned into flight fabrication and test. Even though there have been some delays in the various phases of the instrument development, the SORCE instrument suite is still on schedule to be completed in August 2001. In FY 2000, KSC selected the Pegasus launch vehicle for the SORCE Mission and established the launch services contract with Orbital Sciences Corporation (OSC). Key milestones for FY 2001 include the Mission Operations Review in April 2001, completion of the integration of the SORCE instruments on to the optical bench in August 2001, and completion of the spacecraft bus integration in August 2001.

SAGE

Three SAGE-III instruments were manufactured for long-term monitoring of ozone and aerosols. All three instruments have been delivered. The first instrument is presently in Russia integrated on the Meteor spacecraft proceeding toward a June 2001 launch. The second instrument is undergoing testing and is planned to fly on the International Space Station (ISS) in 2005. The third instrument is planned for flying on a joint mission with Argentina.

SeaWinds

The SeaWinds protoflight model was delivered to Tsukuba, Japan in March 1999 for a launch on the ADEOS II spacecraft by a NASDA H-IIA rocket from Tanegashima, Japan. The spacecraft is integrated and has completed thermal vacuum, acoustic, vibration, pyro-shock and post-dynamic electrical testing. In addition, mass properties and alignment measurements were completed in November 2000. The spacecraft is currently scheduled for launch in 2002.

ACRIMSAT

The Active Cavity Radiometer Irradiance Monitor Satellite (ACRIMSAT) was successfully launched from Vandenberg Air Force Base (VAFB) on December 20, 1999. The spacecraft was manifested on a Taurus launch vehicle with the Korean Multipurpose Satellite (KOMPSAT). The Mission and Operations Readiness Review and Risk Assessment Review were completed on November 29, 1999 at VAFB. The spacecraft was initially operated from the Orbital Sciences Spacecraft Operations Control Center (SOCC) in Dulles, VA. After a successful on-orbit checkout in April 2000, spacecraft operations using the ACRIMSAT ground station located at JPL's Table Mountain Observatory in Wrightwood, CA was taken over by JPL. ACRIMSAT is gathering 18 percent more data than specified in mission requirements and providing the best Total Solar Irradiance (TSI) measurements to date.

QuikSCAT

The QuikSCAT mission, which is filling the ocean vector wind data gap created by the loss of the NASA Scatterometer (NSCAT) on the Japanese Advanced Earth Observing Satellite (ADEOS I) spacecraft, was launched from Vandenberg Air Force Base on June 19, 1999. The Scatterometer data were first released to the general science community on January 31, 2000. The reprocessing of all

the data from the beginning of the mission, with improved rain flag and model function, was completed in July 2000. The Scatterometer has been operating for 19 months (as of January 2001), which is longer than any previous scatterometer. The prime mission will end on June 19, 2001. A mission extension has been approved until September 30, 2002.

Landsat-7

The Landsat-7 satellite was launched on April 15, 1999, and declared operational in July 1999. The satellite has been returning excellent images, which meet or exceed NASA's expectations. First data were available to the public in mid-August 1999. By agreement with the USGS, NASA operated and funded operations in FY 2000. Beginning in FY 2001, the USGS operates and funds the Landsat-7 system.

EOS Follow-On

NASA ESE has developed a science implementation plan, which will drive the selection of EOS follow-on missions. Two of those missions were included in the 2001 budget request: NPP and Landsat follow-on. Studies have also been initiated in FY 2001 for Global Precipitation, Global Winds, Global Earthquake and New DISS activities.

The NPP completed initial spacecraft studies in FY 2000, and will award contracts for more detailed studies in FY 2001. The Advanced Technology Microwave Sounder (ATMS) instrument detailed study contract were completed in FY 2000 and the implementation contract was awarded in FY 2001. A joint NASA/IPO NPP Mission Systems design review was successfully conducted in FY 2001. The tentative launch readiness date is late 2005. At present, NASA is responsible for spacecraft development and integration; one instrument, the Advanced Technology Microwave Sounder (ATMS); overall mission integration; launch vehicle (including support and early checkout); and science data processing. The IPO is responsible for two instruments, Visible Infrared Imaging Radiometer Suite (VIIRS) and the CRoss-track Infrared Sounder (CRIS); ground system development; flight operations; and operational data processing.

Landsat follow-on: Continues the basic global land cover change data set. NASA is hopeful this can be accomplished with a commercial data purchase. A Request for Information has been released as a first step in exploring this avenue. In addition, workshops have been and will be held with potential industry, government and commercial partners to further define the process to enable a commercial data policy.

Formulation will be initiated in FY 2002 for Global Precipitation, Ocean Topography, Ocean Wind Vector. Studies will include those for Solar Irradiance Monitor, and Total Column Ozone.

BASIS OF FY 2002 FUNDING REQUIREMENT

EARTH OBSERVING SYSTEM DATA INFORMATION SYSTEM

	FY 2000	FY 2001	FY 2002
		(Thousands of Dollars)	
Earth Observing System Data Information System.....	278,880	281,391	252,650

PROGRAM GOALS

The goals for the EOS Data and Information System (EOSDIS) are the development and operation of a system which can: (1) operate the EOS satellites; (2) acquire instrument data; (3) produce data and information products from the EOS and other Earth Sciences Enterprise data holdings; (4) preserve these and all other Earth science environmental observations for continuing use; and (5) make all these data and information easily available for use by the user community. The EOSDIS facilitates the goals of Earth science by enabling the public to benefit fully from increased understanding and observations of the environment.

STRATEGY FOR ACHIEVING GOALS

The EOSDIS is currently supporting an array of satellites by providing mission operations, data capture, data production, data archive, data distribution, and user support. This system is designed to evolve over time as the data sources, missions, technologies, and user needs change. This has been effected, through the use of a combination of specialized core systems, user specific systems for instruments or scientific disciplines, commercial off-the-shelf items, and cooperative activities with heritage data centers to ensure continued support to established user communities. In addition, the expansion of data services is encouraged through cooperation with the Distributed Active Archive Centers (DAACs,) Earth Science Information Partners (ESIPs), Regional Science Applications Centers (RESACs), and the Synergy Program. The EOSDIS sustains a partnership with NOAA, USGS, and international partner space agencies.

The EOSDIS development has been divided into six major components:

1. The Polar Ground Stations (PGS) which provide command uplink and telemetry downlink. The PGS are now part of the Ground Network (GN), managed by SOMO and the focus of a major SOMO commercialization effort;
2. The EOS Data and Operations System (EDOS) which receives the raw data stream from the satellites, separates the data by instrument, and performs the initial processing (packet restoration and temporal ordering) and back-up archiving. EDOS interfaces to the TDRSS ground terminal at the White Sands Complex for Terra data, and will interface to the PGS in Alaska and Norway for data from the Aqua, ICESat and Aura missions. The raw data collected from the satellites are sent to the EDOS Level-0 processing center at GSFC, which processes the data and sends them via EBNet to the DAACs and the Science Investigator-led Processing Systems (SIPS);

3. The EOSDIS backbone Network (EBNet) which delivers the real-time data to and from the mission operations control centers and the science data to the DAACs and SIPS. EBNet was originally developed by GSFC, but is now managed as part of SOMO/NISN;
4. The EOSDIS Core System (ECS) includes the Flight Operations Segment (FOS), which provides command and control capabilities to operate the EOS spacecraft (the present implementation of FOS is called the EOS Mission Operations System (EMOS)), and the Science Data Processing Segment (SDPS) which provides data product generation using science software provided by the Principal Investigators (PIs), data archiving, and distribution. The SDPS is operated at the DAACs;
5. The DAACs, which produce EOS standard data products using algorithm software provided by the PIs, archive data, and distribute these data to end users. Each DAAC focuses on the data needs of a specific segment of the user community, with User Working Groups advising individual DAACs. The eight DAACs are:
   - Alaska Synthetic Aperture RADAR (SAR) Facility, Geophysical Institute, University of Alaska, Fairbanks, Alaska
   - Earth Resources Observation System (EROS) Data Center (EDC), U.S. Geological Survey, Sioux Falls, South Dakota
   - Jet Propulsion Laboratory, California Institute of Technology, Pasadena, California
   - Langley Research Center (LaRC), Hampton, Virginia
   - National Snow and Ice Data Center (NSIDC), University of Colorado, Boulder, Colorado
   - Oak Ridge National Laboratory, U.S. Department of Energy, Oak Ridge, Tennessee
   - Socio-Economic Data and Applications Center (SEDAC), Lamont-Dougherty Earth Observatory, Columbia University, Palisades, New York
   - Goddard Space Flight Center, Greenbelt, Maryland
6. The SIPS provide data product generation at Instrument Team sites, and send the data via EBNet to the appropriate DAAC for archiving and general distribution. The SIPS produce data products in a way that takes advantage of the latest technologies and the instrument teams' expertise.

EOSDIS relies also on other agencies (such as USGS which manages the Landsat Data Processing system) and other countries (such as Japan for the ASTER science data production). EOSDIS allows direct access to data acquired from EOS satellites, selected pathfinder data holdings from the USGS and NOAA, and other heritage and ancillary data. Relationships with Canada, Japan, Russia, Israel, Australia and several European countries have been established for the exchange of data with EOSDIS. Many multi-agency efforts, in addition to the NASA EOSDIS, are working to improve data availability to the public, especially the Interagency U.S. Global Change Research Program (USGCRP) Data and Information Working Group and the Federal Geographic Data Committee.

NASA is looking to future data system needs and designs in several ways. The EOSDIS Working Prototype Federation experiment, initiated in 1998, is continuing to develop methodologies for decision making and interoperability in a collaborative, yet competitive, distributed data system topology. Members of the Federation represent the broad scientific and applications community and include representatives from educational institutions, industry, regional governments and consortia, and NASA data centers. NASA is also engaged in long-term planning for the evolution of the current Earth science data system. This New Data Information Systems and Services (NewDISS) comprises a distributed Earth science data system, which, over the next 6-10 years, will evolve from the current EOSDIS. NewDISS is planned to consist of a heterogeneous mix of interdependent components of numerous individuals and institutions. Because the ESE already has made a considerable investment in existing data system components (e.g., DAACs, ECS, SIPS, and ESIPs), as well as product generation, the near-term NewDISS will necessarily evolve from these existing activities. The

long term NewDISS structure could be quite different from the current, as data systems and services evolve to meet science-driven demands and to take advantage of technological innovation.

SCHEDULE AND OUTPUTS

EOSDIS Version 1 Plan: January 1997 Revised: Replaced	Provide support for science data processing, archival, and management of the data from the two EOS instruments operating on the TRMM spacecraft. The ECS contractor failed initial test readiness for EOSDIS Version 1 and NASA issued a Stop Work Order. Replacement systems were developed by EOSDIS at GSFC and LaRC, (extended "Version 0" in-house system), and the systems are performing successfully.
EOSDIS Version 2 Plan and actual: January 1999 through December 1999	Provide support for the launch of Terra and Landsat-7. The capabilities to meet the requirements were provided in a set of incremental deliveries beginning in January 1999 and ending in December 1999. EOSDIS Version 2 is successfully supporting operations of the Landsat-7 and Terra missions
EOSDIS Version 3 Plan: June 2000 Revised: December 2000	Provide science processing and flight operations support for Aqua and ICESat. EOSDIS components needed to meet the objectives of Version 3 are ready; integration and end-to-end testing are being carried out to match Aqua and ICESat launch schedules.
EOSDIS Version 4 Plan: December 2000 Revised September 2002	Provide science processing and flight operations support for Aura. Provide final incremental implementation of ECS A+ requirements. Schedule adjusted commensurate with Aura launch schedule.

ACCOMPLISHMENTS AND PROPOSED RESULTS

Providing broad and efficient access to data products is key to meeting the Agency's mission of advancing and communicating scientific knowledge and the successful functioning of EOSDIS is essential to the accomplishment of all three of the ESE's strategic goals. EOSDIS has been routinely providing and will continue to provide Earth science data products to end-users within 5 days of receipt of request or following production of the requested data product. These products comprise data from currently operating space assets including interdisciplinary data products from the Terra mission, land cover information from the Landat-7 satellite, ocean wind measurement from the QuikSCAT mission, precipitation measurements and observations of tropical storms from the Tropical Rainfall Measurement Mission (TRMM), ocean productivity measurements from the Sea-viewing Wide Field-of-view Sensor (SeaWiFS), detection of ocean surface height changes used to predict El Nino occurrence and strength from the Topex/Poseidon Mission, solar energy input to the Earth from ACRIMSat, and sea ice motion and Antarctic mapping from Canada's RADARSAT. Also provided are measurements on stratospheric dynamics and trace chemicals from the Upper Atmospheric Research Satellite (UARS), the Antarctic Ozone Hole from the Total Ozone Mapping System (TOMS), land use and land cover from the heritage Landsat missions, and measurements of Earth and solar radiation from the Earth Radiation Budget Experiment (ERBE).

The EOSDIS is currently supporting an unprecedented amount of data and information. As a comparison, the EOSDIS effectively handles in one day more Terra data than the Hubble Space Telescope handles in a year or than the Upper Atmospheric Research Satellite (UARS) handles in 1.5 years. Some key indicators of EOSDIS performance are the volume of data archived (over 500 Terabytes at the end of FY 2000, including heritage data), the number of users accessing the DAACs (just under 1.47 million distinct users in FY 2000), and the number of data products delivered in response to user requests (approximately 8.1 million data products delivered in FY 2000**]**. In the past year alone, the EOSDIS has supported a doubling of the entire NASA Earth science data holdings.

The ECS FOS supported a December 1999 launch of the Terra spacecraft and has successfully supported the Terra spacecraft and instrument operations through 2000. ECS FOS capabilities were extended to support Aqua spacecraft and instrument requirements, and ECS FOS successfully demonstrated these capabilities in a number of tests with the Aqua spacecraft conducted during 2000. The FOS Instrument Support Terminals (ISTs), which allow instrument operations teams to plan for the operation of their instruments and monitor instrument performance from their home institutions, are installed and are operational at all operations sites for the Terra instrument teams. ISTs have been installed at the major U.S. operations facilities in support of the Aqua spacecraft and instruments.

Other elements of EOSDIS are continuing to support the Terra mission. The EDOS overcame early problems with processing and distributing Terra science data (not unusual for a new mission of this complexity) and is successfully managing the Terra science data. Upgrades of EDOS to support Aqua and ICESat will become operational in mid FY 2001. The EBNet and Polar Ground Stations are satisfactorily supporting Terra operations (PGS is backup to TDRSS for Terra) and have made the necessary upgrades and enhancements to support the Aqua mission.

Development of the ECS SDPS has progressed well, and this segment achieved stable operations for Terra in 2000. The data are being processed at better than “keep-up” rates, data from the SIPS are being ingested, and all processed data are being archived and are available for distribution. The DAACs also continued to support the Landsat-7 mission. By the end of FY 2000 the DAACs had amassed close to 250 Terabytes of data from the Landsat-7 and Terra missions**.** The Terra Instrument Science Teams began planning for the first reprocessing of the Terra science data sets in FY 2001. System upgrades were made to improve user interface services, to add capabilities required for support of Aqua instruments, increase system capability, and to update to newer versions of Commercial-Off-The-Shelf (COTS) products. The Performance Verification Center (PVC) was established to provide an environment for testing fully loaded performance of new releases, prior to deployment to operational DAACs.

In FY 2000, the ECS contract was restructured, scaling back on some lower priority requirements, and adding new requirements for support of future missions such as Aqua, ICESat, and Aura. A sound cost baseline was established and the contractor has been performing well against this revised baseline.

The ECS Science and Flight Operations Segments were both verified to be compliant with Y2K in FY 2000 and encountered no problems with the year rollover. They received authority to process in December 2000, in accordance with the NASA Policy and Guidance (NPG) 2810.1 that mandates Information Technology (IT) security requirements for NASA data and systems. System changes to achieve full compliance with NPG 2810.1 will be made in FY 2001.

The evaluation, started in FY 1999, of proposals from all the EOS instrument teams interested in producing standard products using SIPS was completed in FY 2000. With four exceptions all of the instrument teams (including those for all instruments on Aura) have chosen to produce all standard products using SIPS. The MISR team on Terra and the AIRS team on Aqua generate their products using the SDPS at DAACs. The MODIS team (on Terra and Aqua) generates Level 1 products and a small number of Level 2 products at the GSFC DAAC, with the rest being produced at their SIPS. In addition, ASTER Level 1 data are produced in Japan and shipped to the EDC DAAC, where higher-level products are produced.

The EOSDIS Federation experiment continued in FY 2000. Federation members developed a constitution and bylaws and are establishing the rules and requirements for membership. The Federation now consists of 24 ESIPs, the eight DAACs and one EOS science computing facility (SCF). Twelve ESIPs focus on research, and science data set production and management while the remainder focus on commercial and extended applications. These groups are developing scientific products, collaborating with one another, both as single entities and in “clusters”, and collectively exploring data set interoperability.

NASA is continuing the long term planning for the evolution of the current Earth Science data system. A team of Earth and information scientists along with NASA managers developed a concept for the NewDISS, which will evolve from the current EOSDIS, the working prototype Federation experiment, and other ESE mission data systems.

The EOSDIS Core System (ECS) software deliveries are planned in FY 2001 to support requirements for the Aqua, Aura, and ICESat missions, and operations readiness testing will ensure that all systems are ready and able to support the Aqua and ICESat launches planned within the next year. Capabilities will be developed for people to create their own clients for searching and ordering data. The EOSDIS will continue to work to meet its planned performance targets. Indicators of this activity will be to continue making data available to users within 5 days of request and improving on prior year targets for archive, distribution, and number of customers served. The primary tasks in FY 2002 will be the operation and completion of the EOSDIS.

BASIS OF FY 2002 FUNDING REQUIREMENT

EARTH EXPLORERS

	FY 2000	FY 2001	FY 2002
		(Thousands of Dollars)	
Total Ozone Mapping Spectrometer	24,508	69	40
Earth System Science Pathfinders	90,000	111,598	84,013
VCL	*18,965*	*13,706*	--
GRACE	*24,632*	*16,113*	*6,500*
PICASSO-CENA	*24,783*	*26,399*	*29,130*
CloudSat	*19,137*	*47,625*	*37,670*
Program Support/Future missions	*2,483*	*7,755*	*10,713*
Experiments of Opportunity	1,000	499	500
Triana	35,100	24,934	--
University Class Earth System Science	2,292	475	--
Shuttle Radar Topography Mission	10,200	3,662	--
Total	163,100	141,237	84,553

PROGRAM GOALS

The name of the program has been changed from Earth Probes to align itself with the exploratory measurement definition/concept. The Earth Explorers Program is the component of Earth Science Enterprise that investigates specific, highly focused areas of Earth science research. It is comprised of flight projects that provide pathfinder exploratory and process driven measurements, answering innovative and unique Earth science questions. The program has the flexibility to take advantage of international cooperative efforts. It provides the ability to investigate processes having unique measurement requirements and which call for quick turnaround and reaction. The Earth Explorers missions consist of the Total Ozone Mapping Spectrometer (TOMS) series, the Earth System Science Pathfinders (ESSP) missions, the University Class Earth System Science (UnESS) pathfinders, Experiments of Opportunity, SRTM and Triana.

