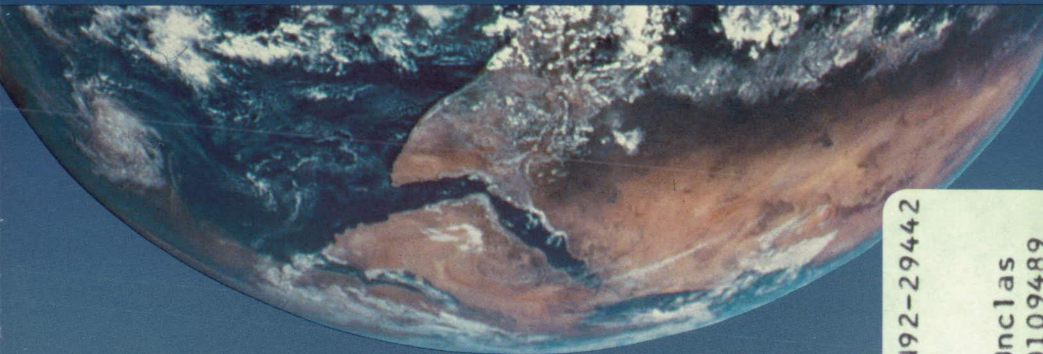
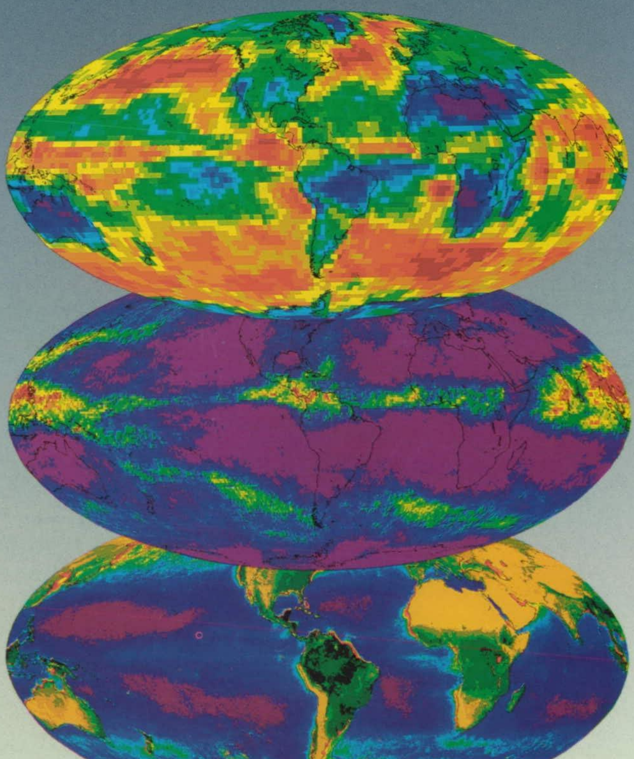
EOSDIS





EOS Data and Information System

EOS Data and Information System (EOSDIS)

May 1992

National Aeronautics and
Space Administration
Washington, D.C. 20546

Front Cover Data Products (from top to bottom)

Average Cloud Cover Percentage—Derived from weather satellite imagery as part of the International Satellite Cloud Climatology Project (ISCCP).

Monthly Mean Global Precipitation—High-Resolution Infrared Sounder-2/Microwave Sounding Unit (HIRS2/MSU) data processed by the Goddard Space Flight Center (GSFC) Laboratory for Atmospheres.

Global Biosphere—Composited image of ocean phytoplankton concentration and land-surface radiation derived from NASA's Nimbus-7 Coastal Zone Color Scanner (CZCS) and the NOAA-7 Advanced Very High-Resolution Radiometer (AVHRR), respectively.

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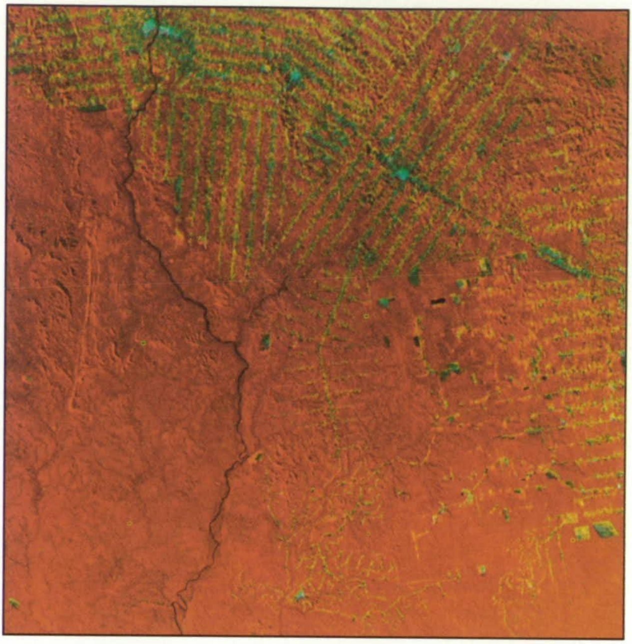
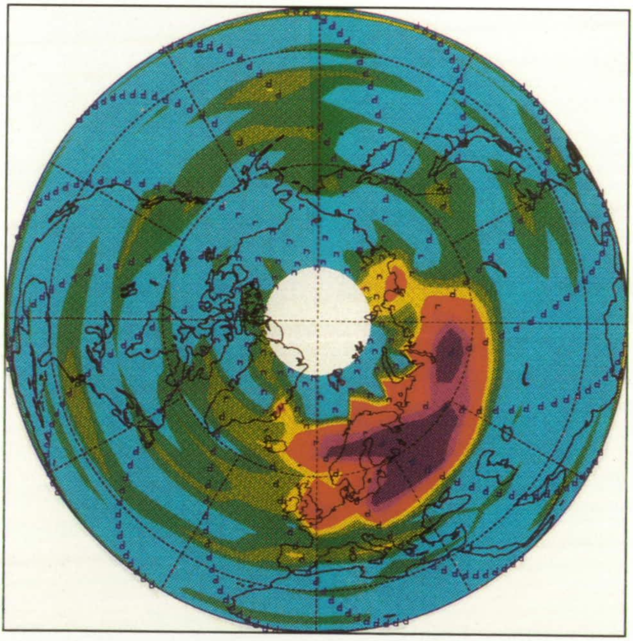


This 1988 Landsat Thematic Mapper (TM) image of Rondonia, Brazil, shows the fishbone pattern of deforestation typical of small farm holdings. As evidenced by the serpentine roads of the upper center, the Brazilian government has attempted to mitigate the excessive fragmentation and rectilinear development associated with earlier settlement patterns.

Recent measurements collected by the Upper Atmosphere Research Satellite (UARS) indicate that an ozone hole could form over the northern hemisphere. Highly reactive chlorine compounds generated by human-produced CFCs snatch away one of the oxygen atoms from ozone (O_3), forming chlorine monoxide (ClO). This UARS image maps ClO at ~20-km altitude on January 11, 1992; bright red and violet show the region of elevated ClO concentrations over northern Europe and Russia.



The United States Government has initiated the U.S. Global Change Research Program (USGCRP) to develop a predictive understanding of the global environment. This monumental challenge is motivated by the critical concern of this age: Humanity now has a major influence on shaping the landscape and atmosphere of the planet. Actions must be taken to assess the Earth's condition, understand its processes, predict its future state, and find ways to ensure that the collective actions of humanity on the environment do not undermine its viability. To participate in this activity is to join in one of the most important and intellectually stimulating undertakings of this or any other time.

In the past decade or so, science and technology have reached levels that permit assessment of global environmental change. This assessment is an enormous and continuing task. No one scientist, laboratory, university, agency, or nation acting alone has the resources to generate the comprehensive understanding required. There is a collective responsibility to fuse existing, diverse intellectual and technological capabilities, and to bring them to bear on the issues of global change.

Scientific success in understanding global environmental change depends on integration and management of numerous data sources, extensive data holdings, and multifarious data products. Yet, to achieve true success in this endeavor requires an information system that enables and stimulates cooperation among many researchers, empowering them to make their contributions to the overall effort. The Global Change Data and Information System (GCDIS) must provide for the management of data, the sharing and harvesting of information, the dissemination of ideas, and the establishment of a widespread community of collaborators. The Earth Observing System Data and Information System (EOSDIS) is NASA's portion of this global change information system.

