

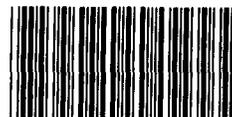
GAO

Report to the Chairman, Committee on
Science, Space, and Technology, House of
Representatives

May 1992

EARTH OBSERVING
SYSTEM

Broader Involvement of
the EOSDIS User
Community Is Needed



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**Information Management and
Technology Division****B-247881****May 11, 1992****The Honorable George E. Brown, Jr.
Chairman, Committee on Science, Space,
and Technology
House of Representatives****Dear Mr. Chairman:**

You requested that we review various aspects of the National Aeronautics and Space Administration's (NASA) Earth Observing System Data and Information System (EOSDIS). NASA has initiated a program, called the Earth Observing System (EOS), to collect an integrated set of data to study the earth's atmosphere, biosphere, oceans, land surfaces, and polar regions as a complete system over a 15-year period. The data from EOS will be processed, archived, and distributed by EOSDIS. As part of your request, you asked us to determine the extent to which users have provided input in defining EOSDIS requirements. This report describes the degree of user involvement and its importance in the EOSDIS planning and development process. Details of our objectives, scope, and methodology are provided in appendix I.

Results in Brief

NASA has not done enough to ensure that input from the full range of anticipated EOSDIS users is incorporated in the system's design. The predominant users of EOSDIS are expected to be the thousands of earth scientists who are not affiliated with the EOS program. However, NASA's planning for the system thus far has relied largely on input from the relatively small number of researchers funded directly by NASA. NASA's guidelines and mechanisms for obtaining further user input in the future do not provide assurance that all segments of the user community will be adequately represented. Because of the uncertainty regarding the total number of ultimate EOSDIS users and the system work loads they will generate, a system development strategy is needed that can adapt to changing user needs.

Background

In recent years, complex scientific questions and policy issues have emerged concerning the effect of natural earth processes and human activities on the environment. These issues and the need for accurate and comprehensive scientific information on which to base environmental policy decisions have led to the creation of a number of research initiatives,

including the U.S. Global Change Research Program. There are nine federal agencies, including NASA, in this program.¹

EOS, a series of space-based observatories containing a variety of instruments that will collect data about the earth, is NASA's main contribution to the Global Change Research Program. A key component of the program is the \$3 billion EOSDIS. It will be the system responsible for archiving and distributing all NASA earth science data, both from past and current missions and, in the future, from the EOS satellites. The information from EOSDIS is intended to enable the scientific community and researchers worldwide to broaden their understanding of environmental change within the entire earth system and to improve their ability to predict future change.

In the past, space research emphasized short-lived, single-purpose missions designed to provide a first generation of data to a few scientific specialists. The objectives of each mission were usually independent of the objectives of other missions. Planned future missions, such as EOS, have adopted a more complex multidisciplinary approach in order to gather data to address multifaceted objectives and answer broad scientific questions. Emphasis is generally shifting from single-investigator exploration to collaborative efforts of various teams of investigators and other global change researchers.

NASA released a request for proposals (RFP) for development of major components of EOSDIS in July 1991, after 7 years of conceptual design and requirements studies. The agency intends to award a contract for detailed design, development, and installation of the system in November 1992. An important aspect of the design and eventual success of EOSDIS will be the degree of flexibility with which the system can accommodate changing user needs and advances in technology. NASA plans an evolutionary approach to EOSDIS development, including prototyping and a series of system versions, each adding incrementally to the previous versions. NASA's plans for prototyping and use of advanced technology are discussed in a previous GAO report.²

¹The other eight federal agencies are the National Science Foundation, National Oceanic and Atmospheric Administration, U.S. Geological Survey, Department of Agriculture, Environmental Protection Agency, Department of Energy, Smithsonian Institution, and Department of Defense.

²Earth Observing System: NASA's EOSDIS Development Approach Is Risky (GAO/IMTEC-92-24, Feb. 25, 1992).