STRATEGY FOR ACHIEVING GOALS

TOMS

The scientific objectives of the TOMS project 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 model 1) on Nimbus-7 and continued with the TOMS instrument (flight model 2) on a Russian Meteor-3, launched in 1991, a TOMS (flight model 3) launched on the Japanese ADEOS in 1996 and the Earth Probe spacecraft also launched

in 1996. The development of a fifth TOMS instrument flight model 5, designated FM-5 has been completed, and was scheduled to fly as a cooperative mission with Russia in late 2000. However, in 1999 Russia indicated that it could not meet that launch date. Presently, the Agency has completed its re-planning and will fly FM-5, on a dedicated spacecraft mission called QuikTOMS. The QuikTOMS spacecraft was procured through the Indefinite Delivery Indefinite Quantity (IDIQ) rapid delivery spacecraft contract. The QuikTOMS observatory will be launched from Vandenberg Air Force Base as a secondary payload on a commercial Taurus launch vehicle in June 2001.

ESSP

The ESSP is a science-driven program intended to identify and develop in a relatively short time, small satellite missions to accomplish scientific objectives in response to national and international research priorities not addressed by current projects. ESSP will provide periodic "windows of opportunity" to accommodate new scientific priorities and infuse new scientific participation into the Earth science 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 first two ESSP missions were selected in March 1997. The Vegetation Canopy Lidar (VCL) mission, led by a University of Maryland, College Park Principal Investigator, is being designed to utilize a multi laser Light-Detection and Ranging (Lidar) instrument to map the vegetation canopy globally. The VCL mission is under replan. The VCL launch date is TBD. The second mission, Gravity Recovery and Climate Experiment (GRACE) is led by a Principal Investigator from the University of Texas at Austin with significant participation by the German Aerospace Center (DLR), which is providing mission operations, launch services and science data analysis. GRACE will utilize an advanced microwave ranging system between two identical formation flying spacecraft to measure the Earth's gravitational field to an unprecedented accuracy. The planned launch date of GRACE on a contributed ROCKOT launch vehicle is November 2001.

The second ESSP Announcement of Opportunity (AO) was released in the third quarter of FY 1998. The Pathfinder Instruments for Cloud and Aerosol Spaceborne Observations – *Climatologie Etendue des Nuages et des Aerosols* (PICASSO-CENA) mission, which was selected in December 1998, is led by a NASA LaRC Principal Investigator. The PICASSO-CENA mission is under replan and the launch date is TBD. PICASSO-CENA is designed to address the role of clouds and aerosols in the Earth's radiation budget. It will employ innovative Lidar instrumentation to profile the vertical distribution of clouds and aerosols. PICASSO-CENA consists of a partnership between NASA and France's Centre Nationale D'Etudes Spatiale (CNES). CNES is providing a PROTEUS spacecraft, the imaging infrared radiometer (IIR), payload-to-spacecraft I&T and spacecraft mission operations. In addition, under this second ESSP AO NASA chose two additional missions, CloudSat and the Volcanic Ash Mission (VOLCAM), for further study. Based on the study results completed in March 1999, NASA selected CloudSat for full development as an ESSP AO#2 mission. VOLCAM was selected as the alternate mission, but was discontinued in 2000 based on the formulation progress of PICASSO and CloudSat. CloudSat, led by a Colorado State University Principal Investigator, is designed to advance the understanding of the cloud-climate feedback question. The mission is focused on understanding the role of optically thick clouds on the Earth's radiation budget using an advanced Cloud-Profiling Radar instrument, and is expected to be launched on half a Delta in 2003. CloudSat is a collaboration between NASA, the Canadian Space Agency (CSA), and the U.S. Air Force; CSA is contributing instrument components and the U.S. Air Force is contributing ground operations.

NASA intends to solicit another set of ESSP missions via ESSP AO #3 in calendar year 2001.

Experiments Of Opportunity

This project offers a capability to undertake short duration flights of instruments on the Space Shuttle and other platforms. The ESE 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.

Triana

The Triana mission is an Earth observation spacecraft to be located at the Sun-Earth L1 point providing a near-term real time, continuous scientific observations of the full sun-lit disc of the Earth.

During 1998 the mission was studied at GSFC and NASA Headquarters released an AO in July soliciting proposals for full Triana mission implementation**.** A selection was made in November for the Scripps Institution of Oceanography to build and conduct the Triana mission. Triana is designed to carry the Earth Polychromatic Imaging Camera built by Lockheed Martin Advanced Technology Company, a radiometer built by the National Institute of Standards and Technology, and a plasma magnetometer that measures solar wind built by GSFC and the Massachusetts Institute of Technology. In October 1999, the Triana mission suspended work per Congressional direction, while the National Academy of Science (NAS) conducted its review of the scientific merits of the mission. In April 2000, after a favorable finding, work was restarted. However, the stand down resulted in a delay of the launch readiness date of no earlier than April 2002. Because the launch date for Triana remains uncertain until the Shuttle manifest becomes definitized, Triana will be placed in storage following completion of spacecraft development.

UnESS

UnESS was to consist of spaceborne investigations of modest science scope. These investigations were to be lead by U.S. University principal investigators with significant student involvement. The first Announcement of Opportunity was released in August 1999, and resulted in the award of four Phase A studies. The program is being cancelled to fund immediate priorities in the Earth Science budget. A small amount of funding will be retained for these activities to complete contractual obligations associated with proposal evaluations.

SRTM

The Shuttle Radar Topography Mission (SRTM) flown on STS-99 in February 2000, was a joint National Aeronautics and Space Administration (NASA) and National Imaging and Mapping Agency (NIMA) mission which collected an unprecedented 8 Terabytes of interferometric Synthetic Aperture Radar (SAR) data (equivalent to about 12,300 CDs). This data will be processed to provide topographic data products over approximately 80% of the Earth's landmass (between 60° North and 56° South latitude).

Development, integration and test, and checkout of the complex, first-of-a-kind processing system will take 19 months, from February 2000 to August 2001. Subsequent production of the topographic products will take 9 months, from September 2001 to May 2002.

SCHEDULE AND OUTPUTS

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.

TOMS FM-5 (QuikTOMS) Plan: August 2000 Revised: June 2001	QuikTOMS is co-manifested as a secondary payload with Orbview 4. Orbview 4, the primary payload, is experiencing integration and test difficulties, which are causing a launch delay.
Vegetation Canopy Lidar (VCL) Plan: May 2000 Revised: TBD	The initial launch delay was due to a launch vehicle change from a Pegasus to an Athena. Further delays in instrument and spacecraft bus development have led to the additional TBD launch delay. The Athena I originally designated to launch VCL from Kodiak Island, Alaska will now launch the KODIAK Star payload compliment. A new launch vehicle has not been selected for VCL. New launch date is under review.
Triana Plan: December 2000 Revised: TBD	Congressional mandated work suspension resulted in Triana being unable to support the previously assigned STS launch. Re-manifesting has resulted in TBD launch date.
Gravity Recovery and Climate Experiment Plan: June 2001 Revised: November 2001	Re-planned launch date reflects delays in flight software and instrument development.
PICASSO-CENA Plan: 2nd Qtr FY 2003 Revised: TBD	Based on findings from the PICASSO-CENA Mission Confirmation Readiness Review, the program was directed to postpone the final confirmation decision. PICASSO is expected to conduct a Delta Confirmation Readiness Review in March 2001, at which time a launch date will be determined.
CloudSat Plan: 2nd Qtr FY 2003 Revised: 3rd Qtr FY 2003	In November 2000 CloudSat successfully completed the confirmation review process which resulted in a launch readiness date of the Third Quarter FY 2003.

ACCOMPLISHMENTS AND PROPOSED RESULTS

TOMS

The QuikTOMS (TOMS FM-5) instrument has been completed and delivered for observatory integration. The QuikTOMS spacecraft bus is currently in integration and test. The QuikTOMS observatory is expected to be able to support the LRD as dictated by Orbview 4, the primary payload.

ESSP

VCL is in the process of being re-baselined and a new LRD will be determined once this process is complete. The Multibeam Laser Altimeter (MBLA) instrument is in development having fully characterized the flight laser design, while the spacecraft bus is in an Integrated System Test. GRACE instrument deliveries are nearly complete, the two spacecraft buses are complete and system level testing will begin in February 2001, with a scheduled launch of November 2001. PICASSO-CENA has completed its preliminary design review and is in the mission confirmation process with implementation expected to begin in April 2001. CloudSat completed formulation in December 2000 and is in implementation with a critical design review scheduled for August 2001. The third ESSP AO draft has been released for comment and the final announcement is expected to be released in 2001.

Experiments of Opportunity

The Experiments of Opportunity Program is the funding source for NASA's participation in the *Satellite de Applicaciones Cientificas-C* (SAC-C) mission. SAC-C is a joint mission between NASA and the Argentine Space Agency (CONAE). The mission was co-manifested with NASA's New Millennium Earth Orbiter-1 mission and was launched November 21, 2000. NASA provided the launch vehicle, scalar helium magnetometer and GPS receivers. The Argentines provided the spacecraft and various instruments such as multispectral scanner, and high-resolution camera. Calibration/validation was completed in the First Quarter of 2001.

TRIANA

Both the spacecraft and instruments have been assembled and are nearing completion of environmental test. The work on the spacecraft and instruments will be completed, and documented prior to storage.

BASIS OF FY 2002 FUNDING REQUIREMENT

RESEARCH AND TECHNOLOGY

	FY 2000	FY 2001	FY 2002
		(Thousands of Dollars)	
Earth Science Program Science	286,399	350,626	357,453
Applications, Commercialization and Education	84,400	114,081	--
Applications, Education, and Outreach (FY 2002 and out)			63,200
Technology	94,515	114,951	96,000
Construction of Facilities.....	1,000	--	--
Total.....	466,314	579,658	516,653

PROGRAM GOALS

The goal of Research and Technology 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 Research and Technology program is divided into three components:

- Research that supports basic Earth science research, analysis, and data analysis of related EOS and other mission science data. Included is the suborbital science program of crewed aircraft and uninhabited aircraft available to researchers and PIs. There is both disciplinary-oriented science that typically focuses on one component or process of the Earth system and interdisciplinary science that emphasizes the linkages between Earth system components. Also included are funding for high performance computing and communications, and the provision of computing infrastructure.

- Applications, Education and Outreach that supports applications program planning and analysis, research, development, and the transfer of knowledge and awareness of ESE science and technology applications through education and outreach in the areas of disaster management, resource management, environmental quality and community growth.

- Earth Science advanced technology that supports development of key technologies to enable our future science missions by reducing their development time and cost.

Each of the major components of Research and Technology has its own set of goals, strategies for achieving goals, performance measures, and accomplishments and plans.

BASIS OF FY 2002 FUNDING REQUIREMENT

EARTH SCIENCE PROGRAM SCIENCE

	FY 2000	FY 2001	FY 2002
		(Thousands of Dollars)	
Research and Analysis – Science	141,849	170,225	167,922
EOS Science	55,000	48,393	54,341
Mission Science Teams - Research	55,850	96,188	94,590
Airborne Science and Applications	23,100	22,649	23,000
Uncrewed Aerial Vehicles (UAV)	3,000	3,492	4,000
Information Systems	7,600	9,679	13,600
Total	286,399	350,626	357,453

PROGRAM GOALS

Earth science research is driven by the hierarchy of scientific questions defined in the Earth Science Research Strategy for 2000-2010. The program goal is to contribute to the development of an improved scientific understanding of the Earth system and the effects of natural and human-induced variations on the global environment. The science program provides the analysis and integration of critical data and models needed to characterize the variability in the earth system and the natural and human-induced forcing factors that affect it; to understand the process by which the Earth system responds to forcing; the regional and global consequences of Earth system variability; and to develop the predictive capability for the Earth system.

STRATEGY FOR ACHIEVING GOALS

The Research and Analysis (R&A) science project is essential to the discovery of new concepts and techniques and serves as the ultimate source of scientific advances that lay the ground work for future satellite missions. The primary mode of research coordination and planning occurs through cooperation under the USGCRP, overseen by the Committee on the Environment and Natural Resources (CENR) Subcommittee on Global Change Research, and the various boards and committees at the National Academies of Sciences. NASA ESE manages its R&A budget largely according to five theme areas: Biology and Biogeochemistry of Ecosystems and the Global Carbon Cycle, Atmospheric Chemistry, Aerosols and Solar Radiation, Global Water and Energy Cycle, Oceans and Ice in the Earth System, and Solid Earth Science. There is also a strong emphasis on assuring an appropriate environment to nurture interdisciplinary science. The Natural Hazards portion of this latter area is addressed under the Applications, Education and Outreach program.

The aim of Earth system science is to increase scientific understanding of the global environment and its vulnerability to both human and natural factors of change (e.g. pollution, climate variability, and deforestation). Viewing the Earth from space is

essential to comprehending the combined influence of human activities and natural variability on its global 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 global-scale objective information on the human use of land in a time of rapid land use development. Another priority is to improve understanding and prediction of transient climate variation, such as El Niño anomalies and to characterize and understand the effects of such variations on the terrestrial and oceanic biosphere. Reducing uncertainties in climate predictions a season or a year in advance would dramatically improve agriculture and energy utilization planning. There is increasing evidence that predictions of extreme weather events can be improved by understanding their links to interannual climate phenomena like El Niño events. Special attention is being given to measuring and modeling the effects of climate forcing factors like clouds, solar radiation, aerosols and greenhouse gases in order to improve our assessments of climate trends on time scales of decades to centuries. There is also appreciable effort going into identifying those processes that couple the biosphere and climate. A continuing priority is to understand the causes and consequences of changes in atmospheric ozone and the feedback processes between atmospheric chemical and climate change. Emphasis is also placed on the changing composition of the lower atmosphere, which is sensitive to the unprecedented increase of pollutant emissions in rapidly developing regions throughout the world.

EOS science consists of research aimed to assure that the EOS data can be accurately validated to ground, airborne and other space-based measurements, and interdisciplinary investigations oriented towards improving understanding of how the Earth works as a system involving multiple interacting components. The former is needed to assure the quality of data produced by EOS instruments, many of which will be producing the first space-based data of their type. The latter are needed to assure creative use of multiple data types together with research models to address questions associated with the linkage between Earth system components.

The objectives of the mission science team/guest investigators are to analyze data sets from operational spacecraft that 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.

The airborne science project funds operations of two ER-2s, one DC-8 aircraft, and one P-3B. The project funds operation and support of a core of remote sensing instruments and a facility for analyzing and calibrating data from those instruments. The specially modified aircraft serve as test beds for newly developed instrumentation and their algorithms prior to space flight. The instrumented aircraft provide remote sensing and *in situ* measurements for many Earth science research and analysis field campaigns in all ESE science areas throughout the world. The ER-2 aircraft, in particular, are unique in that they fly well into the stratosphere and were key in collecting *in situ* data for our understanding of ozone depletion and stratospheric transport mechanisms. One of these provided support and observations, including over flights of hurricane *Georges*, for an interagency experiment designed to improve our capability to predict hurricane landfall and intensity. The DC-8 aircraft provides a unique "flying laboratory" facility for a broad range of disciplines in atmospheric sciences. The P-3B is used mainly for lower altitude operations. Many process-oriented studies involve the use of two or more aircraft together with ground and or balloon-based instruments.

NASA is implementing an Uninhabited Aerial Vehicle (UAV) science demonstration program in order to provide an opportunity for the Earth science research and applications communities to utilize UAVs in a small number of missions over the next few years.

This demonstration program should help to provide experience in the scientific use of UAVs under a variety of operating environments and conditions such as flights of 24 hours and longer duration, higher altitudes at subsonic speeds, and flights in environments hazardous to the onboard pilot in traditional aircraft. Examples of missions that may be enabled by UAVs are those to observe diurnal changes of key atmosphere, oceanic and land surface processes, or missions to observe key Antarctic or volcanic phenomena which have been inaccessible for pilot safety reasons.

The Earth science information system project 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 project funding supports operation of a supercomputing center (the NASA Center for Computational Sciences) at GSFC. A full range of computational services is 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 project monitors and participates in advanced technology projects, such as the HPCC program and National Science Foundation's gigabit test bed programs. Project elements at GSFC and 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 project 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.

SCHEDULE AND OUTPUTS

The scientific issues of concern to Earth science are among the most complex and policy relevant of any major scientific research program. The results of Earth science program science are critical to the development of sound U. S. and global environmental policy, necessary for long-term sustainable development. Each of the science theme areas discussed in the accomplishments and plans section describe performance targets to ensure that the goal and objectives of the Earth science program science are met. A summary schedule and outputs relating to management, business practices, and bases for comparisons applicable to the whole Earth science program are in the table below.

Research & Analysis	FY 2000 Estimate/Actual	FY 2001 Estimate	FY 2002 Estimate
Number of principal investigators	1,100/977	1,208	1,216
Number of research tasks under way	1,525/1,530	1,906	1,919
Average duration of research tasks	3 years	3 years	3 years
Number of science solicitations released	12/9*	12	12
Number proposals received	1,125/834	1,125	1,300
Number of proposals rated very good to excellent	550/pending		
Number of proposals selected	360/pending		
Time to process proposal (selection through obligation)	30 days	45 days	45 days
Number of days until funding is released	Simultaneously with award	Same	Same
Percent of R & A funding obligated:			
Current Budget Authority:	100%/92%	95%	95%
Prior Budget Authority:	100%	100%	100%
Percent of program reviewed by science peers	95%	95%	95%

* Estimate revised due to consolidation of solicitations.

ACCOMPLISHMENTS AND PROPOSED RESULTS

Research & Analysis -- EOS Science

In FY 2000, continuing into FY 2001 and FY 2002, the following are significant accomplishments in the areas of Biology and Biogeochemistry of Ecosystems and the Global Carbon Cycle, Atmospheric Chemistry, Aerosols and Solar Radiation, Global Water and Energy Cycle, Oceans and Ice in the Earth System, and Solid Earth Science.

Biology and Biogeochemistry of Ecosystems and the Global Carbon Cycle: understanding changes in terrestrial and marine ecosystems and assessing their consequences for productivity, resource management, and ecosystem health.