EOSDIS will manage the data resulting from NASA's Earth science research satellites and field measurement programs, and other data essential for the interpretation of these measurements. It will also provide access to data held in the archives of other government agencies, organizations, and countries. EOSDIS will generate user-defined data products, and will facilitate the combination and manipulation of data from all sources as well as their incorporation into models of the environment. Concomitant to fulfilling its data management functions, EOSDIS will encourage interdisciplinary research and assist in breaking down the intellectual barriers between the traditional disciplines of Earth science by offering an integrated view of existing environmental data.

EOSDIS: The Beginning

EOSDIS builds on existing discipline-specific Earth science data centers and data systems. The preexisting data systems that formed the starting point for the initial or Version 0 EOSDIS are listed below:

- NASA Climate Data System (NCDS)
- NASA Ocean Data System (NODS)
- Cryospheric Data Management System (CDMS)
- Alaska Synthetic Aperture Radar (SAR) Facility (ASF)
- Global Land Information System (GLIS)
- NASA Pilot Land Data System (PLDS)
- NASA Crustal Dynamics Data Information System (CDDIS)
- Trace Gas Dynamics Data Information System (TGDDIS).

Data are also being generated by several ongoing NASA flight missions. Projects of particular importance in determining the starting point for EOSDIS are the Upper Atmosphere Research Satellite (UARS) and the Earth Radiation Budget Experiment (ERBE). Today, EOSDIS has responsibility for continuing the data services of the above precursor data systems, and for archive and distribution of UARS and ERBE data as they become available to the research community. In addition, EOSDIS has taken over NASA support for the International Satellite Cloud Climatology Project (ISCCP) and WetNet. The former produces global cloud data sets using geostationary and polar-orbiting environmental satellite observations; the 5-year WetNet experiment serves as a demonstration of data system capabilities, facilitating the cooperative use of satellite microwave imagery to study the hydrologic cycle.

Building on these ideas, a “pathfinder” data set activity has been initiated to identify data sets that can be created using existing operational data and that are critical to global change research. The data sets currently being considered by the science community were derived from the following instruments: NOAA's Advanced Very High-Resolution Radiometer (AVHRR), TIROS Operational Vertical Sounder (TOVS), Visible/Infrared Spin Scan Radiometer (VISSR), and VISSR Atmospheric Sounder (VAS); the Defense Meteorological Satellite Program (DMSP) Special Sensor Microwave/Imager (SSM/I); and Landsat Multispectral Scanner (MSS) and Thematic Mapper (TM).

The data systems and data set initiatives that make up today's EOSDIS employ existing electronic networks for data transfer, interactive sessions, and mail. These services are provided through the NASA Science Internet Program coordinated by Ames Research Center (ARC). This network supports several protocols and is interoperable with the National Science Foundafion (NSF) Internet. At present, the scope of this network consists of a backbone based on T1 technology (1.5 Mbps) connecting 27 regional networks and over 100 tail circuits to research sites, reaching approximately 2,500 end users. In 1994, this backbone will be upgraded to T3 technology (45 Mbps).

Many scientists depend on various NASA data systems and related activities to support their work. During 1990, the precursor systems listed above received about 200,000 requests from users, of which roughly 40 percent were data orders. As EOSDIS develops and evolves, it must always be an operating system that continues user services and access to existing data sets.

EOSDIS Tomorrow

Considerable development is needed in the data system to provide the quality and range of services required to support global change research, and to cope with the quantity and variety of future data acquisitions. During the next 2 decades, EOSDIS will handle data from a number of new satellites (see Table 1). For all NASA Earth science satellites, including non-EOS missions, EOSDIS will supply data archive, distribution, and information management services; for EOS satellites, EOSDIS will also provide data product generation as well as command and control functions. For non-NASA satellites, EOSDIS will provide access to the archives and distribution systems of the responsible agencies (see Table 2).

Finally, EOSDIS will provide analyzed data sets generated by assimilation of applicable observations into global climate models. These model-assimilated data sets will employ model physics and dynamics to infer from the time series of observations a consistent picture for use in research.

Each new mission adds to the stream of data coming into EOSDIS, the volume of EOSDIS holdings, the number of distinct products to

Table 1. NASA Satellites

NASA Satellites (Launch Status)	Mission Objectives
ERBS (Operating) Earth Radiation Budget Satellite	Radiation budget, aerosol, and ozone data from 57° inclination orbit
TOMS/Meteor-3 (August 1991) Total Ozone Mapping Spectrometer	Ozone mapping and monitoring (joint with former U.S.S.R.)
UARS (September 1991) Upper Atmosphere Research Satellite	Stratospheric and mesospheric chemistry and related processes
NASA Spacelab Series (1992 on)	Instrumentation in the Shuttle payload bay to measure atmospheric and solar dynamics (ATLAS), atmospheric aerosols (LITE), and surface radar images [SIR-C and X-SAR (the latter provided by Germany)]
TOPEX/Poseidon (July 1992) Ocean Topography Experiment	Ocean surface topography and ice sheet altimetry (joint with France)
LAGEOS-2 (September 1992) Laser Geodynamics Satellite	Satellite laser-ranging target for monitoring crustal motions and Earth rotation variations (joint with Italy)
SeaWiFS (August 1993) Sea-Viewing Wide Field Sensor	Purchase of ocean color data to monitor ocean productivity
TOMS/Earth Probe (December 1993) Total Ozone Mapping Spectrometer	Ozone mapping and monitoring
NSCAT (1995) NASA Scatterometer	Instrument to measure surface vector winds over the ocean (flight on Japan's ADEOS)
Landsat-7 (1997) Land Remote-Sensing Satellite	High spatial resolution visible and infrared imagery to monitor land surface
TRMM (February 1997) Tropical Rainfall Measuring Mission	Precipitation and related variables, plus radiation budget in lower latitudes (joint with Japan)
EOS-AM Series (1998) Earth Observing System Morning Crossing	Global change measurements, including visible and near infrared imagery (nadir and bidirectional), radiation budget, measurement of CO and CH_4 (includes Canadian and Japanese instruments)
EOS-COLOR (1998) EOS Ocean Color Mission	Purchase of ocean color dàta to monitor ocean productivity
EOS-PM Series (2000) Earth Observing System Afternoon Crossing	Global change measurements, including visible and near infrared imagery (nadir and bidirectional), radiation budget, passive microwave measurements, and measurement of hydrologic cycle (includes ESA and EUMETSAT instruments)
EOS-AERO (2000) EOS Aerosol Mission	Global aerosols and stratospheric chemistry
EOS-ALT (2002) EOS Altimeter Mission	Ocean and ice sheet altimetry
EOS-CHEM (2002) EOS Chemistry Mission	Atmospheric chemistry and ocean-surface scatterometry

Table 2. Non-NASA Satellites

Non-NASA Satellites (Launch Status)	Mission Objectives
NOAA-9 through -J (U.S.—Operational)	Visible and infrared imagery, infrared atmospheric sounding, and ozone measurements
Landsat-4/5/6 (U.S.—Operational) Land Remote-Sensing Satellite	High spatial resolution visible and infrared imagery
DMSP (U.S.—Operational) Defense Meteorological Satellite Program	Visible, infrared, and passive microwave atmospheric and surface measurements
ERS-1 (ESA—Operational) Earth Remote-Sensing Satellite	C-band SAR, microwave altimeter, scatterometer, and sea surface temperature
JERS-1 (Japan—February 1992) Japan's Earth Resources Satellite	L-band SAR and high spatial resolution visible and infrared imagery
ERS-2 (ESA—1994) Earth Remote-Sensing Satellite	Same as ERS-1, plus ozone mapping and monitoring
Radarsat (Canada—December 1994) Radar Satellite	C-band SAR imagery (joint with U.S.)
NOAA-K through -N (U.S.—1994 on)	Visible, infrared, and microwave imagery; infrared atmospheric sounding; and ozone measurements
NOAA-O through -Q (U.S.—2001 on)	Visible and infrared imagery, infrared and microwave atmospheric sounding, and ozone measurements
ADEOS (Japan—February 1995) Advanced Earth Observing Satellite	Global change measurements, including visible and near-infrared imagery, scatterometry, and tropospheric and stratospheric chemistry (includes U.S. and French instruments)
POEM-1 (ESA—1998) Polar-Orbit Earth Observation Mission	Global change and meteorological measurements, including visible and near-infrared imagery, scatterometry, tropospheric and stratospheric chemistry, altimetry, and laser and doppler ranging (includes operational polar-orbiting environmental payload)
ADEOS-II (Japan—Proposed for 1998) Advanced Earth Observing Satellite	Global change measurements, including visible and near-infrared microwave imagery, scatterometry, infrared and laser atmospheric sounding, tropospheric and stratospheric chemistry, and altimetry
TRMM-2 (Japan—Proposed for 2000) Tropical Rainfall Measuring Mission	Precipitation and related variables and Earth radiation budget in tropics and higher latitudes

be catalogued, and the utility of the system to researchers. Figure 1 shows the anticipated growth in EOSDIS data, products, and users during the Mission to Planet Earth era.