The anticipated users of EOSDIS include a broad range of scientists and other users that we categorized into three groups: NASA-affiliated, nonaffiliated, and "other." The NASA-affiliated group consists of the 551 EOS investigators, EOS operations personnel (e.g., EOS program and project officials, data center managers, and project scientists), and other NASA-funded researchers. The nonaffiliated group is comprised of researchers, not funded by NASA or the EOS program, at universities and U.S. and foreign government agencies. The "other" user category includes policymakers at the federal, state, and local levels; commercial researchers; and users applying earth science data for public policy purposes.³

Largest User Group Has Had Minimal Involvement in Development of EOSDIS Requirement and Planning Documents

NASA expects the largest number of EOSDIS users to be nonaffiliated scientists. However, this group has had minimal involvement in defining EOSDIS requirement and planning documents. Despite recommendations from scientific committees to obtain a broad spectrum of user involvement, NASA primarily obtained input from EOS investigators and other NASA-affiliated users.

Science Community's Guidance Stresses Broad User Involvement

The science community, including the National Academy of Sciences and the EOS Science Steering Committee, recommends broad user involvement throughout the development of earth science data systems. Several reports emphasize active involvement of scientists from inception to completion of space missions. In the past, there has often been a lack of scientific involvement in data system design during the early mission planning and system development phases. Typically, the interdisciplinary nature of data has not been fully recognized, and data systems frequently have not been properly implemented. In several reports, the National Academy of Sciences has stated that full involvement of the broad user community will

³NASA also categorizes EOSDIS users as EOS investigators, nonaffiliated users, and "other" users. The difference between our categories and NASA's categories is that NASA included NASA-funded researchers in its nonaffiliated user group and EOS operations personnel in its "other" user group, while we included these people in a NASA-affiliated category.

maximize the science return on space missions and improve the quality of data for users.⁴

More specifically, a 1990 Academy report states that (1) excluding any of the EOS user groups from testing and decision making during EOSDIS design and development would be a major mistake, and (2) when modifications to original specifications are made, the global research community should have a major role in advising on priorities.⁵ The Academy considers broad user input to be essential to ensure that EOSDIS priorities are based on research requirements. The Academy's findings are supported by a 1987 report by the EOS Science Steering Committee, which states that EOSDIS needs to serve a community that extends beyond those involved in the mission.⁶

In addition to these reports, a 1989 NASA study, which assessed the research operations and information systems needs of the space science user community, found that users need to be involved as the project evolves.⁷ According to the study, users need to not only be involved in listing requirements but in prioritizing the requirements and in assessing trade-offs.

Finally, some of the earth science researchers we contacted stated that it is important to obtain input from users outside a project's investigator community because such users can be more objective than those depending upon the project for funding. Some of these and other researchers believe that if input is not obtained from the broader user community, NASA will design a system that may be inappropriate and too inflexible to meet the needs of most earth science researchers.

⁴Data Management and Computation, Volume I: Issues and Recommendations, National Academy of Sciences' National Research Council, National Academy Press, 1982; Issues and Recommendations Associated with Distributed Computation and Data Management Systems for the Space Sciences, National Academy of Sciences' National Research Council, National Academy Press, 1986; Selected Issues in Space Science Data Management and Computation, National Academy of Sciences' National Research Council, National Academy Press, 1988.

⁵U.S. Global Change Research Program: An Assessment of FY91 Plans, National Academy of Sciences' National Research Council, National Academy Press, 1990.

⁶From Pattern to Process: The Strategy of the Earth Observing System, EOS Science Steering Committee Report, Volume II, National Aeronautics and Space Administration, 1987.

⁷Elaine R. Hansen, George H. Ludwig, Alain J. Jouchoux, Randal L. Davis, University of Colorado, "Overarching Science Needs and Issues: Shaping NASA's Research Operations and Information Systems," AIAA/NASA Second International Symposium on Space Information Systems, (Pasadena, California: Sept. 17 - 19, 1990), American Institute of Aeronautics and Astronautics, Washington, D.C., Feb. 1991.

User Input Focused Almost Entirely on EOS Investigators and Other NASA-Affiliated Users

Although the scientific community has recommended input from all EOSDIS user groups, NASA has focused almost entirely on EOS investigators and other NASA-affiliated scientists in defining EOSDIS requirement and planning documents. NASA believes that the needs of all EOSDIS users have been reflected in the development of these documents. However, we found that users not affiliated with NASA had minimal involvement in developing these requirement and planning documents.