NASA research on the biology and biogeochemistry of ecosystems and the global carbon cycle aims to understand and predict how terrestrial and marine ecosystems and biogeochemical cycles are changing. Current emphasis is on remote sensing-oriented carbon cycle science. This research addresses ecosystems as they are affected by human activity, as they change due to their own intrinsic biological dynamics, and as they respond to climatic variations and, in turn, affect climate. Research approaches range from detailed process-level studies, to global-scale observations of productivity and carbon sources and sinks, and to mechanistic modeling of ecosystem dynamics and carbon cycling processes. Major research activities focus on: quantifying changes in the global carbon cycle, especially major fluxes and the active land, ocean, and atmospheric reservoirs; documenting changes in land cover and land use; characterizing the processes that affect the Earth's capacity for biological productivity, and understanding the role of the biosphere in Earth system function.

Accomplishments

Research in FY 2000 builds on the accomplishments of previous years towards advancing the development of models of carbon uptake by terrestrial and marine ecosystems, the creation of quantitative satellite data products, and the increase in understanding of ecosystem processes important for carbon cycling.

The Synthesis and Modeling Program (SMP) of the Joint Global Ocean Flux Study (JGOFS) has developed models along three distinct but related paths: identifying carbon sources and sinks, biogeochemical cycles, and ecosystem dynamics. The SMP has been combining data from JGOFS field programs and satellite data products into models which are then used to improve parameterizations of biogeochemical processes and for skill-testing through detailed model-data comparisons. Models now include multi-element cycling (phosphorus, silicon and iron, in addition to nitrogen) and parameterizations of planktonic community structure. There are now parameterizations for calcification and nitrogen fixation that are being tested in SMP models. Reasonable, large-scale distributions of phytoplankton species can now be reproduced in global ocean models. Ocean-atmosphere and land-ocean interactions are being included, especially the former since atmospheric deposition of iron seems to be an important driver of ocean biogeochemistry. Models are also being used to investigate interannual variability, such as the Pacific-Decadal Oscillation, and future atmospheric carbon dioxide scenarios.

SeaWiFS marked its third anniversary of uninterrupted data on ocean color, and MODIS began producing a wide array of data products on marine ecosystems. Ocean color data products were combined with other satellite data on ocean properties to learn more about the interaction of biological with physical processes such as upwelling and mixing. Ocean color data were used to show the fishing industry where to deploy fishing vessels. SeaWiFS data also was used in a comprehensive study of temporal change in the Earth's biosphere as a result of the 1998-1999 El Niño/La Niña cycle.

The Sensor Inter-comparison and Merger for Biological and Interdisciplinary Ocean Studies (SIMBIOS) project has successfully merged data sets from ocean color scanners from international collaborators to create a seamless, inter-decadal time series of ocean color. These data are being used to derive more comprehensive information about global ocean productivity that is so important to understanding the ocean's response to climate change. In FY 2000 SIMBIOS expanded its international reach, and is now the definitive program for calibration/validation, merger, and inter-comparison of different ocean color sensors.

Near-daily global measurements of the terrestrial biosphere were collected by the Terra MODIS instrument, starting in February 2000. Overlap with the NOAA Advanced Very High Resolution Radiometer (AVHRR) sensor, to establish continuity of the data from the AVHRR to that from MODIS, was achieved, and research to establish quantitative relationships between AVHRR and MODIS data products is nearing completion. The MODIS global Level 0 data, as well as the Level 1A and 1B data (processed, calibrated data), are being archived at the Goddard Space Flight Center (GSFC) Distributed Active Archive Data Center (DAAC). In 2000, a rigorous program of research was conducted to calibrate and validate Terra's biospheric data and data products. Activities included refinement of algorithms and uncertainty estimates based on near-direct comparisons with correlative data such as simultaneous aircraft observations and *in situ* measurements of targets on the Earth's surface and in the atmosphere that have known, stable, or well-measured physical properties. Major field campaigns were conducted, such as Southern African Regional Science Initiative-2000 (SAFARI-2000), and smaller calibration and validation studies to check primary productivity data products.

Preliminary results from the on-going Large Scale Biosphere-Atmosphere Experiment in Amazonia (LBA) study are yielding new insights into the complexity of carbon cycling in Amazonia, with important implications for global carbon budgets and how processes are captured in biogeochemical cycling models.

Synthesis of results from the Boreal Ecosystem-Atmosphere Study (BOREAS) and several other major research programs in North American boreal and arctic ecosystems described the strong role that high-latitude ecosystems play in the climate system. Average temperature and precipitation have increased in the region, but changes in soil moisture are uncertain. Disturbance has increased; in particular, there has been a doubling of the area burned in the past 20 years. There are wide discrepancies among estimates of the size and direction of carbon dioxide fluxes between high-latitude ecosystems and the atmosphere that have not yet been resolved, but appear to relate more strongly to the analytical model chosen than the underlying data. This has set the stage for simple tests to reconcile or resolve the differences and, as a direct result, reduce major uncertainties in estimation of regional carbon dioxide fluxes and the Northern Hemisphere carbon sink.

NASA contributed to the First National Assessment of the Potential Consequences of Climate Variability and Change by providing satellite data and modeling analyses. This contribution included production of climate and ecosystem change/response scenario information and support of research for several U. S. and regional studies. The information provided for the National Assessment, as well as the results of the assessment, will be used to improve predictive models of land cover change and its impacts on natural resources and environmental quality within the U.S.

NASA participated in the SAFARI-2000 field campaign in southern Africa. This study is quantifying the effects of climate variability and management practices on the environment, as well as providing significant information on the transfer of carbon between the atmosphere and the vegetated land surface. NASA conducted a major airborne campaign in fall, 2000 that flew *in situ* and remote sensing instruments over southern Africa to measure many physical, radiative, chemical and biological properties of the land surface and atmosphere. Scientists and policy-makers plan to use the data from the SAFARI 2000 campaign to quantify the annual carbon emissions from southern Africa. SAFARI-2000 data are also being used extensively to validate EOS Terra data and data products.

Plans

NASA will continue to explore the dynamics of the global carbon cycle by developing, analyzing, and documenting multi-year data sets. In addition, new remote sensing oriented carbon cycle research will be initiated to: (1) identify, characterize and quantify global and regional sources and sinks for carbon, (2) develop, improve, and evaluate carbon cycle models, (3) use estimates of global and regional primary productivity to better understand carbon dynamics, and (4) develop new techniques, algorithms, and/or analytical approaches for deriving carbon cycle information.

The SIMBIOS project will continue to merge MODIS ocean color data into the global ocean color time series that began with Ocean Color Temperature Sensor (OCTS) and SeaWiFS. Also, the contemporaneous MODIS and SeaWiFS data will provide much improved temporal and spatial coverage of the ocean for productivity studies. This multiyear global time series will be analyzed to derive phytoplankton biomass and primary productivity for assessing interannual variability in marine ecosystems on regional scales and daily to interannual time scales. It also will be used to help understand and predict the response of marine ecosystems to climate

change. ESE will continue the ocean color time series with 60% global coverage every four days. This will allow continued monitoring of global ocean productivity and identification and quantification of the ocean carbon sink(s). Data from EOS Aqua's MODIS should become available in FY 2001/2002 to add to the temporal coverage. Data from Terra and Aqua also will be used to estimate the efficiency of the carbon uptake by phytoplankton and demonstrate the value of such measurements in assessing carbon and nitrogen cycling in the open ocean.

NASA will continue the development of global land cover/use change and other data products based on Landsat and MODIS data, and provide these, along with new land cover and ocean productivity data from SeaWiFS, as preliminary products and analyses for the Millennium Ecosystem Assessment. The development and production of a global Landsat land cover product for 1999-2000 will be initiated. First results from the Global Observations of Forest Cover (GOFC) project of the Committee on Earth Observing Satellites (CEOS) will be produced based on Landsat-7 data.

NASA will continue collecting near-daily global measurements of the terrestrial biosphere from instruments on EOS Terra and Aqua starting in 2002, and will release the first science quality, derived data products from MODIS for terrestrial and marine primary productivity. These data will be used to assess agricultural and forest productivity and forecast regional food shortages and certain disease and pest outbreaks. They also will help in estimating terrestrial biosphere carbon exchanges with the atmosphere and in developing global and regional carbon budgets.

New research investigations will be solicited for the LBA field campaign's ecological component to continue critical observations, address any gaps and new research direction, and initiate the synthesis and integration phase for LBA research.

Atmospheric Chemistry, Aerosols and Solar Radiation: monitoring and predicting how atmospheric composition is changing in response to natural and human-induced factors and how atmospheric composition responds to and influences climate.

Atmospheric change is the result of strongly interactive chemical and physical processes. Chemistry plays an important role in determining weather and climate, while the physics and dynamics of the atmosphere influence chemical processes and composition. The goals of the atmospheric Chemistry research program are to measure and understand how atmospheric composition is changing in response to natural and anthropogenic forcings, and enable accurate prediction of future changes in ozone and surface ultraviolet radiation, climate forcing factors, and global pollution.

Accomplishments

Fulfilling its Congressional mandate for upper atmosphere and ozone research, ESE has continued to provide the research community with total column ozone, ozone vertical profile, and related data sets. ESE continues to expand understanding of the chemical processes of ozone destruction and replenishment in the stratosphere through a combination of laboratory work, field experiments, and modeling, and is increasing its study of the complex chemistry of the troposphere, the lower portion of the atmosphere in which we live. ESE employs this capability to make essential contributions to international scientific assessments of ozone by the World Meteorological Organization (WMO), as well as interim studies carried out under the auspices of other groups, such as the Stratospheric Processes and their Role in Climate (SPARC) subgroup of the World Climate Research Program. NASA's contributions in this area are to develop and operate space-, airborne-, and ground-based instruments that will map the

fluctuations in ozone, aerosols and related constituent gases in the atmosphere, as well as develop models that can be used to simulate prior and future evolution of atmospheric composition. These models will provide added insight into changes in the atmosphere and potentially its influence on climate.

In FY 2000 NASA utilized an integrated program of space, aircraft, balloon, ground-based and laboratory measurements, along with global and process scale modeling activities to achieve a number of significant accomplishments toward understanding the causes of variations in ozone concentrations and its distribution in the upper and lower atmosphere. In particular, NASA implemented the SAGE Ozone Loss and Validation Experiment (SOLVE). Measurements were made during the timeframe of October 1999 - March 2000 in the Arctic and high-latitude region in winter using the NASA DC-8 and ER-2 aircraft, as well as ground-based and balloon platforms. The mission also acquired correlative data needed to validate the SAGE III satellite measurements that will be used to quantitatively assess high-latitude ozone loss.

The initial analysis and publication of the PEM-Tropics-B field experiment were completed in FY 2000. This information is providing improved knowledge of the processes by which trace gases and aerosols can be transported over long distances from source regions to otherwise less polluted regions of the atmosphere.

In FY 2000 ground-based, balloon-based, and airborne in situ and remote-sensing measurements continued to show evidence that the halogen burden in the lower stratosphere has leveled off and may be starting to decline in response to actions taken in response to the Montreal Protocol. This stratospheric peaking follows a similar occurrence observed in the troposphere several years ago. This information demonstrates consistency in our knowledge of the transport of chemicals between the troposphere and the stratosphere and of atmospheric chlorine chemistry and helps lend further credence to the models used to assess future atmospheric chemical change.

The Total Ozone Mapping Spectrometer (TOMS) continued to provide a global view of the variability of total ozone abundance, which will enable the detection of the anticipated future increase in ozone associated with reductions in the atmospheric halogen burden. The production of three new data products from TOMS data continued in FY 2000. Algorithms were improved for providing surface ultraviolet (UV), tropospheric ozone column amounts, and UV absorbing tropospheric aerosols as daily products. Progress continued in understanding the characteristics in the Solar Backscatter Ultraviolet (SBUV2) satellite measurements in order to intercompare with the overlapping TOMS data set and to gap fill the periods without TOMS data. This has resulted in the release of a new continuous 20-year ozone data set, which represents one of the primary long term records of Earth system change and is used in the evaluation of atmospheric chemistry models as well as input to climate change models.

The first year of data from the Southern Hemisphere Additional Ozonesonde (SHADOZ) network was obtained. Tropospheric ozone values obtained from TOMS data were compared with integrated tropospheric ozone values from SHADOZ to assess the accuracy of the TOMS tropospheric ozone algorithms. SHADOZ data have begun to be used to help improve knowledge of the climatology of ozone in the southern subtropics.

Satellite data from the Second Stratospheric Aerosol and Gas Experiment (SAGE II) together with ground-based lidar data have shown that the distribution of stratospheric aerosol amounts continue to be as low or lower than they have been since accurate global measurements began. In response to the launch delays for the SAGE III instrument due to problems experienced by our

Russian partner, the ESE continued its support of the operation and data processing for the DoD Polar Ozone and Aerosol Mission (POAM) satellite instrument, thereby providing high latitude data on distribution of ozone, aerosols, water vapor, and nitrogen dioxide. The POAM instrument, which uses a similar observing geometry and observational technique as SAGE III, was an integral component of the SOLVE campaign. The SAGE and POAM data will help improve our knowledge of stratospheric aerosols under these new background conditions and their contribution to atmospheric chemical change.

Plans

Stratospheric model development is increasingly focussed on enhanced prognostic ability for Northern hemisphere high latitude ozone loss in an atmosphere perturbed by a growing abundance of greenhouse gases. The work in model development and evaluation makes use of comprehensive analysis of data from the SOLVE coordinated field experiment, which provides detailed observations of the chemical and aerosol distributions present in the Arctic atmosphere.

Work will be done to characterize atmospheric plume flowing out of East Asia; its evolution as it transits eastward over the Pacific Ocean, and its contribution to global atmospheric chemical composition. In FY 2001, a major multi-aircraft campaign known as the Transport and Chemical Evolution over the Pacific (TRACE-P) will be conducted in East Asia to help assess the effects of outflow of trace gases and particulates into the Western Pacific Ocean. This mission will incorporate the use and analysis of satellite data and atmospheric models, and improve our understanding of the way in which changes in global atmospheric chemistry affect and are effected by changes in regional air quality.

The ESE will continue to monitor and assess the impact of the Montreal Protocol and the Framework Convention on Climate Change with globally distributed measurements of the surface level concentrations of long-lived industrially produced trace gases and other biogenically-produced gases such as methane and nitrous oxide. These observations will use the Advanced Global Atmospheric Gases Experiment (AGAGE) in situ network of gas chromatographic and gas chromatographic/mass spectrometric instruments. The focus of these observations will be to continue to document the decrease in the abundance of several industrially produced halocarbons regulated under the Montreal Protocol, observe the early decline of other compounds, and track the further increases in yet other compounds that are radiatively and/or chemically active in the atmosphere. The AGAGE network will continue to closely coordinate with related networks of NOAA and NASA's international partners around the world to assure consistency in the global observation set for these compounds.

ESE will provide improved assessment of the role of the global budget of carbon monoxide and methane (including its role in the global carbon cycle) through the development of the first global climatology of carbon monoxide and total column methane using data from the MOPITT instrument aboard the EOS-Terra satellite. Data assimilation techniques combining these MOPITT measurements with chemical transport models of the atmosphere will be used to help characterize interannual differences in global emissions. Detailed validation of the MOPITT data products based on observations made with a variety of surface- and airborne-based in situ sampling, as well as ground-based optical remote sensing instruments, should enable the development and distribution of improved data products. The data will improve our understanding of the contribution of fires and fossil fuel combustion to global pollution and to better assess our knowledge of the sources of methane and thus its potential contribution to atmospheric and chemical climate change. The analysis of integrated observations involving MOPITT and the aircraft participating

in the TRACE-P mission should also provide unique insights into both the role of pollution on large scale tropospheric chemical composition and on the retrieval algorithm used by MOPITT for measurement of carbon monoxide,

ESE will provide continuity of multi-decadal total ozone concentration measurements using the existing Earth Probe TOMS satellite instrument and its successor the QuikTOMS spacecraft, planned for launch in late FY 2001, and related space and ground based total ozone measurements. The verification of the QuikTOMS data set and its integration into the longer-term data record should be completed in FY 2002. The extended data set will aid in the characterization of long-term evolution of ozone and enable assessment of anticipated ozone recovery processes, and in assessment of the adequacy of current international regulations to protect the ozone layer in a changing climate. The recent behavior of ozone as reflected in this extended ozone data record, together with that of related parameters, will be analyzed and contributed to the 2002 edition of the WMO ozone assessment.

We will continue and extend the data record from the Southern Hemisphere Additional Ozonesonde (SHADOZ) network. These measurements will contribute to the development of a climatology of the high-resolution vertical distribution of ozone in the tropics and will improve the retrievals of tropospheric ozone concentrations based on the residual products from space-based observations. In particular, the extension of the data set should provide an excellent sense of the role of interannual variability of troposheric ozone concentrations in this little measured latitude band, and should play a particular role in helping to establish the validity of tropospheric ozone products from QuikTOMS and other satellite observations (e.g., the European Space Agency's ENVISAT) as well as the tropical stratospheric ozone profiles to be obtained by SAGE III using its lunar occultation mode.

We will continue the long-term (multi-decade) record of the evolution and interannual variability in high latitude ozone, aerosol, and polar stratospheric cloud profiles through the launch of SAGE III scheduled for late 2001. In FY 2002, data from this new instrument will be combined with those from previous instruments such as SAM, SAM II, SAGE, SAGE II, and POAM. This will improve our knowledge of the role that ozone changes may play in contributing to climate change as well as the way in which ozone, aerosol and polar stratospheric cloud concentrations may respond to climate variation. The SAGE III instrument should provide the first ever space-based observation of the vertical profiles of Symmetrical Chlorine Dioxide (OCLO) and Nitrogen Trioxide (NO_3); the former is a particular marker of the halogen chemistry known to be responsible for high latitude ozone depletion.

ESE will continue to explain the dynamics of atmospheric composition by building improved models and prediction capabilities. These coupled aerosol-chemistry-climate general circulation models (including projected changes in anthropogenic emissions) will examine changes in atmospheric composition projected over the 21st century. This first-time parameterization of tropospheric aerosol chemistry will help to diagnose the climatic consequences of such emissions and the associated feedbacks on atmospheric composition. Estimates of the stratospheric contribution to tropospheric ozone will be made through chemical transport and Lagrangian transport models. The stratosphere-troposphere exchange included in these model calculations will be examined for its sensitivity to global warming. The implementation of the Global Modeling Initiative (GMI) will also continue in order to provide metrics, benchmarks, and controlled numerical experiments for model and algorithm simulations performance. This will allow the development of standards of model behavior for participation in assessment exercises.