The sections that follow explain EOSDIS plans and approaches for meeting these challenges.

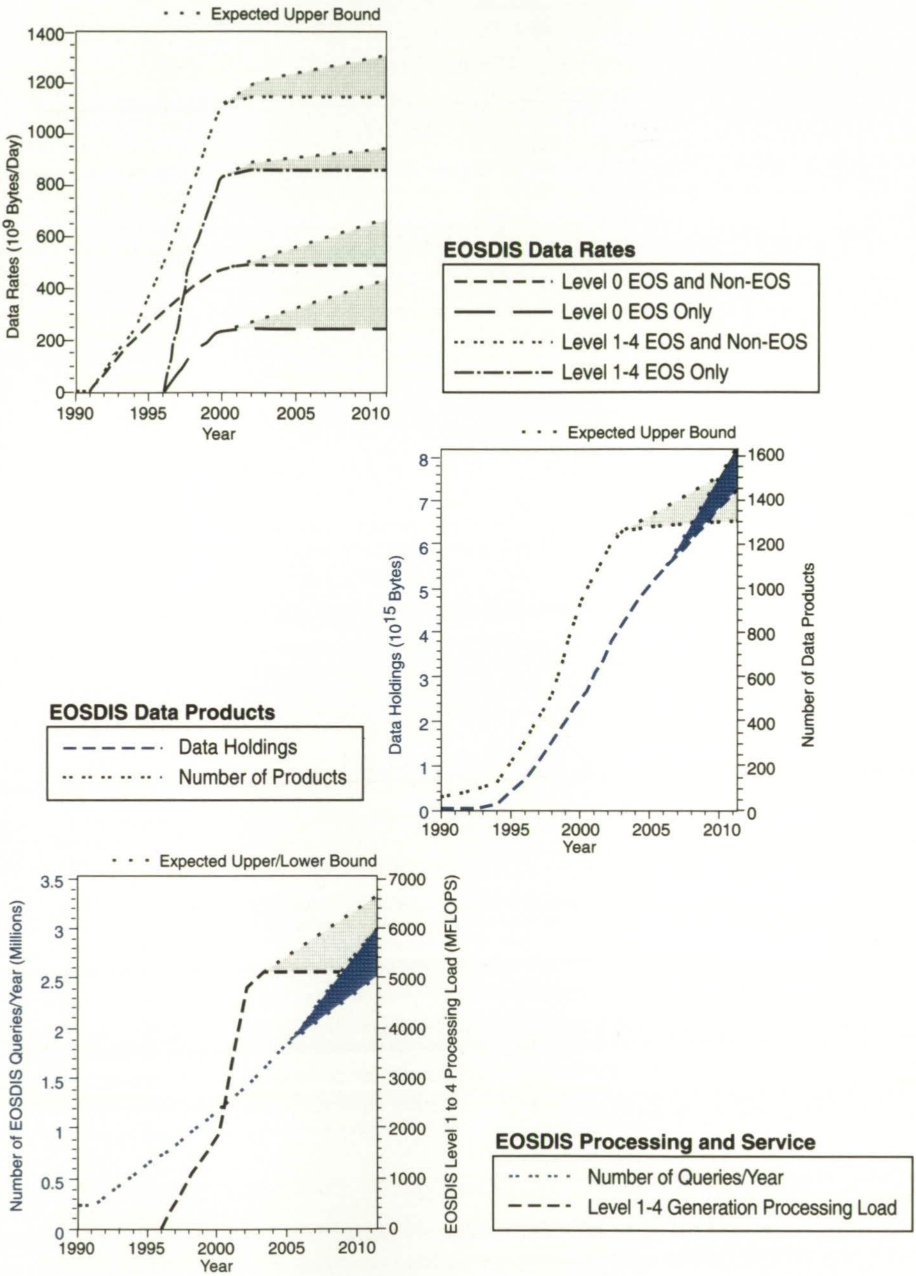


Figure 1. Growth Projections for Selected System Aspects

User Involvement in EOSDIS Implementation

Experience with scientific data systems has shown that users must be intimately involved in virtually every aspect of development and operation if the system is to be successful. The success of EOSDIS hinges on the users' being empowered to shape it to their needs—needs which will evolve with progress in Earth science research and with experience gained in manipulating the data system. Three key elements drive this collaboration:

- Users must make a commitment to interact with system developers and operators.
- Disparate user desires must be forged into specific requirements, reflecting user needs.
- Demands for improvements and modifications must be shaped into a controlled series of periodic system changes.

In addressing the first challenge of having users invest their time in guiding system development and operation, EOSDIS has benefited from the commitment of its Advisory Panel. Panel membership has been drawn from both within and outside the EOS investigator community. Since 1989, the panel has reshaped EOSDIS plans and requirements through extensive review of the work of both EOSDIS management and the contractors engaged in design studies of the system. This effort has extended to service of some members on the procurement team for one of the major contracts for EOSDIS development, and to participation in prototyping of current developments. Other members of the Earth science community have interacted independently with various contractor teams to shape their contract proposals to address user needs.

As EOSDIS grows, broader participation in these activities will be required from the user community. The various advisory bodies and user working groups illustrated in Figure 2 provide one avenue for such participation. These groups exist to address each major functional or institutional element of EOSDIS, their integration into a whole, and their interrelation to the other systems comprising GCDIS. The job of synthesizing user requests and comments into a coherent voice guiding development and operation of EOSDIS must be accomplished within the user community.

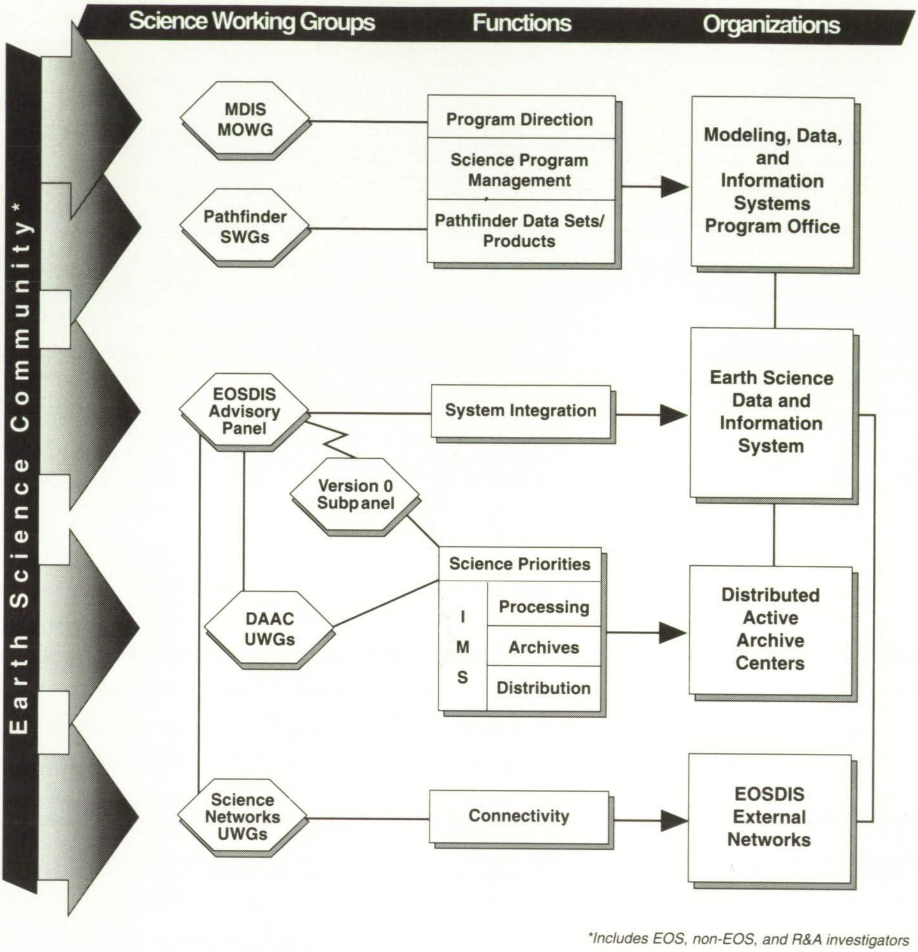


Figure 2. Science Advisory Process

The discipline of change control must be provided by project management and strongly guided by the EOSDIS Advisory Panel. There are two distinct time scales for taking user input and implementing it. New elements and revisions can be prototyped in a process involving rapid feedback from users; full implementation requires acceptance testing and approval of changes by a formal change control board. The EOSDIS Change Control Board will be advised by the appropriate user groups, and will contain user representatives as voting members.