During the EOSDIS design and development process, NASA developed three main sets of EOSDIS requirement and planning documents and used various mechanisms to obtain user input. The three main EOSDIS requirement and planning documents were

- the information system's functional and performance requirements, which establish the system's architectural, operational, performance, and functional specifications and are part of the RFP;
- the EOS instrument data requirements, including descriptions of the data to be provided by EOS and the processing requirements needed to support generating, archiving, and distributing EOS data; and
- the EOSDIS data plan, which compiles information on data that should be accessible through EOSDIS including global change data at the seven Distributed Active Archive Centers (DAACs) and earth science data to be generated before EOS is launched.⁸

NASA used several mechanisms for determining and validating user needs. These mechanisms included soliciting advice from the EOSDIS Advisory Panel, conducting working group retreats, surveying EOS investigators, soliciting information on the draft functional requirements, and awarding two contractor studies on system design requirements.

NASA relied upon the EOSDIS Advisory Panel as a chief mechanism for obtaining user input. This panel was established in 1989; its functions include reviewing EOSDIS on behalf of both EOS investigators and the broad community of scientists expected to use EOS data. NASA believes that this panel reflects the needs of the earth science community because its members are drawn from the 551 EOS investigators, who represent a wide range of global change research disciplines. However, the panel's

⁸The seven DAACs will be responsible for archiving, processing, and distributing EOS and other earth science data through EOSDIS.

membership appears skewed—only 2 of its 24 members are from the nonaffiliated user community and only 1 is from the “other” user group.

In addition, nonaffiliated and “other” users had minimal involvement in the other methods NASA used to develop the key EOSDIS requirement and planning documents, including retreats, a survey, solicitations, and contractor studies. As shown in figure 1, NASA-affiliated users had primary involvement in determining user needs and validating EOSDIS requirement and planning documents, while the nonaffiliated and “other” users had minimal involvement.

Figure 1: User Involvement During the Development of EOSDIS Requirement and Planning Documents

EOSDIS DOCUMENT	NASA-Affiliated Users	Nonaffiliated Users	“Other” Users
EOSDIS Functional Requirements			
Needs Determination	●	△	△
Validation	●	△	△
EOS Instrument Data Requirements			
Needs Determination	●	○	○
Validation	●	△	△
EOSDIS Data Plan			
Needs Determination	●	△	△
Validation	●	△	△

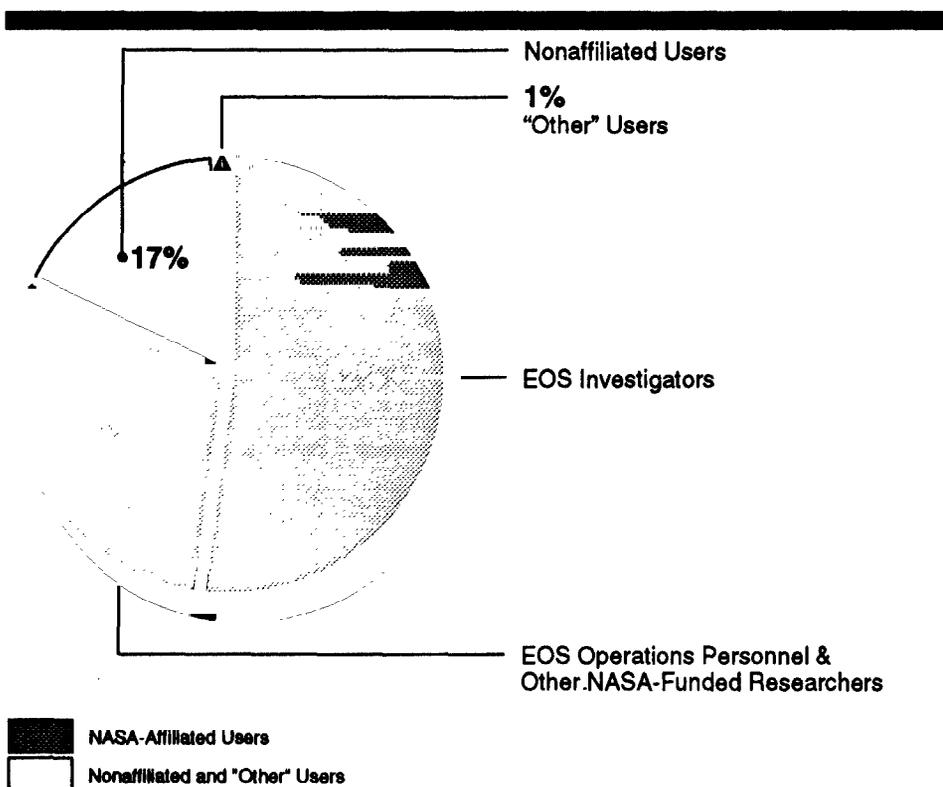
● Primary involvement
 △ Minimal involvement
 ○ No involvement

Note: User involvement with the EOSDIS requirement and planning documents was analyzed through March 1992.