ESE will continue laboratory studies designed to assess the atmospheric fate of new industrial chemicals by characterizing the key photochemical processes (photolysis, reaction with Hydroxyl (OH) responsible for their atmospheric breakdown. In addition, improved laboratory spectroscopic measurements of the water vapor continuum will be conducted in FY 2001 and FY 2002 in order

to reduce the uncertainty in the retrievals of upper troposphere/lower stratosphere water vapor from microwave soundings. In FY 2002, the first results should begin to be obtained from several laboratory studies initiated in late FY 2001 to improve knowledge of the spectroscopy needed for accurate retrieval of data from the HIRDLS, TES, and MLS instruments to fly aboard the Aura spacecraft scheduled for launch in FY2003.

Global Water and Energy Cycle: determining the partitioning and exchange of water and energy between the atmosphere, ocean and land and the consequences to the availability of fresh water.

The principal research objective is to explore the connection between weather processes and climate change and the fast dynamical/physical processes that govern climate responses and feedbacks. Particularly significant is the transformation of water among its three physical states – vapor, liquid, and ice - in the atmosphere and at the surface of the Earth. The condensation of water in cloud and snow control both the albedo and radiation balance of the planet, and the constant renewal of fresh water resources. The development of weather systems, cloud life cycles and their role in the water and atmospheric energy cycles are approached as a single integrated problem. Another central science objective is exploring the responses of hydrologic regimes to changes in climate (precipitation, evaporation, and surface run-off) and the influence of land use practices and natural processes on surface hydrology (soil moisture, snow accumulation and soil freezing) and water resources.

Accomplishments

In FY 2000 the ESE continued to invest in observations, research, data analysis, and modeling in this area. The Tropical Rainfall Measuring Mission (TRMM), launched in 1997, completed its third year of gathering information on rainfall in the tropics where two-thirds of global precipitation falls, and about which there had been little knowledge of its distribution. This is the key to understanding Earth's hydrological cycle, one of the three major processes driving Earth's climate and the global heat balance which drives seasonal change. The data from these measurements are available through EOSDIS. Tropical rainfall estimates from TRMM have further converged (Kummerow et al., 2000) and been combined with other satellite and surface-based measurements to establish a standard for comparison with previous data sets and climatologies. The diurnal variation of precipitation over the oceans has been documented with the first two years of TRMM data and shows a distinct early morning peak. The utility of precipitation information as input into numerical weather forecasting models for improvement of weather forecasts, including hurricane forecasting, has also been shown using a combination of TRMM and other precipitation data. This information will provide a scientific basis for quantitative precipitation forecasts in tropical regions, a principal scientific objective of global climate change research and the U.S. Weather Research Program. The Goddard DAAC distributed TRMM data to 220 users during the mission lifetime up to this point.

The NASA Seasonal to Inter-annual Prediction Project (NSIPP) has implemented a baseline coupled climate prediction system, consisting of the Aries global atmospheric model coupled to the Poseidon global ocean model. Experimental forecasts are able to predict tropical Pacific Sea-Surface Temperatures (SSTs) up to six months in advance. The ocean model has been successfully initialized using Special Sensor Microwave/Imager (SSM/I) surface winds data, a combination of in situ and remotely measured SST's, and sub-surface temperature data from TOGA Atmosphere-Ocean (TAO) moorings. Assimilation of sea surface height data from Topex/Poseidon is now underway and will be used for the initialization of coupled forecast experiments. Future tests will include the use of QuikSCAT surface winds in the ocean initialization procedure. The Mosaic catchment land surface model has

been developed and shown to yield improved representations of the effects of sub-grid-scale topographic variability and of soil physics in meteorological models. Knowledge of soil moisture has been shown to lend to a significant improvement in predictability of precipitation over much of the U.S. in summer. A simple three-layer snow model has been added. The snow model accounts for snow melting and refreezing, dynamic changes in snow density, snow insulating properties, and other physics relevant to the growth and ablation of the snow pack. This information will provide improved seasonal predictions of changes in weather patterns associated with the El Niño cycle, and changes in land surface hydrology. The representation of the atmospheric water cycle has been improved in the atmospheric general circulation model developed by the NSIPP; the new precipitation patterns have a more realistic climatology. The model demonstrated that the predictability of summertime precipitation over the continental U.S. is controlled less by tropical Pacific sea surface temperatures and more by the soil moisture built up over the previous season. Remotely sensed soil moisture, as will be available from AMSR on Aqua, can now be assimilated into the NSIPP land model. This information will provide improved seasonal predictions of changes in climate patterns and hydrometeorology associated with the El Nino cycle.

In FY 2000, the Land Surface Hydrology Program within the ESE conducted research on understanding complex large-scale hydrological processes, retrieval of satellite-based land hydrological properties, land-atmosphere water and energy interactions and water balance, and natural disasters including floods, focusing on several regions including i) the Global Water and Energy Experiment (GEWEX) Continental Scale International Project (GCIP) of the Mississippi River Basin and North America, ii) the Large-Scale Biosphere-Atmosphere Experiment in Amazonia (LBA-hydromet) and iii) the Southern Great Plains (SGP).

In GCIP, research concentrated on the interaction of land surface hydrology and atmospheric phenomena, including the role of soil moisture and vegetation dynamics. In LBA-hydromet, research was conducted on physical climate and land surface hydrology, with emphasis on the influence of land use and land cover change on the variability and predictability of hydrology and climate. In SGP, research focussed on the retrieval of soil moisture using microwave technology, and the influence of soil moisture dynamics on land-atmosphere interactions.

ESE also completed the collection of satellite data needed for the 17-year cloud climatology being developed under the International Satellite Cloud Climatology Project (ISCCP). Data will be used to improve the understanding and modeling of the role of clouds in climate. Since the representation of clouds constitutes one of the major areas of uncertainty of climate models, the ISCCP data will be crucial to evaluating the competing ideas about how to represent cloud processes in global models.

Plans

In FY 2001 ESE will continue to explore the dynamics of the global water cycle by developing, analyzing and documenting multi-year data sets. The program will help resolve the wide disparity of precipitation estimates that currently exist, thus improving our understanding of the global water cycle. The continued operation of TRMM through FY 2001 will provide a fourth year of operation, allowing studies to be carried out in FY 2002 that better reflect the role of interannual variability on tropical precipitation. TRMM will obtain accurate maps of the diurnal cycle of precipitation and, in conjunction with a 10+ year reanalysis of the Special Sensor Microwave/Imager (SSM/I) data, set a benchmark for Tropical precipitation. In preparation for a future space-based measurement of soil moisture, the airborne sciences program will use aircraft and instruments to demonstrate over a variety of landscapes the capability to measure and diagnose soil moisture. It is anticipated that this information will lead to reliable estimates of evaporation,

precipitation, and the recycling of rainwater over continents. In FY 2002, analysis of TRMM data will be carried out along with that from the Convection and Moisture Experiment (CAMEX) to be conducted off the coast of Florida in late FY 2001. The analysis of CAMEX observations should also improve our understanding of the atmospheric circulation and thermodynamics associated with Atlantic hurricanes and thus contributes to the goals of the U.S. Weather Research Program.

ESE will also decrease the uncertainty in determinations of radiation forcing and feedback, and thereby increase accuracy in our knowledge of the processes that lead to heating and cooling of the Earth's surface and its atmosphere. The program will continue the analysis of global measurements of the radiative properties of clouds and aerosol particles being made by the MODIS, the Multi-Angle Imaging Spectrometer (MISR), and the Clouds and Earth's Radiant Energy System (CERES) instruments on the EOS Terra satellite.

ESE will continue to explain the dynamics of the global water cycle by building improved models and prediction capabilities. Improvements will be made to our current understanding of the large-scale effects of clouds in climate and the ability to model them will also be improved through collection and processing of satellite data needed for the multi-decadal global cloud climatology being developed under the ISCCP. A decadal Surface Radiation Budget (SRB) climatology will be completed. These studies will serve as validation of parameterizations of Earth's radiative processes in models that simulate the cycling of fresh water through Earth's atmosphere and the transfer of visible and infrared radiation in the atmosphere. This information will provide a quantitative basis for estimating the components of the radiant energy budget of the Earth, and their impact on climate.

In FY 2002 ESE will continue assembling and processing satellite data needed for the multi-decadal global cloud Climatology being developed under the International Satellite Cloud Climatology Project (ISCCP). A goal is to reduce uncertainty (3-7% in monthly mean) in the current ISCCP data set of globally observed cloud characteristics, particularly in the polar regions, by comparing it with new satellite data sets that provide new constraints on the derived quantities and with in situ ground-based and airborne measurements.

ESE will initiate development of the Cirrus Regional Study of Tropical Anvils and Layers (CRYSTAL) field study. This study will determine the upper tropospheric distribution of ice particles and water vapor and associated radiation fluxes on storms and cloud systems, and on cloud generation, regeneration and dissipation mechanisms and their representation in both regional-scale and global climate models. We will also improve the determinations of radiation forcings and feedbacks, and thereby increase accuracy in our knowledge of heating and cooling of the Earth's surface and atmosphere. The analysis of global measurements of the radiative properties of clouds and aerosol particles being made by the Terra and Aqua MODIS, MISR and CERES instruments will be continued; in FY 2002 there will be a sufficient measurement record from the CERES instruments aboard Terra and TRMM that first full benefit of the multiple observing geometries of the CERES instruments can be obtained to improve knowledge of the Earth's overall radiation budget.

The Land Surface Hydrology Program focuses on research on understanding complex hydrological processes and also on the next step of prediction of hydrological processes, using modeling, satellite observations, and analysis. Research will continue to focus on the retrieval of satellite-based land hydrological properties including new sensors such as MODIS from the Terra platform, as well as land-atmosphere water and energy interactions and the water cycle using satellite data assimilation at regional to global scales, focusing in several areas around the world including the GEWEX continental scale experiment regions. The Land Surface Hydrology

Program (LSHP) will also engage the community to determine research needs and feasibility of future hydrology missions in the areas of soil moisture, cold land processes including snow and freeze/thaw dynamics, and water level and discharge. LSHP will further support the development of a new Global Water and Energy Cycle (GWEC) initiative, and continue support of continental and global hydrological databases needed for the GEWEX International Satellite Land Surface Climatology Project (ISLSCP) and the planned Coordinated Enhanced Observing Period (CEOPS).

In FY 2002, the Land Surface Hydrology Program will continue efforts on understanding and prediction of hydrological processes using observations, modeling, and analysis. Particular focus will be placed on retrieval of satellite-based land hydrological properties using sensors aboard Terra and the anticipated Aqua platform, and ground and aircraft based microwave experiments. Research is being planned for the GEWEX Americas Prediction Project (GAPP) as the logical extension to GCIP in the areas of remote sensing science, land-atmosphere water and energy interactions and water balance modeling, and data assimilation within hydrological and atmospheric models, with focus on land memory, cold land processes, and the transferability of GCIP-derived models to other regions of the globe. LSHP is also planning for two large-scale field experiments for i) cold land processes in Spring 2002 in Colorado, pending the launch of the AMSR sensor on Aqua, and ii) soil moisture in the SGP region. LSHP will continue support of the GEWEX and GWEC initiatives not only for GCIP/GAPP, but also for other large basins of the world.

The NSIPP catchment land surface model, with its improved land surface hydrology, will be coupled to the atmospheric model. Predictability experiments will focus on mechanisms responsible for the large-scale droughts such as those that occurred in the 1930s and 1950s. The results will be analyzed and documented. Finally, in FY 2002 soil moisture and snow cover derived from AMSR data will be used with the land assimilation system to estimate the initial state for the land surface model as part of NSIPP's coupled seasonal forecasts.

Oceans and Ice in the Earth System: This research theme is principally focused on the slower processes that affect the distribution of large liquid and solid water masses on the planet, the circulation of the Earth's oceans and the mass balance of glaciers and ice sheets. Changes in oceans and ice are strongly influenced by their interactions with the atmosphere as well as their internal processes. These include: surface winds, changes in ocean water buoyancy brought about by air-sea fluxes of radiation, heat and fresh water (precipitation minus evaporation), the formation and disappearance of sea-ice, and snow accumulation on ice surfaces, glacier and ice sheet surface melt and discharge (through runoff or calving). All of these changes have subsequent impact on the atmosphere through complex feedbacks between the systems. The research objective is to model and understand the behavior of oceans and ice on all space- and time- scales that are relevant to the dynamics of the coupled ocean-atmosphere system and sea-level rise. Relatively short period and small-scale phenomena associated with upper ocean and coastal zone variability may also be studied, recognizing that process-level knowledge is necessary for predicting the behavior of coupled climate system, for understanding oceanic biological productivity and biogeochemistry, and for many marine applications.

Accomplishments

August 2000 marked the eighth anniversary of the Topex/Poseideon on orbit achievements in measuring global sea surface topography. It remains the "gold standard" for ocean altimetric measurement and continues to supply high-quality data. These data are used operationally in El Niño/La Niña predictions for the Pacific Ocean.

QuikSCAT continues to provide high quality surface wind data over the ice-free oceans. The data were used in a significant number of marine severe weather forecasts in 2000. These data are especially useful in hurricane monitoring. It has been shown that the surface wind signature of hurricane development in the Atlantic precedes cloud motion signatures normally used to identify cyclonic development.

SeaWiFS and MODIS continue to supply ocean color data. It is increasingly realized that these data will be useful in the study of the carbon cycle. Recent analyses are beginning to differentiate different marine plantonic regimes based on distinct signature in the multi-band color data. Ocean physics models incorporating more detailed biological models have been run successfully. Resources devoted to data assimilation techniques and model development are now achieving impressive results. Global assimilation and basin (Pacific, Atlantic) state estimation for parts of the 1990s have been completed. In the summer of 2000, aircraft experiments to measure ocean salinity remotely were very successful. Technology evolution and understanding of the algorithms have advanced greatly over the last three years.

The Goddard Institute for Space Studies (GISS) climate model studies on global warming as a consequence of increase of trace gases have indicated the possible importance of stratospheric ozone processes on surface climate, and thus the need for including the upper atmosphere in climate models. Their climate model also reveals that increasing greenhouse gases amplify the "high" phase of the Arctic Oscillation, providing a plausible reason why Northern Hemisphere winter warming in recent years has been much larger over the continents than over the oceans. Additional model studies have been useful for quantifying and comparing the different natural and anthropogenic climate forcings that influence long-term climate change. A sophisticated oceanic transport model has been coupled to the GISS climate model system. The ocean turbulence model breaks new ground in that it is the first to include salinity within a consistent theoretical framework. Also it is the first turbulence parameterization model to consistently represent vertical mixing throughout the whole ocean, from the strong mixing in the upper mixed layer to the weak mixing at depth. Thus the newer models being developed have improved representation of physical processes and should be able to provide more realistic simulation of future climate change, enabling better climate change assessment. The NASA Seasonal to Interannual Prediction Project (NSIPP) has developed a coupled climate prediction system model, consisting of the NSIPP-V1 global atmospheric model coupled to the Poseidon global ocean model. Experimental forecasts based on ensembles provide a statistical measure of forecast reliability. NSIPP forecasts now contribute to the consensus forecast conducted at the International Research Institute for Climate Prediction. The scalable computer architecture at NASA/GSFC has allowed the conduct of ensembles of multidecade climate simulations. These ensembles are a unique resource for the climate community.

Significant progress was made in studies of ice-covered regions of the Earth. Through collaboration with Radarsat and the Canadian Space Agency, the areas of Antarctica north of 80 degrees South latitude were precisely mapped at an unprecedented resolution in an interferometric mode which will allow estimates of the flow rate of much of the continent. These flow rates are important for estimating the amount of ice that is discharged and the influence of the world's largest ice sheet on sea level. In the northern hemisphere, the first comprehensive estimate of the mass balance of the Greenland ice sheet and its regional character was made using airborne laser altimetry surveys and information from coastal climate stations, complemented by satellite and in situ measurements. The results show that the highest central regions of the ice sheet (above 2000m elevation) are in balance, but with spatial variability. On the other hand, the lower regions are thinning, in many places at a rate of a meter per year. Based on these observations, the overall contribution of Greenland to sea level was estimated at 0.13 mm/yr; the uncertainty in this estimate is still being refined. Trends in sea ice extent for the Antarctica have been examined revealing an increase in the spatial extent of ice cover of about 1.7% per decade. The record of Arctic sea ice extent has been extended to 20 years and is continuing to show a

decreasing trend of 2.7% per decade. This longer time record increases the statistical significance of the trend over previously reported values.

Plans

The launch of the NASA-CNES Jason-1 mission in late FY 2001 will enable a factor-of-four improvement in accuracy in measuring ocean basin-scale sea-level variability versus TOPEX/Poseidon. Once verified it is planned to fly a "tandem mission" to examine ocean time and space scales inaccessible to a single altimeter. Additionally, ESE will generate the first basin-scale high-resolution estimate of the state of the Pacific Ocean as part of the international Global Ocean Data Assimilation Experiment (GODAE). This information will serve as input for seasonal weather forecasting models and should lead to improved representation of the physical coupling between the oceans and the atmosphere in climate models.

Quantitative descriptions of the impact of QuikSCAT data on weather forecasts are beginning to be debated. A better understanding of the role of models and boundary layer parameterizations in assimilation of scatterometer data is expected in FY 2002.

During FY 2001 the ESE plans to continue the development of a unified GISS climate model with improved flexibility and diagnostics and full documentation. Additional GISS model simulations will be carried out with the new and upgraded GISS Global Climate Model (GCM) for the period 1950-2050. These simulations should lead to improvement of our understanding of the role of natural and anthropogenic climate forcings on global mean climate change. Additionally, an evaluation of the new vertical mixing formulation generating vertical turbulent transports in the ocean of the coupled ocean-GISS GCM is expected to reveal better and deeper insight into the long term behavior of the ocean. Assimilation of sea surface height data from Topex/Poseidon is now underway and will be used for the initialization of coupled forecast experiments. SeaWiFS data are being used to assess the penetration scale of the solar heat flux. Future tests will include the use of QuikSCAT surface winds and MODIS/TERRA sea surface temperatures in the ocean initialization procedure.

ESE will continue to explain the dynamics of long-term climate variability by building improved models and prediction capabilities. In all these assessments, use of satellite data products is central to model validation and understanding global change. FY 2002 plans will focus on decade to century time-scale computer simulations with the coupled stratosphere-troposphere and ocean; these simulations will be used to discern the role of atmosphere, land and ocean in producing the observed climate change of the twentieth century. Simulation studies are also planned for simulating the direct and indirect influences of aerosols and black carbon on our environment and cloud processes. Based on the use of turbulent transport theory, new horizontal mixing formulations for the ocean will be developed and used. Forecast skill on the large scale can be expected to improve through the improved representation of the model's intrinsic seasonal and intra-seasonal modes. Forecast skill on the smaller (regional) scale can be expected to improve through better resolution of those scales and through improved boundary layer and cloud liquid water models.