EOSDIS will perform a wide variety of functions, supporting individuals located in various organizations and carrying on several distinct types of activity. EOSDIS functions are broken down into the following major classifications:

- Mission planning, scheduling, and control
- Instrument planning, scheduling, and control
- Resource management
- Communications
- Computational facilities at investigator sites
- Generation of standard data products
- Generation of special data products
- Archiving of data and research results
- Distribution of all information holdings
- User support
- Data location, browse, and ordering.

The organization of EOSDIS functions and activities, together with their interrelationships, is illustrated in Figure 3. Multiple boxes indicate distributed capabilities. For instance, data use in research, algorithm development and maintainance, and data product generation, archiving, and distribution are carried out in many different locations, while mission planning, scheduling, and control take place at a unique site [i.e., the EOS Operations Center (EOC)].

NASA is implementing EOSDIS using a distributed computer architecture based on hardware sharing an open system architecture and technology. This allows for the distribution of EOSDIS elements to many distinct locations. It also supports the evolution of the system by preventing EOSDIS from becoming captive to a single hardware vendor. Software will be layered and developed adhering to language and operating system standards to enhance its portability. Commercially available hardware and software will be used where practical to take advantage of the support provided by working in concert with the larger community. Adherence to standards and encouragement of their development are intrinsic to the EOSDIS development approach.

Connecting a Distributed System

EOSDIS is, and will remain, physically distributed, yet it must appear as a single logical entity to any user. The network bandwidth to the user

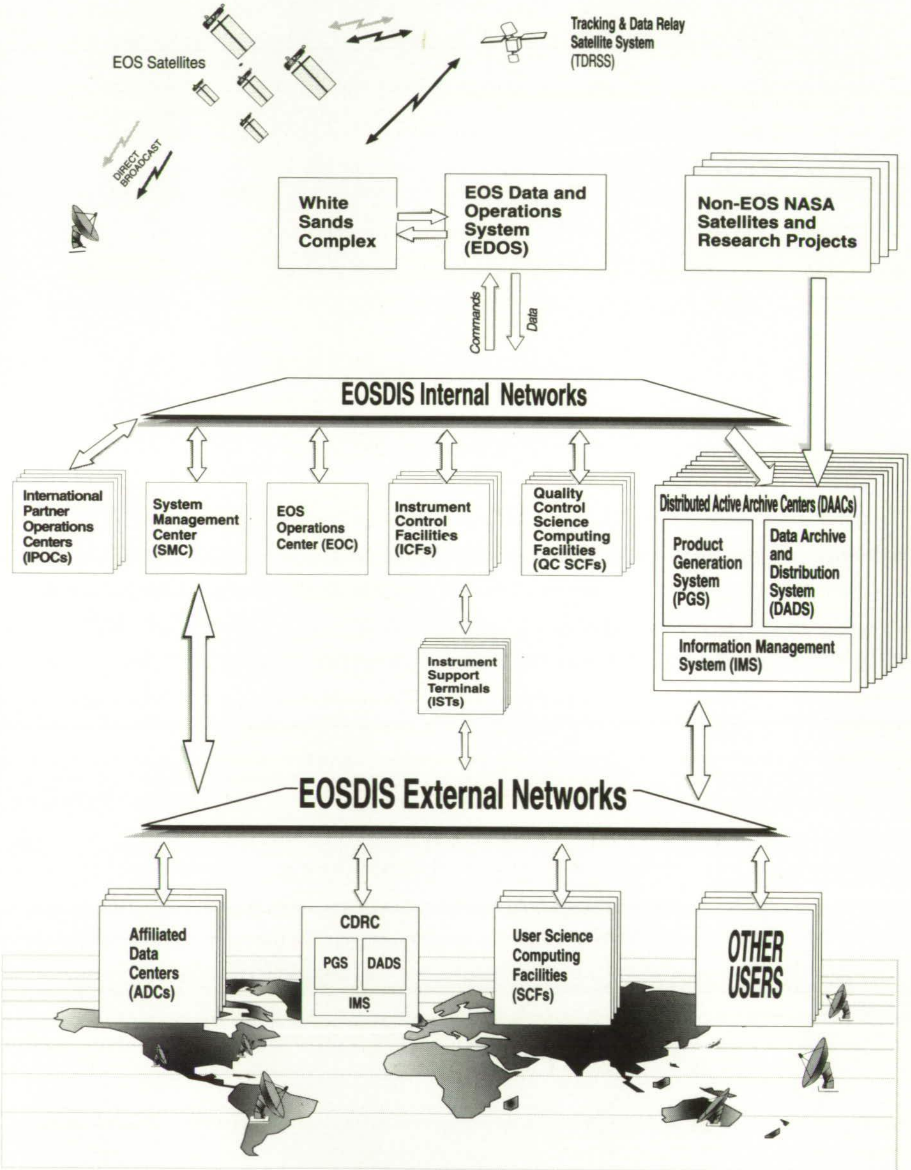


Figure 3. EOSDIS Architecture

community effectively dictates the style of access that can be achieved. The large, distributed community of Earth scientists and other users requires large capacity in this network and broadly available, easy connectivity. This is the function of the EOSDIS External Network. The interconnection of the EOSDIS elements determines how well the system can function as a seamless whole. In this case, the network must function in a controlled manner to enable the various elements to support one another in a timely fashion and to support communication with the satellites. The EOSDIS Internal Network must meet these requirements. Figure 4 illustrates the connections that must be made, but not necessarily the actual architecture of backbone and tail circuits. In implementing the external network, NASA is currently using NASA Science Internet and its connections to NSF Internet, and will make maximum use of the National Research and Education Network (NREN) as it develops. In addition, EOSDIS will rely on the NASA Space Network (NSN) with its Tracking and Data Relay Satellite System (TDRSS) for primary communication between the ground and the EOS satellites.

User Computing Facilities

Scientists and other users will be equipped to interact with the data system (see Figure 5). After networks, the key item determining the nature of EOSDIS access will be the type of equipment required to support the user interface. For the primary user community of environmental researchers, Science Computing Facilities (SCFs) will provide this capability. SCFs will range from personal workstations to supercomputers. To enable access from a wide variety of researchers, the minimum SCF supported by EOSDIS will be one that is affordable within a typical research grant. EOSDIS is providing the equipment and network access required by EOS investigators. Many other sources of research funding—both within and external to NASA—provide funding for computing equipment and communications to support the needs of the Earth science community at large.

EOSDIS will provide access and as many services as possible for users possessing the minimum capability of a personal computer and modem. This is intended to broaden EOSDIS access to users beyond the Earth science community.