In addition, the nonaffiliated and “other” users had minimal involvement in the EOSDIS functional and performance requirement studies prepared by

NASA's two conceptual design phase contractors. As part of this early requirements definition process, NASA awarded contracts to two companies to conduct independent studies on potential system designs. Each company obtained input from the user community. However, as shown in figure 2, of the 455 users contacted by the two contractors, 82 percent were NASA-affiliated users, 17 percent were nonaffiliated users, and 1 percent were "other" users.

Figure 2: Users Involved in System Requirement Definition Studies



Note: 455 users were contacted

We contacted representatives of the nonaffiliated and "other" user groups, including the other federal agencies involved in the U.S. Global Change Research Program, the six key earth science professional associations, a

major trade association of industrial users, and other earth science researchers.⁹ As part of the U.S. Global Change Research Program, an advisory group was established to examine data management issues. None of the federal agency representatives participating in this advisory group reported providing input in defining or validating EOSDIS requirements. Furthermore, none of the seven associations we contacted said that they were asked to define or validate EOSDIS requirements, although two said that this is not an activity that they would typically take part in. Also, only three of these associations reported that NASA representatives discussed global change issues during their annual meetings.

While several of those contacted expressed a belief that NASA should be able to meet the needs of the broad EOSDIS user community based on input from the EOS investigators, others stated that it is also important to obtain input from users outside the NASA investigator community. Some of these association representatives and researchers believe that NASA may not meet the needs of the nonaffiliated and "other" users by simply satisfying the requirements of the EOS investigators. They disagree with NASA's belief that because the EOS investigators were competitively selected from the earth science research community they represent the broad EOSDIS user community and are knowledgeable of their requirements. For example, one researcher explained that the vast majority of the nonaffiliated scientists use less sophisticated computer and information systems than do EOS investigators and, consequently, their data access requirements may vary.

In addition, researchers have identified a number of options for involving users outside the NASA research community. These options include (1) establishing outreach programs at the major universities with earth science programs; (2) conducting symposiums; (3) addressing annual conferences of the earth science professional associations, including international associations; and (4) requesting that a task force be established to review EOSDIS requirements.

⁹The earth science professional associations contacted were the American Institute for Biological Science, American Geophysical Union, American Meteorological Society, American Association of Ground Water Scientists and Engineers, Geological Society of America, and the International Association for the Physical Sciences of the Ocean. The trade association, representing industrial users of remote sensing data, was the GEOSAT Committee.

Wider Science Community Input Is Needed in Future Plans

Although NASA has issued guidance on obtaining future user input during the development of EOSDIS, broad and comprehensive involvement of scientists outside the NASA-affiliated community is needed. NASA intends to rely on input from user working groups located at the seven DAACs. These working groups include some members from the nonaffiliated and "other" user groups. Beyond these groups, NASA's directions for future user input are contained in its configuration management plan and the RFP. Neither the configuration management plan nor the RFP adequately takes into account all segments of the user community.

NASA's EOS Project Configuration Procedures Handbook addresses how changes are to be made to hardware design, software, and other system specifications. The handbook identifies the roles of NASA headquarters, the EOS project office, EOS investigators, and contractors. However, it fails to address the role or the mechanism for input by users outside the NASA community.

Likewise, the RFP does not specifically direct the contractor to obtain input from the nonaffiliated and "other" users. However, the RFP does ask the contractor to describe how the system will be designed to facilitate use by the nonaffiliated and "other" users. Some earth science researchers believe the RFP language is too broad and vague in discussing how the contractor will work with users. For example, one researcher believes the contractor will expend minimal effort to obtain user input from nonaffiliated and "other" user groups unless specifically required to do so by the contract.

User and Work Load Estimates Are Uncertain

The expected number of EOSDIS users and the work load these users will generate are not certain. NASA issued preliminary user and work load estimates after completing major portions of the conceptual development and system requirements process. The estimates are used, in part, to provide the contractor with a basis for designing and developing EOSDIS.