In Antarctica, high-resolution (10 m) maps of regions in Antarctica will be produced and provide an important basis for ice sheet change detection through comparison to previous and future imagery. In Greenland, elevation-change surveys of the areas showing the most dramatic thinning will be conducted to determine if the thinning rate is constant, accelerating, or decelerating. This information will significantly improve our understanding of the ice sheet's contribution to sea level rise.

The launch of ICESat, scheduled for launch in December 2001, will mark the beginning of a campaign of extensive ice sheet elevation measurements. Over time, changes in these elevations will be used to assess the mass balance of the Greenland and Antarctic ice sheets, but the first year of data will be compared to the airborne surveys begun in 1993. This comparison will provide initial assessment of ice sheet mass balance characteristics in the intervening period.

Relationships between sea ice characteristics and atmospheric conditions will continue to be investigated, and the mechanisms for formation and disappearance of sea ice will be better assessed. Links to such phenomena as the Arctic Oscillation or the North Atlantic Oscillation will be better quantified. The Antarctic circumpolar wave (the quasi-periodic motion of sea ice around the continents will be better characterized and its relationship with the responsible forcing mechanisms will be better described.

The AMSR instrument on Aqua, planned for launch late in FY 2001, will provide twice the spatial resolution of the sensors previously used for sea ice extent, concentration, and classification, with more frequencies and polarizations. These data will be used to improve the existing sea ice time series and enhance the understanding of sea ice processes. Additional applications to ice sheets (e.g. assessing the spatial melt extent) and snow cover (e.g. depth and extent) will continue to be developed.

ESE will continue to explain the dynamics of long-term climate variability by building improved models and prediction capabilities. Observational capability will be enhanced through development and demonstration of a technique to measure and diagnose open ocean variations in salinity by 0.1 practical salinity unit (psu) from airborne platforms. Salinity is a critical factor in forcing ocean circulation.

Work will be done to improve understanding and modeling of the aerosol radiative forcing of climate and its anthropogenic component as needed for the 20-year climatology of aerosol optical thickness and particle size. This will be accomplished through the development and validation of aerosol retrieval, cloud-screening algorithms, processing of satellite data and transport model evaluations. We will demonstrate the experimental seasonal climate predictions by using next-generation super computing systems and new-coupled air-ocean-land-ice models. This demonstration will incorporate all available satellite observations (e.g., TOPEX, Jason, Seawinds, TRMM, SeaWiFS, and MODIS) of key ocean surface parameters such as wind vectors and altimetry. The accuracy of realistically forced long-term climate models will be enhanced to simulate observed global temperature research. Particular emphasis will be placed on the seasonal and spatial variability over the last 40 years to develop improved confidence in ability of models used for climate prediction. This information will provide the scientific basis for reliable assessments of potential future changes in global and regional climates.

Solid Earth Sciences (in cooperation with Natural Hazards program in Applications Program, see below): Understanding the processes which govern the structure and dynamics of Earth interior and the forces which shape the Earth's crust using the vantage point of space and airborne platforms. This understanding has and will continue to lead to improvements in society's ability to understand natural hazards.

The resources for this theme area are shared between Earth Science Program Science and the Applications programs. This programmatic split under different divisional mandates reflects the nature of the Solid Earth and Natural Hazards Programs, which have striven to make research and development efforts useful in a practical way to society.

The long-standing Earth science research program in fundamental solid Earth science explores issues such as the dynamics of the Earth's interior and crust, tectonic motions, earthquake mechanisms, volcanic eruption processes, and the evolution of landscapes. Results of this and other relevant activities are developed and applied to the assessment and mitigation of natural disasters for the practice of disaster management, working together with practitioners at the international, federal, state and local levels. Through the development of technologies designed to observe and understand the Earth, the ESE possesses an inventory of observational capabilities and techniques that can be developed and applied to understanding natural hazards, characterizing natural disasters, and monitoring conditions that may lead to such events.

Accomplishments

During 2000, as the Southern California Integrated GPS Network (SCIGN) neared completion, it recorded on a daily basis the both slow inexorable crustal deformation associated with the interaction between the Pacific and North American tectonic plates. ESE led a consortium of federal state and private institutions in the development of SCIGN that included NSF, the USGS, and the Keck Foundation. Data and solutions for site velocities and time series of site positions were made available on the internet. These measurements clearly identified discontinuities in the direction and magnitude of crustal motion across fault lines. Federal, state and local agencies and companies are using the Southern California Integrated GPS Network (SCIGN) data to study ground deformation related to earthquakes, and to continually assess the vulnerability and risk of earthquakes to the region. This information will provide a scientific basis for understanding the earthquake cycle and laying out the foundation for earthquake prediction. The Hector Mine Earthquake provided a unique glimpse of the ultimate utility of the SCIGN network and of another NASA technology- Interferometric Synthetic Aperture Radar. The SCIGN network captured the initial shock wave of the earthquake as it propagated throughout the region at frequencies well below that of seismometers- thereby extending a critical view into the physics of the earthquake mechanism. Furthermore, fortuitous availability of scarce INSAR data from the European ERS-2 satellite combined with the GPS data have provided scientists with the first highly detailed inter and post seismic deformation measurements at the millimeter level. Southern California will likely prove to be a highly productive natural laboratory to test space borne remote sensing tools for natural hazards research.

ESE has strongly supported the development of international services to provide space geodetic measurements. These measurements are essential to the maintenance of a global reference frame for nearly all long term positioning requirements from Geographic Information Systems, surveying for legal and development purposes, ocean topography such as El Niño, hydrology and topography. FY 2000 saw the first likely explanation of a mysterious wobble in the Earth's rotation known as the Chandler Wobble. Using the ESE space geodetic measurements and new advanced models of ocean and atmospheric circulation, researchers at the Jet Propulsion laboratory demonstrated that ocean pressure variations were sufficient to excite the Chandler wobble.

In FY 2000, ESE researchers participated in the production of the most accurate geomagnetic field model yet, based almost solely upon satellite magnetic data gathered by the Oersted satellite and the Danish Space Research Institute. The magnetic field models are included in electronic form in many modern navigation systems, serve as reference models for mineral exploration, and are published in map form for marine and airborne navigators. These data are also advancing our knowledge of the Earth's crust and the mysteries of the circulation deep within the earth's core that generates the magnetic field. The magnetic field has been decreasing dramatically in recent years, suggesting to some that we may be entering a period of reversal of the Earth's magnetic

field observed so often in the Earth's geologic history. Advanced modeling techniques are being applied to these new data sets in an attempt to better predict the evolution and the consequences of the geodynamo.

FY 2000 saw the development of the first global differential GPS correction. The new technology will allow for global real time positioning on the surface, in the air, or in orbit to better than 20 centimeters or eight inches. This development will have significant impact on global commercial interests such as agriculture, mining, robotics, and transportation. A beta version of this correction signal is being broadcast over the U.S. by NAVCOM and we expect a global signal broadcast in the next few months. NASA has also suggested that the future improvements in the GPS incorporate aspects of this new technology thereby improving the positioning and timing accuracy of the system by over a factor of ten.

FY 2000 saw the execution of the data collection phase of the ESE-led Pacific Rim II campaign. The purpose of this mission was to deploy NASA's airborne SAR, Topographic SAR, and airborne MOIDIS/ASTER simulator instruments in and around the Pacific Rim region for ecologic, hydrologic, and geologic process studies, topographic science and technology, and radar science and technology. Twenty-two countries participated in the cooperative campaign, which collected data at 201 sites in 18 different countries.

Plans

The installation of the 250 station SCIGN GPS network will be completed in FY 2001/FY 2002. Completion of the SCIGN network will provide a near real time capability for the evaluation of crustal deformation associated with earthquakes. Ground deformation information within the SCIGN array will be available within hours of an earthquake as opposed to the months required for post seismic GPS surveys. During the next five years we will evaluate the SCIGN array and validate its ability to generate data to develop an understanding of the connection between seismic risk and crustal strain leading to earthquakes. We will continue to develop the algorithms and technology of the SCIGN network to improve its utility to both the science community and to civilian, municipal, county and state government for risk assessment and disaster management. Of primary interest is improving the speed and capability of analysis software and its products. We will strive to both develop fully integrated deformation models that include GPS, seismic, and other remote sensing data sets such as INSAR and optical data sets, and to increase the timeliness of dissemination of the raw data and the model outputs for use by disaster management authorities. This will require working with data users to improve their communications infrastructure for the network. ESE will support the EarthScope initiative as a partner with the USGS and the National Science Foundation (NSF) in the development of the Plate Boundary Observatory (PBO) which constitutes a five fold increase in the number of GPS monuments in the western U.S. and Alaska. ESE's role in PBO will be to support the maintenance of the vital reference frame and GPS orbit information as well as algorithm and instrument development.

Research will continue with the development of algorithms for the GRACE Mission to better understand variations in the Earth's gravity field related to partitioning of water and atmosphere between the ice caps, ocean, and land areas. In addition ESE will continue the development of the next generation laser ranging system (SLR2000) in anticipation of its deployment in FY 2006. Based on the current budget profile ESE can not maintain the legacy system and develop SLR 2000. ESE is currently seeking partnerships that will allow for continued operation of the legacy system during development of SLR2000. SLR2000 development remains the highest priority because it will improve tracking efficiency at a lower operations cost when fully deployed. The SLR2000 system will improve the determination of the global geodetic reference frame for a host of scientific, military, and civilian applications.

ESE will conduct analyses of the near-global SRTM 30-meter topographic data for global geologic and geomorphic process studies. The SRTM will provide the first continuous digital elevation model of 80% of the Earth's surface for better understanding the composition and processes on the Earth's surface for scientific understanding. Reduction of the global data set will continue throughout FY 2002.

In FY 2001 ESE will complete the installation of the Mark IV correlator upgrade in the Very Long Baseline Interferometry (VLBI) system which will provide a factor of three to four improvement in the processing power and sensitivity of Earth rotation estimates. During FY 2001 ESE will experiment with the utility of continuous Very Long Baseline Interferometry (VLBI) observations using the Continuous Observation of the Rotation of the Earth (CORE) concept as a means of improving our understanding of atmospheric, oceanic, and internal forces affecting Earth dynamics. In FY 2002 ESE will continue to explore the dynamics of the Earth's interior and crust by developing, analyzing, and documenting multi-year data sets. We will use the daily orbit solutions for all GPS constellation satellites as a basis for cm-level orbit determinations and mm-level ground-based GPS positioning and navigation. This will enable near-real-time assessment of ground deformation for disaster response after earthquakes, and swelling of the ground as a precursor to explosive volcanic eruptions.

FY 2001 will see the first results from a three-satellite constellation of high accuracy geomagnetic satellites (Oersted, SAC-C, and CHAMP). This will be the first ever high-resolution multi-satellite study of the geomagnetic field. These same satellites also constitute the first operational GPS remote sensing constellation to measure ionospheric, atmospheric structure and dynamics and explore the utility of GPS based bistatic radar. These satellites were supported and launched under NASA's Experiments of opportunity as international collaborations with much reduced development of operations budgets. ESE expects that many new observational strategies will emerge from this constellation in the years ahead. This constellation when joined by GRACE in early FY 2002 will constitute NASA's first non-photonic remote sensing constellation.

During FY 2002 ESE will produce the first estimate of the secular (Long Term) change of the Earth's magnetic field from continuous satellite measurements of the geomagnetic field and complete the evaluation of the Continuous Observations of the Rotation of the Earth (CORE) concept to demonstrate a nearly 300% improvement in Earth rotation precision using the new Mark IV correlator technology and an international consortium of VLBI observatories.

Also in FY 2002 ESE will complete SLR2000 prototype development and begin evaluation of the performance of new SLR2000 automated satellite ranging station, evaluate the ability of the real-time precision GPS positioning software to produce better than 40 cm global real-time positioning using NASA's Global GPS Network and complete preliminary algorithms for mass flux estimation from temporal gravity field observations in preparation for the GRACE mission.

EOS Science

In 1988, NASA issued an Announcement of Opportunity (AO) for the selection of instruments, science teams and interdisciplinary investigations in support of the Earth Observing System (EOS). The initial EOS/IDS investigations were selected in 1990 to conduct basic research, develop methods and models for analysis of EOS observations, develop and refine models of Earth system processes, and forge new alliances among scientific disciplines fostering a new perspective into how the Earth functions as an integrated

system. These investigations involved analysis of data from missions such as Topex/Poseidon, UARS, international instruments (e.g. ADEOS, ERS, Radarsat) and in situ observations, with results being made available through EOSDIS to enhance broad participation by the science community at large. Subsequently, additional IDS investigations were selected bringing the total to 60. EOS science teams will be recompeted during FY 2001 for selection in early FY 2002.

Mission Science Teams and Guest Investigators

The mission science team/guest investigators program provide the opportunity for scientists from all institutions to participate in the analysis, verification, and utilization of data from NASA's currently operating space-based instruments. Funding provides for analyzing data from the UARS, TOPEX, Earth Radiation Budget Satellite (ERBS) and other space borne instruments such as Solar Backscatter Ultraviolet (SBUV/2), TOMS, QuikSCAT, and TRMM. The exploitation of UARS data still involves more than 100 investigators from the United States and many other countries, notably Canada, the United Kingdom, and France. Key TOMS and SBUV/2 participants include NOAA, Russia, and Japan. Key ERBS users include a diverse set of institutions including NOAA (NOAA manifested Earth Radiation Budget Experiment (ERBE) sensors on NOAA-9 and -10 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/SeaWiFS principal users include GSFC, the European community, Japan, Canada, and Australia and 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) and the International Geosphere-Biosphere Program (IGBP). Active international participation through the International Ocean Color Coordinating Group is carried out to help synthesize data from the various space-based ocean color sensors of different nations that are currently operating. NSCAT investigators include scientists from JPL, NOAA, and Japan (manifested the NSCAT for flight on their ADEOS-1 spacecraft), and universities in New York, Washington, Oregon, and Florida. TRMM is a joint mission with Japan to measure tropical precipitation from a low inclination orbit. Participants in the analysis of Shuttle Imaging Radar/X-Band Synthetic Aperture Radar (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.

In a number of cases, data from one instrument have been shown to have use in other applications, and the mission analysis programs actively encourage such uses. Mission science teams are typically competed triennially. The budget for these teams increased in FY 2001, as funds that were provided to the EOS instrument science teams for algorithm development are being converted to mission analysis following the launch of the relevant missions and spacecraft.

Airborne Science and Applications

In FY 2000, seven major deployments were flown on the core NASA Earth science fleet, for approximately 1230 flight hours. The campaigns produced science data for atmospheric chemistry, land-cover/land-use, clouds research, fire and biomass burning research, and geological applications. Additional deployments with interagency aircraft provided science data for soil moisture, sea salinity, and arctic ice. Almost all planned activities were achieved despite a difficult year due to unplanned extended maintenance

needed for both heavy-lift aircraft. Interagency and commercial aircraft provided substitute platforms for those research activities that could not be delayed.

For FY 2001, four major campaigns are planned for arctic ice, tropospheric chemistry, and atmospheric dynamics and hurricane research. EOS Terra and NMP EO-1 validation activities will continue. In FY 2002, six major campaigns are planned in support of EOS Aqua validation/precipitation research, arctic ice, terrestrial ecology in Amazonia, Great Lakes ice research, and tropical convection research. In FY 2002, the core ESE fleet is fully subscribed; therefore we will continue to pursue acquisition of flight hours on other cooperative or commercial aircraft to fulfill requirements that cannot be met by the core fleet.

Uninhabited Aerial Vehicles (UAVs)

The UAV science project is exploring alternative air platforms for the Earth science airborne project. Initially it will make i*n situ* and remote-sensing measurements focused on atmospheric sciences. These UAVs will stay over a target for extended periods to measure detailed temporal changes, provide unique views of cloud structures and provide calibration and verification of Earth science satellite instrumentation. In FY 2000, the UAV-based Science Demonstration Program was initiated via a NASA Research Announcement (NRA) that elicited 46 proposals in all areas of Earth science and applications. Eleven proposals were selected for additional study into the implementation of UAV missions. Implementation study results are due in 2001, and will be used to develop a business model in FY 2002 for future UAV acquisition decision-making. Two to three projects will be selected for full implementation from these eleven in FY 2001. The projects will be initiated in 2001, and are expected to fly in beginning in 2002, demonstrating the unique value added to Earth science and applications research by the UAV platform. The UAV Science program is also cooperating with the UAV flight development program to develop a scientifically credible mission profile to demonstrate the new Environmental Research Aircraft Sensor Technology (ERAST) long-endurance, high-altitude platform, which is also expected to fly in 2002.

Information Systems

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

BASIS OF FY 2002 FUNDING REQUIREMENT

APPLICATIONS, EDUCATION AND OUTREACH

	FY 2000	FY 2001	FY 2002
		(Thousands of Dollars)	
Research and Analysis – Applications	33,300	42,007	
Commercial Remote Sensing	35,900	51,020	
Education	15,200	21,054	
EOS Fellowships and New Investigators	4,800	6,985	
Education and outreach	5,400	9,080	
GLOBE	5,000	4,989	
Subtotal Without Education Agency Investment	84,400	114,081	
Education Agency Investment	[7,300]	[10,278]	
Total	[91,700]	[124,359]	
Research and Analysis – Applications			45,700
Program Planning and Analysis			5,600
Applications Research			17,500
Applications Development			22,600
Education			16,500
Informal Education			1,000
Formal Education			14,500
K-16 program			2,100
Graduate Fellowships and New Investigators			7,400
GLOBE			5,000
Professional Education/Development			1,000
Outreach			1,000
Total			63,200

Note: The Education Agency Investment is reported in the Agency Education account in FY 2002.

PROGRAM GOALS

The goal for the Applications, Education and Outreach program is to expand and accelerate the realization of economic and societal benefits from Earth science, information and technology. This will be done by enabling productive use of Earth system science results, data and technology in the public and private sectors, implementing educational materials and programs to stimulate interest in Earth science through Education programs, and increasing public understanding of and involvement in Earth system science through outreach activities.

STRATEGY FOR ACHIEVING GOALS

Starting in FY 2002, the Headquarters Applications Program is restructured to consist of three major programmatic elements: Applications, Education, and Outreach. The SSC's Commercial Remote Sensing Program (CRSP) role was enhanced and expanded to become the ESE Lead Center for Remote Sensing Applications. As part of this new role, the CRSP has become the GeoSpace Applications and Development Directorate (GADD). The GADD will lead the Applications Research and Applications Development initiatives. The past CRSP activities and future activities of the Lead Center will be fully integrated into the new Applications programmatic elements. The restructuring of the Applications program involves a transition to a strategy of implementing high impact applications projects whereby we will:

- Conduct formal analysis and planning to determine when and where to make a NASA investment for maximum benefit.
- Partner with other federal agencies on projects of mutual interest.
- Collaborate more closely with industry to ensure that their investment in new products and services is used to NASA's advantage.