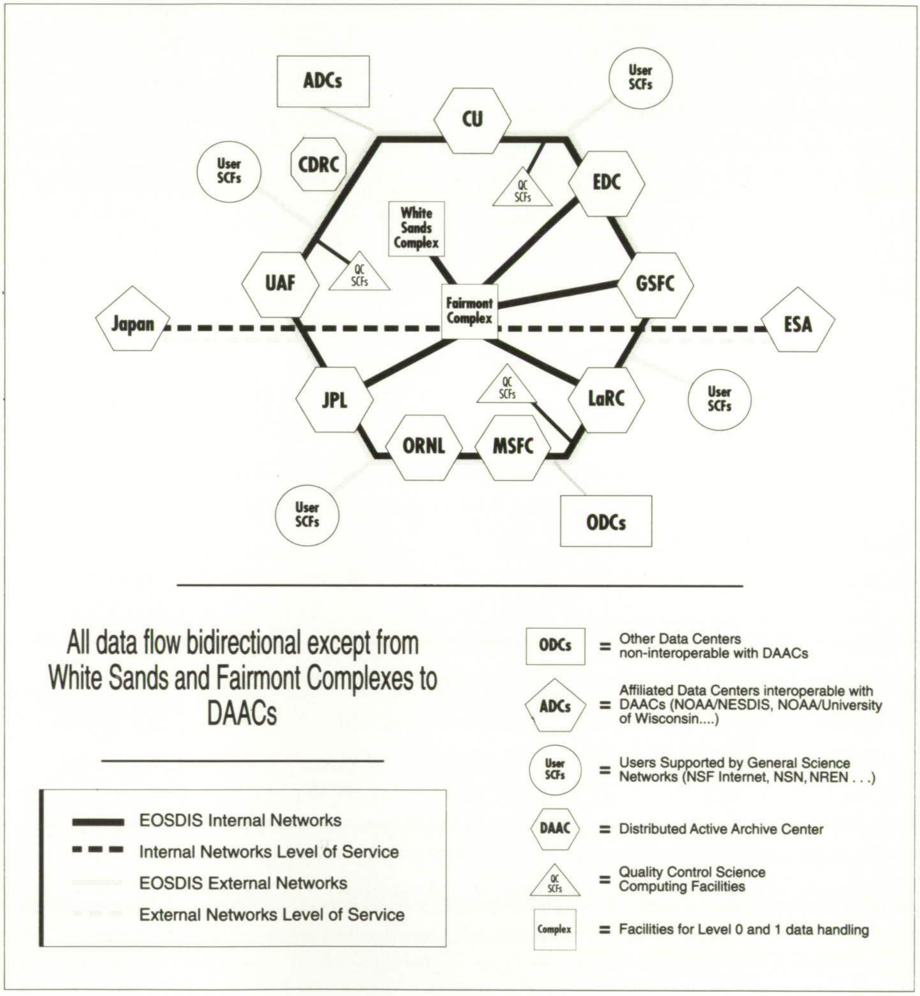


Figure 4. Networking Strategy

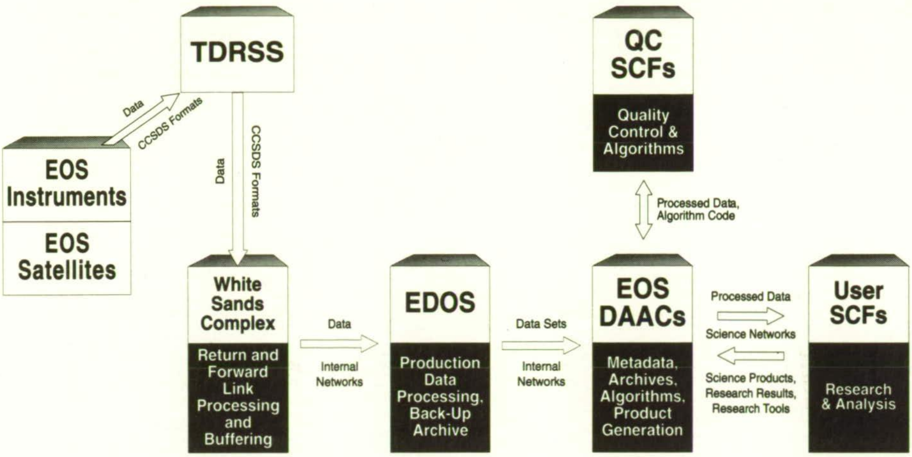


Figure 5. Science Data Flow

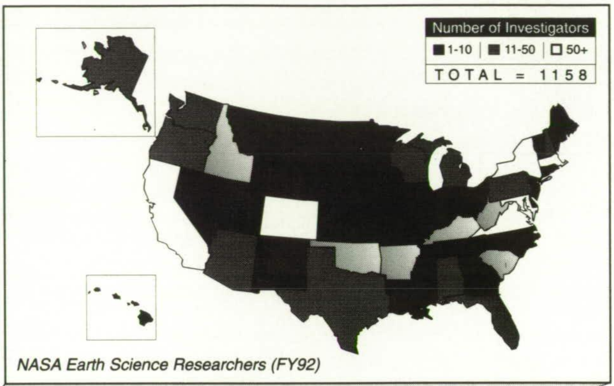
Distributed Active Archive Centers

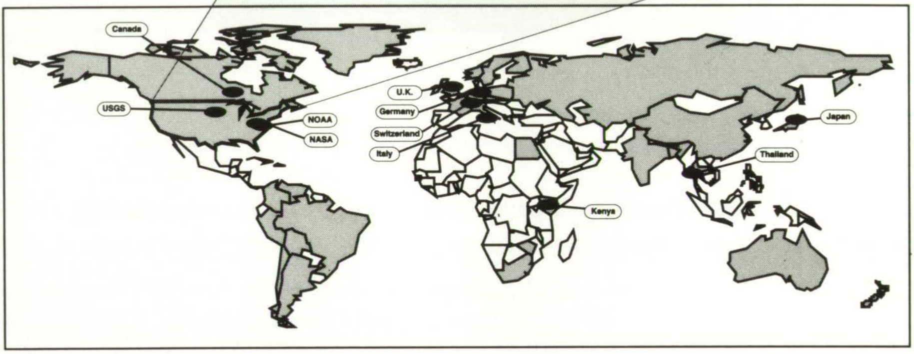
Once data are acquired or data products generated, they will be made available to the users, including the research community (see Figure 6). Most data represent a significant investment of public support for research, and holding these data is a public trust. Accordingly, EOSDIS provides for the institutionalization of these responsibilities to ensure that data will be available indefinitely in an easily usable form. These institutions are referred to as Distributed Active Archive Centers (DAACs). DAACs generate EOS standard data products and carry out NASA's responsibilities for data archive, distribution, and information management. DAACs serve as the primary user interface to EOSDIS.

At present, eight DAACs spanning various types of Earth science data have been selected by NASA to carry out the responsibilities for EOSDIS data management. These assignments were based primarily on the current distribution of expertise and activity. An additional center receiving funding through NASA will deal with socio-economic data related to global environmental change. The planned responsibilities of these centers are given in Table 3, and points of contact for user support are listed in Appendix A.

International Team Members

Australia	31
Austria	2
Belgium	2
Brazil	13
Canada	38
China	4
Egypt	2
France	79
Germany	22
Hungary	5
India	2
Indonesia	1
Israel	1
Italy	36
Japan	55
Mexico	2
New Caledonia	3
Norway	3
Saudi Arabia	1
South Africa	3
The Netherlands	13
United Kingdom	56





Participation in the International Geosphere-Biosphere Program (IGBP)
Location of CEOS and UNEP nodes for International Directories of Global Change Data

Figure 6. Scientific Participation in EOSDIS

Sources of Algorithms

The expertise in generating useful data products from EOS data resides in the science community. Accordingly, responsibility for the algorithms to generate EOS standard data products, along with the quality control of these products, is assigned to the EOS science investigators. The EOS Investigator Working Group (IWG) will provide ongoing peer review of the developed algorithms. Transformation of scientific algorithms into full-scale operational tools for delivery of EOS products will be facilitated by use of SCFs, in coordination with DAAC personnel. Clearly, the science community at large will generate many other useful products. Where appropriate, these additional products derived from EOSDIS data holdings will be archived and distributed by the system.

Table 3. EOSDIS-Sponsored Data Centers

Earth Science DAACs

Center	Initial Systems	Areas of Interest	EOS and Other Missions/Instruments
GSFC Goddard Space Flight Center	NCDS, PLDS, CDDIS	Climate, meteorology, stratosphere, ocean biology, and geophysics; AVHRR and TOVS pathfinder data sets	MODIS-N, AIRS, MHS, AMSU, SeaWiFS, GLRS-A, HIRDLS, TOMS, and TMI
LaRC Langley Research Center	ERBE processing	Clouds, radiation, aerosols, and tropospheric chemistry	CERES, ERBE, MOPITT, MISR, EOSP, SAGE, and TES
EDC EROS Data Center	GLIS, Landsat processing	Land processes	ASTER, HIRIS, SAR (land), Landsat (MSS and TM), and AVHRR
UAF University of Alaska–Fairbanks	ASF system	SAR imagery of ice, snow, and sea surface	ERS-1, JERS-1, ERS-2, Radarsat; and ongoing role as ground station
CU University of Colorado	CDMS	Polar oceans and ice	SMMR, SSM/I, and OLS
JPL Jet Propulsion Laboratory	NODS	Physical oceanography	TOPEX/Poseidon, NSCAT, STIKSCAT, and ALT
MSFC Marshall Space Flight Center	WetNet	Hydrologic cycle; SSM/I pathfinder data sets	MIMR, TMI, TRMM PR, LIS, and SSM/I
ORNL Oak Ridge National Laboratory	TGDDIS	Trace gas fluxes	Ground-based data relating to fluxes of trace gases (e.g., CO_2, CH_4)

Socio-Economic Data and Applications Center

Center	Initial Systems	Areas of Interest	EOS and Other Missions/Instruments
CDRC CIESIN Data and Research Center	—	Human dimensions of global change and policymaking applications	Socio-economic data