Applications elements include: 1) Program Planning and Analysis (PP&A), 2) Applications Research, and 3) Applications Development. PP&A will determine how priority issues that face public and private sector decision-makers can be addressed with the science and technology of ESE. Applications Research will focus on discovery and testing NASA-derived science and technology results and capabilities that may potentially impact issues of national and global significance. Applications Development involves field testing science and technology results in a realistic setting in order to determine their fitness for a target application, and creating prototypical applications in an operational setting. Applications validation is part of Applications Development, and involves the systematic and documented technical measurement, test, or evaluation of ESE and external (public agency or private) technologies, data, models with the objective of validating these against standards, user defined requirement, processes and best practices.

Applications research includes Natural Hazards research (in cooperation with Solid Earth Science program of the Research Program). This involves understanding the processes that lead to natural hazards, and will continue to provide improvements in society's ability to be more proactive in its approach to disaster management by preparing for and mitigating against the costly affects of natural disasters. The long-standing Earth science research program explores issues such as the dynamics of the atmosphere and weather systems, the dynamics of the Earth's interior and crust including earthquake mechanisms, volcanic eruption processes, and the evolution of landscapes. Results of this and other research are developed and applied to the assessment and mitigation of natural disasters for the practice of disaster management, working together with practitioners at the

international, federal, state and local levels. The aim is to allow a more proactive approach to disaster management, focusing on sustainable mitigation and preparedness versus focusing on response and recovery activities.

The Education programmatic element will include 1) Informal Education, 2) Formal Education, and 3) Professional Development. Informal Education seeks to increase public awareness and understanding of how the Earth functions as a system and NASA's role in enabling development of that knowledge. Formal Education (including GLOBE) enables the use of Earth science information and results in teaching and learning at all levels of education. It also includes continued training of interdisciplinary scientists at the graduate and early-career levels to support the study of the Earth as a system. Professional Development aims to build capacity for productive use of Earth science results, technology, and information in resolving everyday practical problems.

Outreach seeks to increase awareness of the potential for applying ESE science and technology to non-science community problems and issues, and providing information to decision makers and other NASA stakeholders on applications results, status of projects and derived benefits.

SCHEDULE AND OUTPUTS

The Applications Research effort 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 Academies of Sciences. The applications research consists of one of the five management areas: the Natural Hazards portion of Solid Earth and Natural hazards. A summary schedule and outputs relating to management, business practices, and bases for comparisons applicable to this theme area is shown in the table below.

Natural hazards only	FY 2000 estimate/ actual	FY 2001	FY 2002 Estimate
Number of principal investigators	15/70*	65	90
Number of research tasks under way	16/75*	70	80
Average duration of research tasks	3 years	3 years	3 years
Number of science solicitations released	.5/1	1	1
Number proposals received	60/90	90	150
Number of proposals rated very good to excellent	20/30	30	50
Number of proposals selected	15/20	20	30
Time to process proposal (selection through obligation)	30 days/45 days	45 days	45 days
Number of days until funding is released	Same	Same	Same
Percent of R & A funding obligated:			
Current Budget Authority:	100%	100%	100%
Prior Budget Authority:	100%	100%	100%
Percent of program reviewed by science peers	95%	95%	95%

* These are substantially higher than last year due to misinterpreting how separate tasks were accounted for. Individual tasks for separate PIs were bundled under several summary labels and consequently were not counted individually.

ACCOMPLISHMENTS AND PROPOSED RESULTS

In FY 2000, continuing into FY 2001, the following are significant accomplishments in the area of Natural Hazards and applications research.

Accomplishments

Natural Hazards

In February 2000, the Shuttle Radar Topography Mission (SRTM) instrument aboard the Shuttle Endeavor recorded the data required to produce the first moderate-resolution digital elevation topographic map of the world. In addition, the ground data processing system was completed and the orbit/avionics information were processed. These two accomplishments were precursor activities that will allow the full production processing to begin. The data from the SRTM is allowing scientists in federal, state and local agencies, and academia to study the terrain for the purposes of basic research and also provides a multi-disciplinary applications tool for urban and infrastructure planning, resource management, environmental assessments, and disaster management including risk/vulnerability and consequence assessment.

During 2000, as the Southern California Integrated GPS Network (SCIGN) neared completion, it recorded on a daily basis the crustal deformation associated with the interaction between the Pacific and North American tectonic plates. Federal, state and local agencies and companies are using the SCIGN data to study ground deformation related to earthquakes, and to continually improve the assessment of the vulnerability and risk of earthquakes to the region. Information from the SCIGN array is providing the scientific basis for understanding the earthquake cycle and will lay out the foundation for earthquake prediction in the future. In addition, local agencies and surveying groups use SCIGN data for their spatial reference system that forms the basis for Geographic Information Systems applications. ESE, Berkley Seismological Laboratory, USGS, and local universities, used Interferometric Synthetic Aperture Radar (SAR) and GPS arrays data to conduct studies along the Hayward Fault in the San Francisco Bay region. The results of these studies found that the northern segment of the fault is not accumulating elastic strain as believed previously and therefore has a lower risk of an earthquake than previously estimated.

The first global differential GPS correction led by ESE was developed in FY 2000. The new technology will allow for global real time positioning on the surface, in the air, or in orbit to better than 20 centimeters or eight inches, and will have significant implications or global commercial interests such as agriculture, mining, robotics, and transportation. ESE expects the first commercial roll out during FY 2001.

The data collection phase of the ESE-led Pacific Rim II campaign was executed in FY 2000. The purpose of this mission was to deploy NASA's airborne SAR, Topographic SAR, and airborne MOIDIS/ASTER simulator instruments in and around the Pacific Rim region for scientific studies in ecology, hydrology, and geology, as well as environmental applications, geological hazards

assessments, coastal hazards assessments, topographic science and technology, and radar science and technology. Twenty-two countries participated in the cooperative campaign, which collected data at 201 sites in 18 different countries.

ESE developed a new volcano eruption detection procedure using EOS Terra data sets that automatically detects eruptions and monitors and track plumes. These procedures will be infused into ongoing efforts with the Federal Aviation Administration (FAA) for use in aircraft routing and warning systems, and will help promote safe air travel. Cooperative programs with USGS and other international organizations on the deployment of volcano monitoring systems continued. These systems are being tested and validated by operational agencies in a number of locations including Hawaii, Mexico, Italy, the Caribbean, and the Philippines.

Through the Flood Insurance Rate Mapping program, ESE studied flooding and floodplain processes, how to process and distribute imagery of current flooding, and assessed the accuracy of new data collection techniques. These studies and assessments were aimed at the broad use of this information in flood damage assessment and for floodplain map development. ESE completed the first phase of the cooperative program with Federal Emergency Management Administration, the Army Corps of Engineers, and commercial data collection firms, to evaluate and demonstrate the utility of remote sensing data for improved, faster and less costly flood plain mapping, which resulted in the publication Light Detection and Ranging (LIDAR) and Interferometric Synthetic Radar Aperture (IfSAR) performance specifications for floodplain mapping. The follow-on phase of this activity also began with the implementation of the results of the earlier activities. Examples include the cooperative NASA/FEMA/Corps or Engineers provision of technical guidance/assistance and quality checking/validation activities associated with state-funded and operational mapping programs in North Carolina, Alaska, and Utah, using the published performance standards.

Plans for Natural Hazards for FY 2002 are described in the Applications Research Section below.

Applications Research (old structure)

The goal of the Earth Science Applications Research Program (ESARP) is to demonstrate the productive use of ESE science and technology in the public and private sectors in response to user needs. To achieve the goal, the ESARP works with non-NASA public and private partners to demonstrate Earth Science results, data and technology to a broad range of users for near-term practical applications.

In FY 2000, the seven Regional Earth Science Applications Centers (RESACs) applied remote sensing and related technologies to problems of regional significance and conducted region specific assessments. The RESACs were advised of the Applications Program new priority to establish operational applications that exploit ESE data, science and technology, and to consider development of such applications as part of the RESAC objectives. The RESACs responded by implementing plans for a special session on RESAC research and applications at the annual meeting of the American Society of Photogrammetry and Remote Sensing in 2001. The outcome of the RESACs will be an enhanced knowledge of potential regional consequences of climate change and variability by regional stakeholders such as state and local governments and private industry that will lead to practical advances in the management of regional resources.

Projects, funded jointly by ESE and the U.S. Department of Agriculture (USDA), developed and demonstrated applications in vegetation mapping and monitoring, environmental risk and damage assessment, resource management and precision agriculture.

Three ESE/USDA pilot projects in Arizona, Mississippi and Utah leveraged existing Land Grant and Space Grant networks into a cooperative NASA ESE-Space Grant/USDA Cooperative Extension Service Strategic Alliance in Geospatial Information Technology (i.e., remote sensing, Geographic Information System (GIS). These activities extended ESE's science results and pushed the existing applications science envelope forward in partnership with USDA. The Alliance uses remote sensing, GIS, GPS and other geospatial technologies to improve the benefits of traditional university extension activities for the Nation's farmers.

The Type 3 ESIPs (which were selected in late FY1998 as part of the EOSDIS Prototype Federation) focused on applications development and interactions with the potential broader user community; e.g., NBC Channel 4 in Washington, D.C. (weather and news) developed an integrated News and Weather Visualization System for use within NBC owned and operated television stations. The New Mexico Earth Data Analysis Center (EDAC) is working with state, regional, and local problems; e.g., EDAC and the New Mexico Land Office and Middle Rio Grande Council of Governments developed baseline GIS databases and remote sensing applications for land economics and regional hydrology, and have developed a multimedia image sampler to introduce the broader user community to the types of data available for operation and commercial applications

Specifications for state, local, regional and tribal government applications were complied through a series of regional workshops. Midwest and western regional workshops were held in Missouri (April 2000) and California (September 2000), the Northeast (November 2000), the Southeast (February 2001) and are scheduled for Alaska in May 2001. The workshops successfully acquired information about applications needs in the target community and communicated the plans to the community. A draft Broad Agency Announcement (BAA) for state, local and tribal government applications was completed in FY2000. The BAA will be issued in April 2001. A common land cover data product was developed in FY 2000, through cooperation with the USGS and based on Landsat 7 data. The product will be available in late-FY 2001 and builds on the North Atlantic Land Characterization(NALS) and Multi Resolution Land Characterization (MRLC) data sets compiled in the 1990's.

A memorandum of Understanding (MOU) was completed and implemented with the Western Governors' Association (WGA) to support WGA's efforts to incorporate NASA data, science and technology in applications. This will assist WGA member states in meeting mandated reporting requirements and decision support related to environmental assessment issues.

In FY 2000, the first ESE joint solicitation on Research and Applications was developed that encourages development of applications from ESE sponsored research. The joint solicitation, released in October 2000, identifies three science areas for proposals, carbon cycle, land use/land cover change, and terrestrial ecology, and provides the opportunity for the community to expand the science research to include applications. Proposals under this solicitation are being received and evaluated in FY 2001.

ESE expanded cooperative work with other agencies including Department of Transportation (DOT), the Environmental Protection Agency (EPA) and the U.S. Agency for International Development (USAID). ESE and DOT implemented a program in remote sensing applications that awarded four grants to university consortia to perform research on use of remote sensing and related technology to transportation issues including environmental management, infrastructure development, and emergency response. DOT also awarded eleven individual project grants in remote sensing applications. ESE and EPA identified issues to be addressed with ESE capabilities and are developing a program to address the issues identified in 2001. ESE and USAID and participated in conferences and workshops in the United States and Europe on the potential contribution of ESE capabilities for monitoring land cover/land use change related to carbon sequestration programs.

In FY 2001, Policy, Planning and Analysis (PP&A) activities were initiated in the Applications Research area. PP&A is responsible for shaping the direction of future Applications Programs, and defines the most pressing and priority information needs faced by resource managers in user organizations and determines how these needs can be satisfied with current and anticipated science and technology results. In FY 2001, PP&A activities are focused on four major applications "theme" areas that hold the most promise for economic and societal benefits: (a) Environmental Assessment; (b) Resource Management; (c) Community Growth; and Disaster Management. Assessment Panels were established in each of these areas consisting of policy-makers and acknowledged leaders.

Applications Research (ESARP) Plans for FY 2002 are reported in the Applications Research Section below.

Commercial Remote Sensing

The goal of the Commercial Remote Sensing Program (CRSP) is to accelerate the development of a preeminent U.S. remote sensing industry and link ESE scientists with the commercial remote sensing industry to develop mutually beneficial partnerships. To achieve this goal, the CRSP implements partnership programs that demonstrate joint development of technology and applications with private companies, agencies, and educational centers. Examples are the Scientific Data Buy (SDB) and the Earth Observation Commercial Applications Program (EOCAP) Hyperspectral Initiative.

In FY 2001, CRSP's increased role in Remote Sensing Applications resulted in an organizational change at the Stennis Space Center (SSC). A new directorate GeoSpace Applications and Development Directorate (GADD) was formed.

The CRSP/GADD continues to manage over 100 partnerships including programs transferred from Headquarters to SSC as the Lead Center for Applications. These partnerships focus on extending the benefits of ESE research and technology and stimulate the commercial development of value added products and services through direct working relationships with the end users in other federal government agencies, disaster management, resource management, environmental quality and community growth. The partnerships discover user requirements in a pre competitive environment and pilot techniques and methods to establish feasibility that can lead to systemic change in the end users operations.

In FY 2000, CRSP continued to successfully implement the Science Data Purchase through the direct placement of over 200 commercial tasking requests supporting science research on all seven continents. Further support was provide to the Landsat continuity Mission and Ocean Winds working groups to assist scientists and commercial providers to understand the potential commercial opportunities in future ESE science missions.

In FY 2000 CRSP and USDA worked with the growers associations representing cotton, corn, wheat and soybeans to refine the requirements definitions, translate these requirements to remote sensing technology performance and set up validation programs for six agricultural applications.

Plans for GADD for FY 2002 are described in the Applications Research and Applications Development Section below.

Education and Outreach

In FY 2000 the Education program had accomplishments in all major programmatic areas. In *Cross-cutting* activities, ESE evaluated 63 Earth science learning materials in its educational product review and approved 21 for distribution by the enterprise: 8 curriculum support products, 5 informal materials and 8 resources for educational product developers.

In formal education (K-16 and GLOBE), in-service educator training workshops (1-2 week intensive), and pre-service and graduate semester long courses for educators were conducted nation-wide. New undergraduate courses were created for pre-service education students at institutions, which previously did not teach Earth System science. The Earth System Science Educators Alliance (ESSEA) was formed as a support network for educators in this area.

ESE continues its effort in training the next generation of earth scientists and engineers, contributing to a workforce of interdisciplinary scientists to address the study of Earth as a system. These scientists and engineers will use remote sensing knowledge and data in practical fields related to Earth and environmental sciences, and the effects of natural and human-induced changes on the global environment. In FY 2000, 132 graduate fellowships (including 53 new awards) and 17 early-career research grants were awarded. Beginning in FY 2001, ESE is expanding the New Investigator Program to support at least 30 early-career research grants in any given year.

In informal education, ESE Earth science results and data were increasingly popular within the broadcast community. There were 129 live interviews broadcast during "prime-time" from five live shot campaigns; 31 images were broadcast during National TV News (i.e., 6:00 PM Evening News); press releases were broadcast nationally; and broadcast media issued 260 requests for archive ESE footage. Sponsored survey of museum professionals by their colleagues and the results inform ESE of what it must do for museum professionals to utilize NASA's Earth science content. A pilot effort was conducted to train Girl Scout council and troop leaders in aspects of Earth science. Another Girl Scout Regional Council pilot effort resulted in the creation of two badge programs in atmospheric sciences for younger and junior girls.

Plans for Education are described in the Applications – Education Section below.

Plans

RESEARCH AND ANALYSIS – APPLICATIONS

In FY 2002, the Headquarters Applications Program is being restructured to consist of three major programmatic elements: Applications, Education, and Outreach. Commercial Remote Sensing Plans for FY 2002 are reported in the Applications PP&A, Research and Development Section.

Applications

- **Program Planning & Analysis (PP&A)**

PP&A activities are responsible for shaping the direction of future Applications Programs. PP&A defines the most pressing and priority information needs faced by resource managers in user organizations and determines how these needs can be satisfied with current and anticipated science and technology results. They determine the readiness of the marketplace to support the newly developed applications and the ability of the user institutions to sustain the applications in operational use, and develop an Applications Investment Portfolio on an annual basis which identifies a suite of prioritized opportunities based on estimates of risk, payoff, and timelines. Assessment Panels for theme areas, Environmental Assessment, Resource Management, Community Growth, and Disaster Management, will meet twice in FY 2001 to define user needs and establish the integrated direction for future program activities.

- **Applications Research** will focus on discovery and testing NASA derived science and technology results and capabilities that may potentially impact issues of national and global significance.

Operational Application Prototypes will determine how priority issues that face public and private sector decision-makers can be addressed with the science and technology of ESE.

The Joint Research and Applications solicitation will select approximately 10-12 projects in the applications areas relating to carbon cycle, carbon sequestration, land use/land cover change, and terrestrial ecology. The Solicitation seeks to support projects that exploit ESE capabilities in development of applications that can be used operationally to model the terrestrial aspects of the carbon cycle and land cover/land use changes related to terrestrial carbon sequestration efforts. Additional Research and Applications joint solicitations in areas such as water resources, quantity and quality are planned for FY 2002.

We will select approximately 8 to 12 projects under the first release of the Broad Agency Announcement (BAA) solicitation for state, local, regional and tribal government applications. Funding permitting, the BAA will be re-issued early in FY 2002 for additional projects.

Regional applications workshops will conclude with workshops in New York (November 2000), Tennessee (February 2001) and Alaska (May 2001). Additional regional and state-specific workshops may be held in FY 2002 as determined by the response to the initial BAA solicitation.

The joint ESE/EPA workshop in FY 2001 that identified key issues for EPA that can be addressed with ESE capabilities will lead to a planning process for development of projects in FY 2002 that address EPA requirements.

The Geospatial Extension Specialist (GES) projects, in cooperation with USDA/Cooperative State Research and Extension Service (CREES) and the NASA Space Grant, will be expanded to additional states, and joint NASA and USDA funds will be sought for the projects.

The Applications Program will collaborate with the South Florida Water Management District, and other agencies in the South Florida region, on tasks related to the multi-billion dollar Everglades Restoration Project for FY 2002.

The RESACs and ESIPs will begin phasing out in FY 2002. Decisions on how, when and if to re-compete these programs will be made in FY 2001.

NASA and the National Governors Association (NGA) will complete the MOU to facilitate the transition of developed applications into state executive agencies.

Environment and Health activities include projects in vector-borne disease detection, environment and health data exchange, and Shuttle imagery.

Completion of the SCIGN network will enable a near real time capability for the evaluation of crustal deformation associated with earthquakes. ESE will enable the posting of ground deformation information within hours of an earthquake as opposed to the months required for traditional post-seismic GPS surveys. ESE will develop the algorithms and technology of the SCIGN network to improve its utility to both the science community and to civilian, municipal, county and state government for risk assessment and disaster management activities. ESE will strive to develop fully integrated deformation models that include GPS, seismic, and other remote sensing data sets such as (IfSAR) and optical data sets, and increase the timeliness of the model outputs for use by disaster management authorities.

ESE will conduct analyses of the near-global SRTM 30-meter topographic data for global geologic and geomorphic process studies. The SRTM is providing the first continuous digital elevation model of 80% of the Earth's surface for better understanding the composition and processes on the Earth's surface. This will result in increased scientific understanding, better urban and infrastructure planning, environmental assessments, aircraft flight planning for aviation safety, and better natural hazards assessment and overall disaster management. Reduction of the global data set will continue throughout FY 2001.

ESE will test an automatic volcano eruption detection procedure using EOS Terra data sets that will automatically detect eruptions and monitor and track plumes, and will infuse the resulting procedures into joint NASA and Federal Aviation Administration (FAA) aircraft routing and warning systems efforts. This information will help promote safe air travel. ESE will continue to work with USGS and other International volcano monitoring programs on the implementation of low-cost GPS arrays and the use of interferometric SAR data for the development of warning systems regions vulnerable to explosive volcanic eruptions.

ESE will continue processing and analysis of PacRim II data for hazards assessment and modeling in cooperation with operational organizations such as the Pacific Disaster Center, NOAA, and the USGS.

ESE will continue to execute other cooperative programs in Disaster Management including those with:

- FEMA for better utilization of NASA science, data and technology for proactive disaster management) in general, for floodplain mapping and for risk assessment modeling using HAZUS (Hazards US) in particular;

- DOD for the better integration of Earth observation data and development of risk and consequence models into the Pacific Disaster Center. The first set of modeling activities will be implemented in FY 2001.
- The Association of American State Geologists for better use of ESE science and data in the applied geological community in general and specifically for the execution of responsibilities in all 50 of the State Geological Survey's
- Other state/local governments (e.g., NC, AK, and Utah) for the application of new technologies for floodplain/terrain mapping and modeling.

ESE will continue global real time navigation at the decimeter level and plans to investigate and validate the utility of this technology for new space borne, airborne, ground-based technologies, and will promote commercial participation in this effort. ESE will use the daily orbit solutions for all GPS constellation satellites as a basis for cm-level orbit determinations and mm-level ground-based GPS positioning and navigation. This will enable near-real-time assessment of ground deformation for better assessment of hazards as well disaster response for earthquakes, swelling of the ground as a precursor to explosive volcanic eruptions, landslides, and monitoring ground subsidence related to the extraction of fluids in the crust (e.g., ground water and petroleum).

EOCAP Hyperspectral Initiative involves partnership programs that demonstrate joint development of remote sensing technology and applications with private companies, agencies, and educational centers. In FY 2002, we will continue focusing EOCAP joint commercial applications research to stimulate the development of new commercial products. These products will ultimately provide the basis for commercial services to continue to support the ongoing geo-spatial needs of the Agricultural and Transportation agencies and the respective markets they represent. Additional commercial sources of science data (from data buy) for global change research and applications will also be investigated for use. The science data will be made available to Earth science researchers for their investigations.

- **Applications Development** involves field testing science and technology results in a realistic setting to determine their fitness for a target application, and creating proto-typical applications in pre-competitive yet near real operational settings. The planned FY 2002 developments will include:

Agriculture (AG) 20/20

Continuation of the agricultural initiative with USDA that leads to a joint solicitation and total award of fifteen to twenty partnerships of which four to six competitively selected partnerships will be with end users representative of the cotton, corn, wheat and soybean growers. These partnerships will focus on improvements in farm management practices utilizing geospatial technologies that can lead to increases in productivity and efficiencies.

State and Local

The implementation of the State, Local and Tribal Government Initiative will begin through the competitive award or four to six cooperative application pilot projects based on knowledge gained in Regional Workshops. These projects will enable the commercial development of practical tools for these government decision-makers based on the feasibility of employing geospatial technologies that address their critical requirements.

The Regional Applications Center for the Northeast (RACNE) pilot project will investigate, develop and facilitate use of NASA and other remotely sensed data in Cayuga County, NY, and will focus on the management of the 24 county watershed area of the New York Finger Lakes.

Activity will continue with the National States Geographic Information Council (NSGIC), Western Governors Association (WGA), Aerospace States Association (ASA), National Association of Counties (NACO), Mid-America States Consortium and National Conference of State Legislatures (NCSL) to plan a set of Applications Research Program demonstrations that will be dedicated to the needs of state and local government resource manages and policy-makers. Regional workshops will be held to increase communication and expand collaboration with and among the State and Local government user communities. The workshops will demonstrate ESE data products and science results to the state and local government community for their use in practical decision-making.

- **Applications Verification and Validation: I**nvolves the systematic and documented technical measurement, test, or evaluation of ESE and external (pubic agency or private) technologies, data, models with the objective of validating these against standards, user defined requirements, processes and best practices. The planned FY 2002 validation developments will include:

Creation of a Joint ESE and American Society for Photogrammetry and Remote Sensing (ASPRS) multi-disciplinary team to develop Digital Imagery Mapping Guidelines and refinement of draft Digital Imagery Standards and digital certification techniques. This team will provide a lead role in the development of LIDAR and Thermal guidelines.

Continue systems characterization activities supporting other federal agencies (DOE Multi-Thermal Imager ground truth), commercial entities (Resource 21 data simulations and validation) and Post 2002 missions Landsat Continuity and Tropo-spheric winds missions trade studies.

Continue joint NASA, NIMA, USGS and Space Imaging IKONOS data validation for the NASA research community.

EDUCATION

In FY 2002, the Education portion of the Applications Program will be restructured. Education will include three project areas: (1) Informal Education, (2) Formal Education; and (3) Professional Development. These three areas will be integrated and coordinated via a new Cross-Cutting area which will establish education focused *themes* that unify content, topics and messages across all aspects of education (informal, formal and professional) and all efforts (flight projects, field campaigns, grants, cooperative agreements, and Center efforts.) This thematic integration and coordination will be enhanced by a partnership with the National Science Foundation digital library effort that will enable projects within the different Education elements to readily share content.

In FY 2002, ESE will continue its activities in Informal Education focused on broad public awareness and understanding of the Earth as a system, the related technologies and applied uses, and the relevance to our daily lives via broadcast media (the mode by which most Americans learn about science and technology). Activities in this area are expected to yield the same magnitude of results as in previous years, with level funding. Efforts will focus on activities to improve the awareness of ESE content within the

museum community; e.g., workshops, presentations and exhibits at conferences, and the Cross-cutting partnership with NSF will focus on access and usability of content by this community. The two pilot efforts with the Girl Scouts will merge into a single effort and will focus on models for scaling-up the efforts in both dimensions—leader training and badge endorsement at the national level. Pilot efforts will begin in FY 2002 in training and awareness building within the profession of Interpretation. Interpreters staff public programs at national, state and regional parks within the U.S. and are instrumental in developing permanent and rotating exhibits within these venues. Training sessions will occur at professional conferences, as an element of the National Park Service training program for Interpreters, and in other venues as identified.

Formal education will have two sub-elements: 1) K-16, and 2) Graduate and Early Career. GLOBE will be integrated into the K-16 sub-element. In FY 2002, the K-16 sub-element will focus on systemic improvement activities marrying educator enhancement activities and development of curriculum support materials to the systemic improvement activities. Efforts will focus on filling content/concept gaps in the array of curriculum support materials, and on establishing a scalable and affordable approach to educator enhancement. GLOBE efforts will be gradually integrated into the systemic improvement activities so that the numerical goals of GLOBE migrate from a focus on schools to a focus on educators, classrooms and district-wide participation in science learning, using GLOBE as the means.

During FY 2002, NASA will continue conducting workshops to train teachers in the use of Earth Science education products, and coordinate with the education organizations to affect systemic integration of ESE content into established curricular materials and learning venues. ESE will continue its annual solicitation and selection of graduate student fellowships and support at least 30 active early career research grants in Earth science.

ESE will initiate new efforts in Professional Development, focused in two areas: 1) training of professionals currently in the workforce who are allied with a funded applied applications activities at the federal, state and local level (e.g., in-service professionals), and 2) training of undergraduates in key applied fields so that they enter the marketplace with discipline specific skills in applied remote sensing (measurement, analysis, interpretation). ESE will use existing NASA investments (e.g., in undergraduate curriculum and curriculum support materials, and equipment grants at academic institutions), and then augment these as necessary. In addition, a planning activity will be undertaken to determine the existing undergraduate and professional development programs (evening, week-end, distance learning, semester and short-courses) within U.S. academic institutions and professional societies that currently offer applied, discipline-specific remote sensing as an element of the curriculum. In-service efforts will strive to utilize these existing capabilities and to expand them to better meet the needs of the in-service professionals. In FY 2002, a blend of modalities will be used to implement in-service efforts that will include pilot efforts in: 1) the use of undergraduate and graduate fellowships; 2) augmentation of existing professional development programs for GIS and natural resource managers within the federal government; and 3) scholarships for in-service personnel and their institutions to participate in existing focused training.

OUTREACH

As part restructuring the Applications program, Outreach is established as a separate effort, and will be managed by the Headquarters Applications Program. Outreach goals are to develop formal outreach plans to deliver the necessary information to appropriate stakeholders in a systematic manner, conduct special events and E-media activities (e.g., information portals, exhibits, tours, publications, web sites), and coordinate ESE outreach activities with Public Affairs to achieve the optimum benefit for NASA and the taxpayers.

BASIS OF FY 2002 FUNDING REQUIREMENT

TECHNOLOGY INFUSION

	FY 2000	FY 2001	FY 2002
		(Thousands of Dollars)	
Technology Infusion	72,615	93,202	74,200
New Millennium Program	35,200	49,989	35,800
Advanced Information Systems Technology	12,600	15,446	9,500
Advanced Technology Initiatives	9,815	12,800	8,900
Instrument Incubator Program	15,000	14,967	20,000
High Performance Computing and Communications	21,900	21,749	21,800
Total	94,515	114,951	96,000

PROGRAM GOALS

The Earth Science Technology program develops and demonstrates technologies that will enable future missions, that will reduce the cost of future missions, and that will enable a maximum 3-year acquisition timeline for flight and ground systems. The program consists of five major areas that will lead to the successful and timely development and infusion of technologies into future programs. The New Millennium Program (NMP) validates space platform and instrument technologies required for future missions. NMP space-validated technologies are required before new technologies can be flown on science or operational missions. Advanced Technology Initiatives (ATI) focus and refine ESE technology requirements and advance key component and subsystem technologies required for the next generation of process and monitoring missions. The Instrument Incubator Program (IIP) develops new instruments and measurement techniques at the system level. Advanced Information Systems (AIS) develops advanced end-to-end mission information system technologies to capitalize on the technological advances of future missions and the increased data of future missions. The goals of the NASA High Performance Computing and Communications (HPCC) project are to accelerate the development, application and transfer of high performance computing technologies to meet the engineering and science needs of the Earth science community. The ESE HPCC investment will focus on advanced developments of particular interest in Earth and space science.

STRATEGY FOR ACHIEVING GOALS

New Millennium Program

The NMP reflects a commitment to develop new technology to meet the scientific needs of the next few decades and to reduce future Earth science mission costs through focused technology demonstrations for Earth orbiting missions. The Office of Earth Science (OES) has joined the Office of Space Science in the NMP in order to capitalize on common work from core technology development projects and specific spacecraft and instrument studies. The program will identify and demonstrate advanced technologies that

reduce cost or improve performance of all aspects of missions 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, the Earth Observers (EOs), 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 performance of Earth science missions.

Advanced Information Systems

Information technology advances play a critical role in collecting, handling, and managing very large amounts of data and information in space and on the ground. The objectives of the ESE Advanced Information Systems Program are to identify, develop and (where appropriate) demonstrate advanced information system technologies which:

- Enable new Earth observation measurements and information products,
- Increase the accessibility and utility of Earth science data, and
- Reduce the risk, cost, size, and development time of OES space-based and ground-based information systems.

Advanced Technology Initiative

Investment strategies within the Advanced Technology Initiatives are structured to implement a broad spectrum of developments to enable future ESE missions -- from advanced concepts, through technology advancements up the Technology Readiness Level (TRL) ladder, to readiness for infusion into future missions. Emphasis is being placed on developing new capabilities for Earth science sensors; integrated, autonomous, self-calibrating instruments and visionary architectures for future Earth Science observing systems.

Instrument Incubator Program

The IIP is expected to reduce the cost and development time of future scientific instruments for Earth science. The instrument incubator project will aggressively pursue emerging technologies and proactively close the technology transfer gaps that exist in the instrument development process. The program takes detectors and other instrument components coming from NASA's fundamental technology development projects and other sources, and focuses on combining them into new instrument systems that are smaller, less costly, less resource intensive, and that can be developed into flight models more quickly for future Earth science missions. This includes key follow-on instruments that will provide measurements that will support the new Earth Science Research Plan.

High Performance Computing and Communications

The NASA HPCC program consists of two discipline-related integrated projects. These projects are Earth and Space Sciences (ESS), managed by the Office of Earth Science and Learning Technologies (LT). 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 ten principal investigator teams and twenty-one NASA/NSF sponsored Grand Challenge investigations and to implement them on

advanced parallel computers. The LT project focuses on providing the technology base and applications to accelerate the implementation of the national information infrastructure and to communicate and distribute science and engineering materials to the education community. The LT project uses remote internet technologies 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 and engineering data.

SCHEDULE AND OUTPUTS

Preliminary Design Reviews - Confirms that the proposed project baseline is comprehensive (meets all project 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.

Earth Observer-1
Plan: February 1997
Actual: February 1997

Earth Observer-2 Revised schedule due to delays in initiating the selection process
Plan: June 1998
Actual: October 1998

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.

Earth Observer-1 Schedule changed to accommodate a grating spectrometer, which was added to the mission
Plan: April 1997
Actual: June 1997

Instruments Delivered - Confirms that the fabrication, integration, certification, and testing of all system hardware and software conforms to 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.

Earth Observer-1 Schedule changed to accommodate the Hyperion alternative for providing the hyperspectral
Plan: May 1999 capability following failure to provide wedge filter detectors
Revised: June 1999

Earth Observer-2 Plan: August 2000	After critical design review, it was determined that the SPARCLE system cost had grown significantly. After detailed peer reviews of the technical, cost and schedule status, the project was terminated. However, the progress made on the lidar technology development is still valuable and was documented

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.

Earth Observer-1 Plan: April 2000 Actual: November 2000	Schedule changed to accommodate the Hyperion alternative for providing the hyperspectral capability and to complete system integration and tests EO-1 was launched successfully in November 2000.
Earth Observer-2 Plan: Deleted	Project was terminated due to cost growth.
Earth Observer-3 Plan: 2005	Project in formulation.

ACCOMPLISHMENTS AND PROPOSED RESULTS

New Millennium Program

The Earth Observer (EO-1) Advanced Land Imager (ALI) is the first mission selected under the NMP series. It was launched successfully in November 2000. The EO-1 consists of an ALI instrument, a hyperspectral instrument (called Hyperion), a spacecraft, and numerous advanced technologies as an integral part of the mission. The project is now in the mission operation phase, conducting the required technology validations.

Due to the manufacturing difficulties at the ALI detector contractor, the imaging capability of the ALI was rescoped to a grating imaging capability with limited swath coverage to preserve the overall mission schedule and cost. The decision was made in the summer of 1998 to continue the hyperspectral capability, however, through another contractor's design. An additional module called Hyperion was completed by TRW that provides the hyperspectral functionality. The EO-1 mission and the associated technologies have been performing according to plan. Technology validation workshops are being planned in March and August 2001, to discuss and disseminate the technology validation results.

The Announcement of Opportunity for the EO-3 mission was released in 1999; 4 innovative measurement concepts were selected for concept definition study in February 1999. These concepts would test breakthrough technologies for remote sensing from geostationary Earth orbits. The concept definition studies were completed in September 1999. After detailed review, a Geostationary Imaging Fourier Transform Spectrometer was selected as the EO-3 mission. The concept will test advanced technologies such as large area focal-plane array, new data readout and signal processing electronics, and passive thermal switching, which will be used

for measuring temperature, water vapor, wind and chemical composition with high resolution in space and time. The EO-3 project is currently in formulation, moving towards a Preliminary Design Review in March 2001. EO-3 is being planned as a partnership with the Office of Naval Research in the Department of the Navy. This partnership will include provision of funding for spacecraft and launch for the mission as well as transferring the Geostationary Imaging Fourier Transform Spectrometer (GIFTS) operation to extended Indian Ocean observations. The details of this partnership are still being negotiated. The current plan for the launch of the mission is late 2004 to 2005.

Advanced Technology Initiative

The emphasis of the ATI program will be placed on those technologies that will reduce resource requirements for the instruments or enable new missions, science measurements or applications. Additional emphasis will be placed on new emerging technologies or on those technologies where leveraging opportunities are available. Further details on instrument technologies being developed are described below.

The first ATI instrument solicitation was a broad call that addressed all five Earth science themes in the ESE strategic plan. The NASA Research Announcement was released on September 16, 1999 and 23 awards were announced on January 14, 2000. The awards addressed a broad range of technology categories to reduce the risk, size and development costs for Earth observing instruments and enable new Earth observation measurements. Awards were made for instrument components in active and passive optical, active and passive microwave as well as advanced electronic components for future ESE instruments. A second NRA is anticipated in FY 2002 to address key component technologies to support the measurements in the recent ESE Science Plan. A brief overview of these first 23 ATI awards is given in the paragraphs below.

Advanced Information Systems

The first Advanced Information Systems Technology NRA (FY 2000) was issued on November 26, 1999 and closed on January 25, 2000. This NRA solicited both hardware and software technology proposals for on-board, space-based applications in the following five categories of information system activities:

1. On-board Satellite Data Processing and Intelligent Sensor Control
2. On-board Satellite Data Organization, Analysis and Storage
3. Data Transmission and Network Configuration
4. Intelligent Platform Control
5. Information Systems Architectures and Standards.

Of the 117 proposals submitted, 30 were selected for award from each of the five categories solicited covering a variety of topics ranging from satellite on-board processing, data collection and analysis, information transmission and wireless networks, to satellite platform control and flight operating systems. The approximate value of the awards are $26 million over a three year period and will involve government, industry and university partners in 12 states and the District of Columbia.