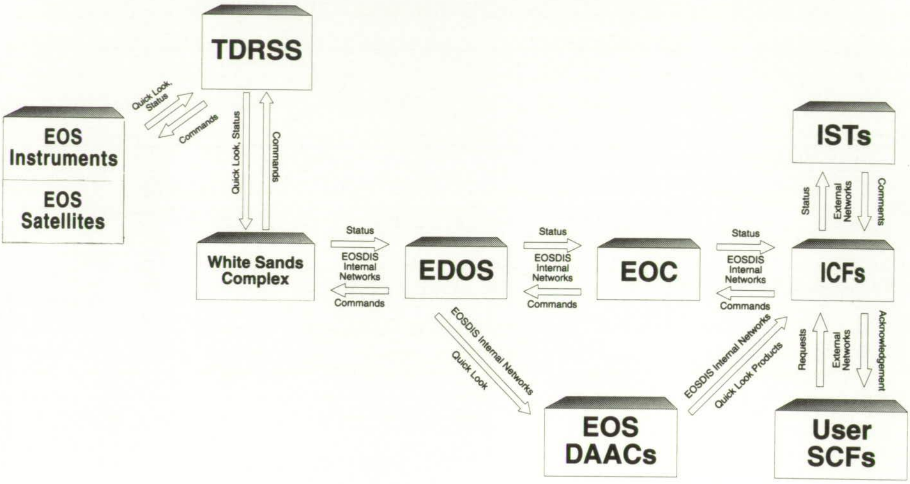


Figure 7. Command and Control

Flight Operations

The flight operations segment of EOSDIS will provide for the command and control of EOS instruments and spacecraft. The EOC will be located at Goddard Space Flight Center (GSFC) to generate commands to the instruments and spacecraft of NASA within the International Earth Observing System (IEOS), as well as monitoring the health and performance of these flight elements (see Figure 7). International partners flying instruments on NASA EOS spacecraft will be able to supply these functions for their instruments from their own centers. Principal Investigators (PIs) and facility instrument teams will be able to participate in the monitoring of their instruments and in resolving anomalies in instrument performance from their home institutions through use of a special set of software that can be run on a local computer workstation.

EOSDIS Management

EOSDIS program management is being directed by the Modeling, Data and Information Systems (MDIS) Program Office within the

Earth Science and Applications Division at NASA Headquarters. The implementation effort is led by the Earth Science Data and Information System (ESDIS) Project at GSFC. The management team for EOSDIS includes the institutional employees at the DAACs, in addition to the extensive project staff at GSFC. NASA is including in this team some of the most experienced information system development and operations managers drawn from within and outside the agency.

The initial implementation of EOSDIS—Version 0—provides knowledgeable personnel an operating infrastructure to test and refine the evolutionary methodology essential to EOSDIS success. Version 0 also permits experienced managers from the existing Earth science data systems the opportunity to share lessons learned while interconnecting these systems. The management team has been structured to carry the design philosophy throughout subsequent versions of EOSDIS.

NASA's implementation of EOSDIS includes three comprehensive contracts. A single EOSDIS Core System (ECS) contractor will be selected to ensure that the overall EOSDIS will function as a single, distributed system. An EOS Data and Operations System (EDOS) contractor will provide data capture, communications processing, Level 0 data distribution to the DAACs, and Level 0 back-up archive. And a separate Independent Verification and Validation (IV&V) contract will test and verify the functionality and performance of all elements of the ground system, and their integration with the EOS flight system. Final operational acceptance testing of all EOSDIS contractor deliveries as to compliance with interfaces and satisfaction of specifications and standards is included in IV&V.

EOSDIS is unique in its open data policies, in its large and distributed community of users and contributors, in its design as a gateway to data and users beyond U.S. borders, and in the role it will play as an adaptive tool for Earth science research.

Data Principles

Given the critical nature of research into the global environment, data should flow easily throughout the worldwide research community. Accordingly, the U.S. Government has developed a set of principles governing data policy for the USGCRP (see Table 4). Building on these principles, one key aspect of EOS data policy is that there will be no period of exclusive data access for any group of investigators. This policy will also apply to all NASA satellite missions launched after UARS. It is anticipated that up to 3 months may be required following the launch of each new satellite to permit the algorithms delivered prior to launch to be adjusted to work with the actual data and calibration values. EOS data will be available to scientific users at the marginal cost of filling a request, and scientific users will be required to make available their research results and any derived data products. Where these results are of significant interest, they can become part of the EOSDIS data holdings and be distributed under the EOS data policy.

Interagency Cooperation

The USGCRP depends on EOSDIS as a key resource in meeting the goals set by its agency partners: NASA, NOAA, DoD, DOE, DOI, EPA, NSF, USDA, HHS, Smithsonian Institution, and TVA. Through this interagency collaboration, the USGCRP has defined the GCDIS, which includes the Global Change Catalog System, a network-connected federation of data information systems allowing free and open access by the general community. In 1992, most of the existing agency information systems pertaining to global change will be connected, including EOSDIS.

NOAA, USGS, and DOE have responsibility for the long-term archival of EOSDIS data once these data are 3 years old. NOAA will gradually take responsibility for the EOS oceanic and atmospheric data; USGS will manage the long-term archival of land surface data

Table 4. Data Management for Global Change Research Policy Statements

The overall purpose of these policy statements is to facilitate full and open access to quality data for global change research. They were prepared in consonance with the goals of the U.S. Global Change Research Program and represent the U.S. Government's position on the access to global change research data.

1) The Global Change Research Program requires an early and continuing commitment to the establishment, maintenance, validation, description, accessibility, and distribution of high-quality, long-term data sets.

2) Full and open sharing of the full suite of global data sets for all global change researchers is a fundamental objective.

3) Preservation of all data needed for long-term global change research is required. For each and every global change data parameter, there should be at least one explicitly designated archive. Procedures and criteria for setting priorities for data acquisition, retention, and purging should be developed by participating agencies, both nationally and internationally. A clearinghouse process should be established to prevent the purging and loss of important data sets.

4) Data archives must include easily accessible information about the data holdings, including quality assessments, supporting ancillary information, and guidance and aids for locating and obtaining the data.

5) National and international standards should be used to the greatest extent possible for media and for processing and communication of global data sets.

6) Data should be provided at the lowest possible cost to global change researchers in the interest of full and open access to data. This cost should, as a first principle, be no more than the marginal cost of filling a specific user request. Agencies should act to streamline administrative arrangements for exchanging data among researchers.

7) For those programs in which selected principal investigators have initial periods of exclusive data use, data should be made openly available as soon as they become widely useful. In each case, the funding agency should explicitly define the duration of any exclusive use period.

at the EROS Data Center (EDC); and DOE will manage trace gas dynamics data at the Oak Ridge National Laboratory (ORNL). Through joint agreements, NASA, NOAA, DOE, and USGS will ensure that all EOSDIS data holdings are available as a baseline for long-term study of global change.

International Coordination

NASA's EOS Program and EOSDIS are part of a large international endeavor. The Earth Observations International Coordination Working Group (EO-ICWG) is the forum in which the international partners discuss, plan, and negotiate the cooperation essential for success of IEOS. IEOS includes NASA's EOS and its Japanese and European counterpart programs, as well as polar-orbiting meteorological systems of these countries. In the EO-ICWG, a common data policy is nearing completion; a joint data management plan is being developed; and other aspects of mission coordination are taking place.

The Committee on Earth Observations Satellites (CEOS) provides a forum for cooperation among agencies with Earth observations satellite programs. CEOS members include Japan, Canada, the European Space Agency (ESA), Germany, France, Italy, Brazil, the United Kingdom, Australia, the European Organisation for the Exploitation of Meteorological Satellites (EUMETSAT), India, and the U.S.; Norway and New Zealand are CEOS observers. The CEOS Working Group on Data coordinates key data-related issues for both CEOS and EO-ICWG. These issues include negotiation of international data format standards applicable to Earth observations data; implementation of an international directory network with initial nodes overseen by NASA, Italy (ESA), Canada, and Japan; and demonstrations of data exchange using commercially available networks in support of collaborative research projects.

NASA recognizes that a final design for EOSDIS cannot be stated, ordered, produced, installed, and operated indefinitely. The only feasible approach to EOSDIS involves evolution and adaptation—a process of steps in which users are continually served while system improvements are made. EOSDIS will support an aggressive program of prototyping in which users are active participants. User requirements will become better known through experience with EOSDIS, and needs will change over the life of the program. Also, new information systems technology will continue to emerge, allowing EOSDIS to take advantage of advances in computer science.

EOSDIS design and implementation are open to change. It will incorporate layering and standards and vendor independence to the fullest extent possible. The prototyping program will allow new features, functions, and implementations of new technology to be tested and evaluated in a near-operational setting, with successful prototypes implemented in the operational EOSDIS. The EOSDIS prototyping program has begun in the Version 0 effort and at the DAAC sites, and will expand with the involvement of the ECS contractor and university groups. The forces behind EOSDIS evolution—user feedback and technological change—and the prototyping program will continue for the life of the EOSDIS system. EOSDIS will never have a "final" version. The following milestones have been defined for the evolving EOSDIS:

- **During 1991**—EOSDIS continued current user services provided by existing discipline-oriented Earth science data centers, but brought them under a single management structure.
- **From 1992 to 1994**—An operating prototype EOSDIS (Version 0) will be developed, interconnecting existing Earth science data systems via electronic networks, interoperable catalogues, and common data distribution procedures to ensure better access to data. Beginning with existing systems offers several advantages—to evolve toward EOSDIS while taking maximum advantage of existing experience, and to ensure that there be no disruption in current user services. By interconnecting the existing systems, Version 0 will serve as a functional prototype of selected key EOSDIS services. As a prototype, it will not

have all the capabilities, fault tolerance, or reliability of later versions; however, EOSDIS Version 0 will support use by the scientific community in day-to-day research activities. Such use will test existing services to determine what additional or alternative capabilities are required of the full EOSDIS. Operational use of Version 0 is expected in mid-1994.

- **From 1995 to 1998**—A fully operational EOSDIS (Version 1) will be designed and developed while Version 0 is operating, thus benefiting from Version 0 user feedback. Version 1 assets will be physically distributed, but the system will appear completely integrated to users and will provide researchers with the complete set of capabilities needed for EOS science and mission operations. New capabilities of the Version 1 data and information system will be merged progressively into the Version 0 system to provide smooth and transparent transition to enhanced services.
- **Beyond 1998**—Capacity will be added as required to support EOS spacecraft launches. EOSDIS capabilities and services will be evaluated continually by the research community, and technology and capability will be refreshed or augmented as the need arises.

To facilitate its evolution, EOSDIS will have an open system architecture. To meet this objective, EOSDIS design employs the Unix operating system and will be compliant with standards that are presently emerging (e.g., Posix/X-windows). The communications-related standards of the Consultative Committee on Standard Data Services (CCSDS) will be used where appropriate. As further standards emerge in the user community, EOSDIS will adopt and support them. The hardware and software of the system will be modular so that individual elements can evolve independently within the constraints of their clearly defined interfaces.

EOSDIS in 1994

In the process of evolving toward an integrated system, EOSDIS will preserve the contacts that users currently have with existing data centers, and will maintain user services. The overall objective is to provide a graceful transition from current to enhanced capabilities from a user point-of-view. By 1994, the existing Earth science data centers will be interconnected to provide enhanced user services to the scientific community, as described below.

Science Oversight. One of the first activities of EOSDIS was to define methods for increasing participation by the research community in the definition, testing, and re-design of the system. Such involvement ensures that finite resources are allocated with maximum benefit for the users. By 1994, the following aspects of the EOSDIS system will be firmly in place:

- DAAC personnel working closely with user working groups to identify data sets required by the community
- Users setting priorities for new levels of service to add to existing capabilities.

Coordinated User Services. User services will be coordinated among the eight DAACs and CDRC, with Affiliated Data Center (ADC) involvement as follows:

- A mutual referral service will be in place that permits inquiries at one DAAC to locate data sets of interest at any EOSDIS-supported data center or at an ADC.
- Trained and knowledgeable staff will be familiar with system-wide holdings, and will help users to find the data they want.

Convenient System Services. Any user will be able to electronically access DAAC directories and other DAAC services, either directly or via the Global Change Master Directory. This access will permit descriptive information to be obtained about global change data so that a user can make an informed choice about whether to place an order. When orders are filled, data holdings will be distributed to researchers at no more than the marginal cost of reproducing the data. The following descriptions illustrate the benefits that EOSDIS Version 0 will provide to researchers:

- Turnaround time for finding, ordering, and receiving data sets will be reduced, thus allowing the user to spend more time focused on his or her own research.

- The Information Management System (IMS) will support data and information search and order across DAACs, CDRC, and selected non-NASA ADCs . A user will be able to log into any DAAC and find out about the data holdings at other sites. The user will be able to submit a request to order the data from a single site, yet have multiple DAACs fill his or her order. This activity will permit searches based on a user's area of interest, time range, parameter, or source and sensor.
- Users may use the Internet to download data sets using common easy-to-use procedures, as well as receiving data on standard distribution media.
- High-priority data sets will be distributed in standard formats, with ingest software that reads the format also included.
- Selected user community-identified data sets will have sample browse products generated and available for display on remote workstations. These browse products will be available on an experimental basis.
- DAAC internal computing and communications will migrate towards an open systems architecture, with adequate mass storage to support upcoming Earth science missions.
- Interfaces with ongoing and upcoming Earth science missions (e.g., TOMS, UARS, ERS-1/2, JERS-1, TOPEX/Poseidon, and SeaWiFS) will be in place, making data from all these missions accessible via one search and order procedure.

Product Generation. Initial support will be provided to test algorithms developed at EOS investigator SCFs. Limited product generation will take place at the DAACs using data from precursor missions. Pathfinder data sets for sea surface temperature and vegetation greenness will be available for the years covering 1981-1994.

EOSDIS in 1998

The launch of the first EOS spacecraft (EOS-AM1) is scheduled for 1998. By this time, EOSDIS will provide operational capabilities for information management, archive, and distribution at all DAACs open to the general research community. As described below, EOSDIS will also be capable of mission management for the EOS satellites and instruments.

Information Management. EOSDIS enhancements will focus on serving a larger community of research users (projected to number 10,000 or greater) and to service up to 1,000,000 user requests annually. Original IMS capabilities will be upgraded subsequent to testing and refinement of prototypes. Enhanced IMS capabilities available in 1998 will include the following:

- Increased search capabilities (e.g., based on statistical summaries of data content, not just data location on the Earth)
- Browse for all data sets used on an operational basis (integrated into the data search and order process)
- Increased and expanded access to data set histories, data algorithm documentation, and research results
- Expanded scope of access for data and information search (e.g., cooperative searches for internationally held data sets)
- Support for science users in the formulation of data acquisition requests for EOS data.

Data Distribution and Archive. EOSDIS capabilities will allow data sets to be delivered to investigators on a routine or as-needed basis. Distribution formats have yet to be determined; however, as stated earlier, EOSDIS will support the use of formats that conform to international standards. The archive and distribution capabilities at all nine EOSDIS-sponsored data centers will be fully operational and available for community use. Additional capabilities are identified below:

- Increased mass storage to provide more access to data on-line and near-line for quicker data delivery
- Increased network bandwidth for more timely access to data
- Distribution of data on state-of-the-art, high-quality media
- Access to quick-look data in support of field campaigns
- Common and consistent accounting procedures, providing data to research users at the marginal cost of filling the data order
- Network links to the PIs to permit routine and continuous quality assurance of data products by the investigator
- Software utilities supporting algorithm development, which permit the scientist to focus on science rather than on formatting software or data management support

- Product generation on state-of-the-art computing facilities
- Network and information links into other agencies, permitting access to data validation sources, operational data, and *in situ* measurements.

Product Generation. A full-scale capability will exist to support the ongoing migration and testing of algorithms from the EOS scientists to the DAACs, where the algorithms will be implemented in standard product generation. Pre-launch algorithms for EOS-AM1 standard products will have been delivered, and full testing of the processing, archiving, and distribution capabilities of the DAACs will have been conducted.

EOS Mission Operations. Systems will be in place well before the launch of the first EOS satellite to provide the full functionality and capacity required to support it. The command and control functions will also be brought on-line and fully tested with simulated EOS data in operational scenarios.

Ongoing Mission Operations. After the EOS observatories are launched and providing high volumes of data, EOSDIS will continue to evolve and add capabilities in response to lessons learned through its use. Continued prototyping will occur, and the active involvement of users in the ongoing evaluation and development of EOSDIS will be actively sought. This continuing evolution will enable EOSDIS to incorporate advances in data system technologies, as well as adapt to changing user requirements.

The best summary of EOSDIS is to examine the way EOSDIS should appear from several perspectives once its implementation is mature.

Intensive Research Users. Intensive research users of satellite and other global change data will perceive EOSDIS as the routine provider of extensive data sets, which arrive at their laboratories as reliably as technical journal subscriptions and as the equivalent of the research library from which additional information and other useful data can be obtained as needed. For some of this class of users, EOSDIS will also be the means for requesting special data acquisitions from the EOS satellites much as one would direct a telescope to make a needed series of observations.

Occasional or New Research Users. Researchers making occasional use of global change data or exploring the possible use of such data will find EOSDIS as the means to identify and obtain requisite data. This service is analogous to the services traditionally obtained from card catalogs, various indexes, and librarians. EOSDIS will also provide access to data beyond its own holdings in other relevant national and international information systems, and will enable the user to browse sufficiently to determine whether a particular data set is or is not likely to be useful.