The near-term investment strategy for Information Systems continues the Advanced Prototyping System (APS) effort, formerly known as ESDIS Prototypes, in support of EOSDIS, the NewDISS, and other ESE ground system development technology needs. Prototyping is accomplished through the Quick Response System (QRS), and the objectives are to leverage technologies to reduce costs and enhance the use of EOS data, and to explore technologies to enable NewDISS. Technologies are currently categorized into five areas: science processing, storage management, interactive access, data server access and infrastructure, and open distributed architecture.

Instrument Incubator Program

The IIP supports the development of new instruments and measurement techniques from paper studies through laboratory development and ground or air validation. NASA received 123 proposals of which 27 have been selected and are under contract. Selected projects include three from industry, six from NASA field centers, eight from universities and ten from national laboratories. Most of these IIP projects represent efforts to reduce the cost, size, mass, and resource use of current measurement approaches. Several will enable or improve measurements that cannot be made satisfactorily today. The first set of projects have start dates ranging from December 1998 to April 1999. The projects range in length from 1 to 3 years and will end between March 2000 and February 2002.

Future Incubator solicitations will focus on specific areas of science or measurement technology, taking into account the ongoing set of IIP projects, the current science priorities as reflected in the latest ESE Science Research Plan, the current set of future mission scenarios, and existing and planned technology partnerships. Based upon these considerations, the second IIP NRA will be released in 2001. For the purpose of this announcement, the following technology areas will be the primary focus for development: (1) lasers and lidar systems; (2) passive microwave radiometers; and (3) radar systems.

Proposals for other technology developments that address high priority ESE needs and are highly innovative will be considered.

The advanced geostationary study effort has been evaluating various new imaging, sounding, and lightning mapper instrument concept designs and technologies that could be applied to using geosynchronous orbit as a cost effective vantage point for supporting Earth science research objectives as well as NOAA observational requirements. The study effort has also investigated technologies and concepts for advance geosynchronous spacecraft and associated ground data processing and distribution techniques required to support the advanced instrumentation. All activities have been closely coordinated between NASA and NOAA.

In FY 2001 and FY 2002 the technology program will continue to achieve success in timely development and infusion of technologies, thereby enabling future missions and reducing their total cost. Indicators of this performance will be to annually advance at least 25% of funded instrument technology developments one Technology Readiness Level (TRL); mature two to three technologies to the point where they can be demonstrated in space or in an operational environment; and enable new science measurement capability or significantly improve performance of an existing one. These performance indicators will be refined as the Enterprise gains experience with its technology development initiatives.

BASIS OF FY 2002 FUNDING REQUIREMENT

CONSTRUCTION OF FACILITIES

	FY 2000	FY 2001	FY 2002
		(Thousands of Dollars)	
Construction of Facilities.....	1,000	--	--

For additional detail, refer to the Mission Support, Construction of Facility section.

BASIS OF FY 2002 FUNDING REQUIREMENT

MISSION OPERATIONS

	FY 2000	FY 2001	FY 2002
		(Thousands of Dollars)	
Mission operations			
(Upper Atmosphere Research Satellite)	7,050	10,589	4,000
(Total Ozone Mapping Spectrometer)	3,200	6,885	6,495
(Ocean Topography Experiment (TOPEX)	9,657	6,692	6,557
(Tropical Rainfall Measuring Mission)	11,100	14,671	15,604
(Earth Science)	17,000	18,941	19,594
Total	48,007	57,778	52,250

PROGRAM GOALS

Operations, Data Retrieval and Storage (ODRS) provides the data and data products from EOS precursor missions, including the UARS, TOPEX, TOMS, NSCAT and TRMM, required to understand the total Earth system and the effects of humans on the global environment.

STRATEGY FOR ACHIEVING GOALS

This program supports the observations and data management portion of Earth science activities.

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, 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 proponents include NOAA, Russia (manifested a TOMS on their Meteor 3 satellite launched in 1991), Japan (manifested a TOMS on their ADEOS satellite launched in 1996). Key ERBS users are a diverse set of institutions including NOAA (manifested Earth Radiation Budget Experiment (ERBE) sensors on NOAA-9 and -10 launched in the 1980's), GSFC, LaRC, the State University of New York, Oregon State University, and the Scripps Institution of Oceanography.

Alaska Synthetic Aperture RADAR (SAR) Facility (ASF) missions include the European Space Agency Remote Sensing Satellite (ERS-1-2), the Canadian (RADARSAT) for new acquisitions, , Japanese Earth Remote Sensing Satellite (JERS-1), and RADARSAT mission for historical and archival missions. Key participants involved in the ASF include the European Space Agency, Japan NASDA, Canadian Space Agency, NASA, NASA/Goddard Space Flight Center, NASA/Wallops Flight Facility (WFF), the Jet Propulsion Laboratory (JPL, the Ohio State Byrd Polar Research Center, and University of Alaska which hosts the ASF, SAR data acquisition and usage involved countries throughout the world, including, Italy, Saudi Arabia, China, Australia, France, Canada, Brazil, the United Kingdom, and Germany.

SCHEDULE AND OUTPUTS

OPERATIONAL SPACECRAFT/INSTRUMENTS

Common to all missions:	
Archive 95% of planned data acquisition	The primary criteria for success of an operational spacecraft are to obtain 95% of the planned data acquisition.
UARS (launched September 1991) continuing operations through September 30, 2001	The spacecraft launched in September 1991 with an expected three-year mission life. It has gone well beyond the expected mission life providing data to support improvements 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. The spacecraft is transitioning to real-time operations due to a second recorder failure in November 1999. 95% operational. Processing 4,000 Bytes/second. UARS mission is planned for termination effective September 30, 2001.
TOPEX/Poseidon (launched August 1992) continuing operations	The spacecraft launched in August 1992 with an expected 3-year mission life. The extended mission is now in its ninth year of mission life. 100% operational. Processing 2000 Bytes/second.
ERBS/ERBE/SAGE II (launched Oct. 1984, December 1984 and September 1986) continuing operations	The ERBS spacecraft launched in October 1984. It has gone well beyond the expected mission life. 67% operational. SAGE processing 1,600 Bytes/second. ERBE processing 200 Bytes/second.

Alaska SAR Facility Missions: ERS-1 (launched 1991) JERS-1 (launched 1992) ERS-2 (launched 1995) RADARSAT (launched 1995) ADEOS (launched 1996) ADEOS-2 (launch 2002) Antarctic Mapping Mission (2001)	The Alaska SAR Facility is a ground receiving station and data processing station, which now supports ERS-2 and RADARSAT operational missions and continues to support ERS-1, JERS-1, ERS-2, and RADARSAT historical and archival missions. The Modified Antarctic Mapping Mission is an updated campaign using images from the Canadian Radarsat Satellite which is mapping the entire Antarctic continent and its evolutionary processes. These images are available for the NASA approved Antarctic research community. All of these are international missions. There are currently no unique metrics defined for ASF other than the common metric listed above, which exceeds RGS: 99/7% operational, acquisition 9956 Bytes/Second/Day. DAAC: 95% operational production Bytes/Second/Day.
TOMS FM-3 (launched July 1996) continuing operations	The TOMS-EP spacecraft was launched in July 1996 with an expected five-year mission life. It has completed its primary mission phase. 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. 100% operational. Processing 250 Bytes/second.
TRMM (Launched November 1997) continuing operations through 2004	The spacecraft launched in November 1997 with a 3-year mission life. All operations are nominal, except the CERES instrument, which is non-operational due to an anomaly with Data Acquisition Assembly Converter. 95% operational. Processing 250,000 Bytes/second.
SeaStar / SeaWiFS / Ocean Color (Launched August 1997 continuing operations for data processing)	The spacecraft launched in August 1997. This is a data buy from Orbital and the operation of the spacecraft is an Orbital responsibility. 100% operational. Processing 41,700 Bytes/second.
Landsat-7 (Launched April 1999)	Landsat-7 was launched April 15, 1999 and declared operational in July 1999. NASA agreed to operate the satellite through FY 2000. 100% operational. Processing 250 scenes/day. USGS assumed operation and funding responsibility beginning October 1, 2001.
Terra (Launched December 1999)	Terra spacecraft was launched December 18, 1999 and with checkout completed in April 2000. 100% operational. Terra is processing 200 gigabytes of data per day.

ACCOMPLISHMENTS AND PROPOSED RESULTS

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 purposes from all operational spacecraft and instruments. The current emphasis on global modeling in support of policy decisions on such matters as the impact of deforestation, ozone depletion,

and environmental quality worldwide has led to the acquisition and manipulation of unprecedented amounts of environmental data. The accompanying computational demand has led to a doubling of production computing capacity and quadrupling of mass storage capacity in the last two fiscal years.

In the mission operations project, responsibility for assigned missions is assumed approximately 120 days after launch. Data are acquired, processed, disseminated, and archived to meet mission requirements for user availability of timely and accurate data products.

User requirements will be met in 2000 and 2001 by continuing operations of on-orbit spacecraft and instruments including the UARS, TOPEX, and ERBS missions; and continuing receipt of ERS-1, JERS-1, and RADARSAT data at the Alaska SAR Facility, in addition to data for OTD, SeaStar/SeaWiFS, TOMS and TRMM.

BASIS OF FY 2002 FUNDING REQUIREMENT

INVESTMENTS

	FY 2000	FY 2001	FY 2002
		(Thousands of Dollars)	
Minority University Research & Education Program (MUREP)	7,300*	8,780*	
Education	--	1,497*	
Total	7,300*	10,277*	

* FY 2000 and FY 2001 MUREP covered in Applications, Commercialization and Education (ACE).
* In FY 2002, this activity has been transferred to the Agency Education program.

PROGRAM GOALS

The above funding requirements represent the ESE budget contribution to the Minority University Research and Education Programs (MUREP) and the Education Program.

STRATEGY FOR ACHIEVING GOALS

The Earth Science Strategic Enterprise investments in higher education institutions include Federally mandated outreach to the Nation's Historically Black Colleges and Universities (HBCUs) and Other Minority Universities (OMUs), including Hispanic-Serving Institution and Tribal Colleges and Universities. This outreach is achieved through a comprehensive and complementary array of strategies developed in collaboration with the Office of Equal Opportunity Programs. These strategies are designed to create a broad-based, competitive aerospace research capability within Minority Institutions (MI's). This capability fosters new aerospace science and technology concepts by integrating Earth Science Enterprise-related cutting-edge science and technology concepts, practices, and teaching strategies into MI's academic, scientific and technology infrastructure. As a result, increasing the production of more competitive trained U.S. students underrepresented in NASA-related fields who, because of their research training and exposure to cutting-edge technologies, are better prepared to enter graduate programs or the workplace. Other initiatives are focused on enhancing diversity in the Earth Science Strategic Enterprise's programs and activities. This includes exposing faculty and students from HBCUs and OMUs, and students from under-served schools, with significant enrollments of minority students, to the Enterprise's research efforts and outcomes, educational programs, and activities. To support the accomplishment of the Enterprise's mission, these programs are implemented through NASA Centers and JPL. The Centers and JPL support the MUREP through use of their unique facilities, program management and grant administration, and commitment of their personnel to provide technical assistance and assist in other facets of program implementation. Extensive detail as to how this funding is utilized is located under the MUREP portion of the budget.

In carrying out its Education Program, NASA is particularly cognizant of the powerful attraction the Earth Science mission holds for students and educators. The unique character of Earth Science exploration, scientific, and technical activities has the ability to captivate the imagination and excitement of students, teachers, and faculty, and channel this into an investment which support NASA's Education Program.

In fulfilling its role to support excellence in education as set forth in the NASA Strategic Plan, the NASA Education Program brings students and educators into its missions and its research as participants and partners. NASA provides the opportunity for educators and students to experience first hand involvement with Earth Science Enterprise scientists and engineers, facilities, and research and development activities. Examples of such opportunities include the Learning Technologies Program, a new Undergraduate Internship Program, and the Graduate Student Researchers Program. The participants benefit from the opportunity to become involved in research and development endeavors, gain an understanding of the breadth of Earth Science activities, and return to the classroom with enhanced knowledge and skills to share with the entire education community. Detail as to how this funding is utilized is located under the NASA Education portion of the budget.

BASIS OF FY 2002 FUNDING REQUIREMENT

EARTH SCIENCE INSTITUTIONAL SUPPORT

	FY 2000	FY 2001	FY 2002
		(Thousands of Dollars)	
Institutional Support to Earth Science	[246,979]	[231,569]	236,978
Research and Program Management (R&PM)	[230,682]	[208,909]	220,129
Personnel and related costs	[173,528]	[166,141]	168,902
Travel	[6,080]	[5,226]	5,426
Research Operations Support (ROS)	[51,074]	[37,542]	45,801
Construction of Facilities (CoF) - (Non-Programmatic)	[16,297]	[22,660]	16,849
Earth Science Full-Time Equivalent (FTE) Workyears	[1,976]	[1,816]	1,733

PROGRAM GOALS

The two primary goals of this budget segment are to:

1. Acquire and maintain a civil service workforce, that reflect the cultural diversity of the Nation and, along with the infrastructure, is sized and skilled consistent with accomplishing NASA's research, development, and operational missions with innovation, excellence, and efficiency for the Earth Science Enterprise (ESE).

2. Ensure that the facilities critical to achieving the ESE are constructed and continue to function effectively, efficiently, and safely, and that NASA installations conform to requirements and initiatives for the protection of the environment and human health.

RESEARCH AND PROGRAM MANAGEMENT (R&PM): program provides the salaries, other personnel and related costs, travel and the necessary support for all administrative functions and other basic services in support of research and development activities at NASA installations. The salaries, benefits, and supporting costs of this workforce comprise approximately 80% of the requested funding. Administrative and other support is approximately 18% of the requests. The remaining 2% of the request are required to fund travel necessary to manage NASA and its programs.

CONSTRUCTION OF FACILITIES (CoF): budget line item provides for discrete projects required for components of the basic infrastructure and institutional facilities and almost all are for capital repair. NASA facilities are critical for the ESE, to sustaining the future of aeronautics and advanced space transportation, which both support military and private industry users. NASA has conducted a thorough review of its facilities infrastructure, finding that the deteriorating plant condition warrants an increased repair and renovation rate to avoid safety hazards to personnel, facilities, and mission, and that some dilapidated facilities need to

be replaced. Increased investment in facility revitalization is needed to maintain a facility infrastructure that is safe and capable of supporting NASA's missions.

ROLES AND MISSIONS

The detail provided here is for the support of the ESE institutions - Marshall Space Marshall Space Flight Center, Stennis Space Center, Ames Research Center, Dryden Flight Research Center, Langley Research Center, Goddard Space Flight Center, and NASA Headquarters.

MARSHALL SPACE FLIGHT CENTER (MSFC)

The ESE funds approximately 2% of MSFC's Institution cost. Through the Global Hydrology and Climate Center (GHCC), a joint venture with academia, MSFC engages in research, education, and the development of Earth science applications. The GHCC focuses on using advanced technology to observe and understand the global climate system and applies this knowledge to agriculture, urban planning, water resource management, and operational meteorology.

STENNIS SPACE CENTER (SSC)

The ESE funds approximately 17% of SSC's Institution cost. Through the Applications Program, SSC will enhance U.S. economic competitiveness via commercial partnership programs that apply remote sensing technologies in business applications and reduce new product development costs. As part of the Applied Research and Data Analysis program, SSC will conduct fundamental and applied research which increases our understanding of environmental systems sciences, with emphasis on coastal research of both land and oceans.

AMES RESEARCH CENTER (ARC)

The ESE funds approximately 5% of ARC's Institution cost. ARC builds instruments and computer models for measurement and analysis of atmospheric constituents and properties from aircraft platform are being developed. Applied research and developments to enhance the use of remote and in-situ sensing technology for Earth resources applications continues. ARC provides information systems and high end computing support for Earth Sciences knowledge acquisition.

DRYDEN FLIGHT RESEARCH CENTER (DFRC)

The ESE funds approximately 6% of DFRC's Institution cost. DFRC conducts flight operations in support of Airborne Science Missions utilizing aircraft for data collection and observation.

LANGLEY RESEARCH CENTER (LaRC)

The ESE funds approximately 13% of LaRC's Institution cost. LaRC performs an agency-designated Atmospheric Science mission role in support of the ESE in the NASA Strategic Plan. As Lead Center for Focused Atmospheric Science Missions, LaRC conducts a

world-class peer reviewed and selected atmospheric science program in support of national goals in preserving the environment and in fundamental science. Specific LaRC discipline areas of expertise are Earth radiation research, particularly the role of clouds in the Earth's energy budget; middle and upper atmospheric research; and tropospheric research. LaRC performs innovative scientific research to advance the knowledge of atmospheric radioactive, chemical, and dynamic processes for understanding global change; develops innovative passive and active sensor systems concepts for atmospheric science measurements. LaRC conducts a technology development program that develops advanced laser and LIDAR technologies for Earth science missions; advanced passive remote sensing technologies; develops advanced ultra-lightweight and adaptive materials, structural systems technologies and analytical tools for significantly reducing the end-to-end cost and increasing the performance of earth observation space instruments and systems. LaRC conducts an Application, Education and Outreach program that utilizes scientific data for non-scientific applications and in support of science and math education. LaRC also serves as a Primary Data Analysis and Archival Center (DAAC) for Earth Radiation and Atmospheric Chemistry for the Earth Observing System.

GODDARD SPACE FLIGHT CENTER (GSFC)

The ESE funds approximately 34% of GSFC's Institution cost. GSFC is the Lead Center for Earth Science, including the Earth Observing System (EOS). This process and modeling research effort will provide the basis for establishing predictive global change models for policy makers and scientists.

GSFC manages the Earth Explorers Program and conducts science correlation measurements from balloons, sounding rockets, aircraft and ground installations. It also manages, on a reimbursable basis, the acquisition of meteorological observing spacecraft for the National Oceanic and Atmospheric Administration (NOAA).

Lead Center for the Independent Verification & Validation (IV&V) Facility in Fairmont, West Virginia. The IV&V Facility is responsible for providing independent assessments of project software and for the management of all software IV&V efforts within the Agency.

NASA HEADQUARTERS (NASA HQ)

The ESE funds approximately 11% of NASA HQ's Institution cost. The mission of NASA HQ is to plan and provide executive direction for the implementation of U.S. space exploration, space science, Earth science, aeronautics, and technology programs. This includes corporate policy development, program formulation, resource allocations, program performance assessment, long-term institutional investments, and external advocacy for all of NASA.

At NASA HQ, the broad framework for program formulation will be conducted through ESE. Consistent with the NASA strategic plan, the ESE develops program goals and objectives to meet the needs of external customers within the policy priorities of the Administration and Congress.

The Enterprise's Institutional Support figure includes an allocation for funding Headquarters activities based on the relative distribution of direct FTE's across the agency. A more complete description can be found in the Mission Support/two Appropriation budget section.