NASA Mission Management. Those charged with managing the EOS spacecraft and related systems will use EOSDIS to control and command the system, determine its present and past condition, and communicate with EOS scientists, engineers, and system developers. EOSDIS will provide the means to generate the data products of the satellites and deliver them to users, and to readily resolve anomalies in system performance.

Policymakers and System Managers. Those charged with the formulation of public policy and the oversight of government functions will find that EOSDIS supports access to its data holdings for research and non-research users alike, ensuring that the full public value is being realized from the public investment in EOS. In addition to data, they will find easy access to the research findings and scientific environmental assessments that serve as the basis for policy formulation on matters that may benefit from such information. EOSDIS should also be seen as an important tool in international relations with countries working for global environmental management.

DAAC User Support Points of Contact

Consortium for International Earth Science Information Network
2250 Pierce Road
University Center, Michigan 48710
(517) 791-7371

EROS Data Center
U.S. Geological Survey
Sioux Falls, South Dakota 57198
(605) 594-6969

Goddard Space Flight Center
Greenbelt, Maryland 20771
DAAC User Support/Code 934—(301) 286-3209
NASA Master Directory/Code 633—(301) 286-9761
NASA Science Internet/Code 930.4—(301) 286-9514
Version 0 Network Support/Code 520—(301) 286-1074

Jet Propulsion Laboratory
4800 Oak Grove Drive
Mail Stop 300-323
Pasadena, California 91109
(818) 354-6980

Langley Research Center
Mail Stop 157B
Hampton, Virginia 23668
(804) 864-6554

Marshall Space Flight Center
Building 4646/ES 44
Huntsville, Alabama 35812
(205) 544-4086

Oak Ridge National Laboratory
P.O. Box 2008
Building 1000/Mail Stop 6335
Oak Ridge, Tennessee 37831
(615) 574-0390

University of Alaska
Alaska SAR Facility
Geophysical Institute
Fairbanks, Alaska 99775-0800
(907) 474-7487

University of Colorado
National Snow and Ice Data Center
Campus Box 449
Boulder, Colorado 80309
(303) 492-1834

Acronym List

ADC	Affiliated Data Center
ADEOS	Advanced Earth Observing Satellite
AIRS	Atmospheric Infrared Sounder
ALT	Altimeter
AMSU	Advanced Microwave Sounding Unit
ARC	Ames Research Center
ASF	Alaska SAR Facility
ASTER	Advanced Spaceborne Thermal Emission and Reflection Radiometer
ATLAS	Atmospheric Laboratory for Applications and Science
AVHRR	Advanced Very High-Resolution Radiometer
CCSDS	Consultative Committee for Standard Data Services
CDDIS	Crustal Dynamics Data Information System
CDMS	Cryospheric Data Management System
CDRC	CIESIN Data and Research Center
CEOS	Committee on Earth Observations Satellites
CERES	Clouds and Earth's Radiant Energy System
CFC	Chlorofluorocarbon
CIESIN	Consortium for International Earth Science Information Network
CU	University of Colorado
CZCS	Coastal Zone Color Scanner
DAAC	Distributed Active Archive Center
DADS	Data Archive and Distribution System
DMSP	Defense Meteorological Satellite Program
DoD	Department of Defense
DOE	Department of Energy
DOI	Department of Interior
ECS	EOSDIS Core System
EDC	EROS Data Center
EDOS	EOS Data and Operations System
EOC	EOS Operations Center
EO-ICWG	Earth Observations International Coordination Working Group
EOS	Earth Observing System
EOSDIS	EOS Data and Information System
EOSP	Earth Observing Scanning Polarimeter
EPA	Environmental Protection Agency
ERBE	Earth Radiation Budget Experiment
ERBS	Earth Radiation Budget Satellite
EROS	Earth Resources Observation System
ERS	Earth Remote-Sensing Satellite
ESA	European Space Agency
ESDIS	Earth Science Data and Information System
EUMETSAT	European Organisation for the Exploitation of Meteorological Satellites
FY	Fiscal Year
GCDIS	Global Change Data and Information System
GLIS	Global Land Information System
GLRS	Geoscience Laser Ranging System

GSFC	Goddard Space Flight Center
HHS	Health and Human Services
HIRDLS	High-Resolution Dynamics Limb Sounder
HIRIS	High-Resolution Imaging Spectrometer
HIRS	High-Resolution Infrared Sounder
ICF	Instrument Control Facility
IEOS	International Earth Observing System
IGBP	International Geosphere-Biosphere Program
IMS	Information Management System
IPOC	International Partner Operations Center
ISCCP	International Satellite Cloud Climatology Project
IST	Instrument Support Terminal
IV&V	Independent Verification and Validation
IWG	Investigator Working Group
JERS	Japan's Earth Resources Satellite
JPL	Jet Propulsion Laboratory
LAGEOS	Laser Geodynamics Satellite
Landsat	Land Remote-Sensing Satellite
LaRC	Langley Research Center
LIS	Lightning Imaging Sensor
LITE	Lidar In-Space Technology Experiment
MDIS	Modeling, Data, and Information Systems
MHS	Microwave Humidity Sounder
MIMR	Multifrequency Imaging Microwave Radiometer
MISR	Multi-Angle Imaging Spectro-Radiometer
MOBLAS	Mobile Laser
MODIS-N	Moderate-Resolution Imaging Spectrometer-Nadir
MOPITT	Measurements of Pollution in the Troposphere
MOWG	Management Operations Working Group
MSFC	Marshall Space Flight Center
MSS	Multispectral Scanner
MSU	Microwave Sounding Unit
NASA	National Aeronautics and Space Administration
NCDS	NASA Climate Data System
NESDIS	National Environmental Satellite, Data, and Information Service
NOAA	National Oceanic and Atmospheric Administration
NODS	NASA Ocean Data System
NREN	National Research and Education Network
NSCAT	NASA Scatterometer
NSIDC	National Snow and Ice Data Center
NSF	National Science Foundation
NSN	NASA Space Network
NSSDC	National Space Science Data Center
ODC	Other Data Center
OLS	Optical Line Scanner
ORNL	Oak Ridge National Laboratory
PGS	Product Generation System
PI	Principal Investigator
PLDS	Pilot Land Data System
POEM	Polar-Orbit Earth Observation Mission

PR	Precipitation Radar
QC	Quality Control
R&A	Research and Analysis
Radarsat	Radar Satellite
SAGE	Stratospheric Aerosol Gas Experiment
SAR	Synthetic Aperture Radar
SCF	Science Computing Facility
SeaWiFS	Sea-Viewing Wide Field Sensor
SIR-C	Shuttle Imaging Radar-C
SMC	System Management Center
SMMR	Scanning Multispectral Microwave Radiometer
SSM/I	Special Sensor Microwave/Imager
STIKSCAT	Stick Scatterometer
SWG	Science Working Group
TDRSS	Tracking and Data Relay Satellite System
TES	Tropospheric Emission Spectrometer
TGDDIS	Trace Gas Dynamics Data Information System
TIROS	Television Infrared Observing Satellite
TLRS	Transportable Laser Ranging System
TM	Thematic Mapper
TMI	TRMM Microwave Imager
TOMS	Total Ozone Mapping Spectrometer
TOPEX	Ocean Topography Experiment
TOVS	TIROS Operational Vertical Sounder
TRMM	Tropical Rainfall Measuring Mission
TVA	Tennessee Valley Authority
UAF	University of Alaska-Fairbanks
UARS	Upper Atmosphere Research Satellite
U.K.	United Kingdom
UNEP	United Nations Environment Programme
U.S.	United States
USDA	U.S. Department of Agriculture
USGCRP	U.S. Global Change Research Program
USGS	U.S. Geological Survey
U.S.S.R.	Union of Soviet Socialist Republics
UWG	User Working Group
VAS	VISSR Atmospheric Sounder
VISSR	Visible/Infrared Spin-Scan Radiometer
X-SAR	X-Band Synthetic Aperture Radar

Back Cover Art*—This collage provides a representative sampling of the space-based, airborne, and ground-based elements that comprise Mission to Planet Earth—the NASA contribution to the U.S. Global Change Research Program, which will yield comprehensive observations needed to study the Earth as an integrated system. From top to bottom, the illustration includes UARS, TOPEX/Poseidon, a NASA ER-2, the NASA DC-8, and laser ranging stations (TLRS-4 and MOBLAS-7, which are colocated at the GSFC Optical Research Facility).*