NASA prepared two preliminary EOSDIS user estimates that varied widely and have not been incorporated into an official EOSDIS requirement document. A 1990 user estimate contained in a preliminary version of the functional requirements document projected as many as 100,000 users, based on past experience at earth science data centers. However, a preliminary study, prepared in 1991 by an EOS investigator, estimated a maximum of 10,000 users in 1992, based in part on the number of members in the major earth science professional associations and users of selected data centers. This estimate does not include nonresearch users

such as those at state and federal regulatory agencies. Although NASA now believes that the EOSDIS user estimate is closer to 10,000, it has not issued an official estimate. Neither the 10,000- nor the 100,000-user estimate appears in the final functional requirements document issued to prospective EOSDIS contractors. However, this document does indicate that the EOSDIS accounting system should be designed to track information on 100,000 users.

The final EOSDIS functional requirements document, which is part of the RFP, also includes an estimate of the number of data queries EOSDIS should be able to process, but the EOS project's data manager noted that this figure is only preliminary. The functional requirements indicate that NASA expects an average of 400 user queries an hour, consisting of directory searches, status checks on data requests, or queries to access other data base functions. Depending on their nature, these queries could be very resource-intensive, making heavy demands on EOSDIS' communications resources and data handling functions. The system is also expected to support 100 simultaneous users. According to EOS project officials, these estimates are more meaningful in designing the system than in estimating the number of users the system is expected to serve.

To determine the above user work load estimates, NASA conducted a study in 1990 that involved compiling information on data requests and queries from several data centers. The study found considerable uncertainty regarding user activity. For example, it notes that there is no common understanding of current data center activity and that a better estimate of the size of the user community and how often users will interact with EOSDIS is needed. Although the study did identify preliminary work load estimates, it recommended further review and modeling of the daily and annual distribution of user activity.

Any future reviews are expected to be conducted by the EOSDIS contractor. The EOS project data manager said that the contractor is expected to provide a more specific estimate of the number of simultaneous users querying the system and a better assessment of the actual size of the EOSDIS user community. These reviews will then be used in designing and sizing the system.

As more definitive information is obtained on the user community and its associated work load, the EOSDIS design must be flexible enough to incorporate changes in system processing and other requirements. According to the National Academy of Sciences, EOSDIS should have a

system architecture sufficiently flexible to accommodate such changes and implement them in an evolutionary manner.¹⁰ Furthermore, the Academy concluded that EOSDIS poses significant continuing challenges and must have an ongoing mechanism for acquiring advice from the user community.

Conclusions

The science community, internal steering groups and committees, and others have urged NASA over the past decade to seek broad user involvement throughout the development of scientific data systems. Because EOSDIS is intended to serve the research needs of a broad community of federal, domestic, and international users, it is essential that NASA ensure that the needs of these users are incorporated in the EOSDIS design. However, NASA has not yet obtained broad user input nor has it established strong mechanisms for obtaining such input as the system evolves. At the same time, there is considerable uncertainty about the total number of eventual users and the work load they will generate.

Some have expressed confidence in NASA's ability to design EOSDIS to meet the needs of the broad user community based on input provided almost exclusively by EOS investigators. We disagree with this belief. In fact, we find it difficult to believe that a successful EOSDIS system development will result from a strategy that has thus far failed to obtain input in determining or validating requirements from most of the federal agencies participating in the Global Change Research Program, as well as thousands of other potential users.

The process by which user needs are incorporated over time is also a critical element in the future success of EOSDIS. Continuous and systematic input from the broad earth science research community is needed to ensure that appropriate user requirements are incorporated into the design of the system.

¹⁰U.S. Global Change Research Program: An Assessment of FY91 Plans, National Academy of Sciences' National Research Council, National Academy Press, 1990.

Recommendation

We recommend that the NASA Administrator strengthen input from the full range of anticipated EOSDIS users by either establishing a new independent committee that represents the broad global change research community or strengthening existing advisory groups, such as the EOSDIS Advisory Panel, to achieve the necessary broad representation. In addition to the EOS investigators, the committee or committees should represent federal agencies involved in global change research, earth science researchers not affiliated with NASA, and foreign and commercial organizations involved in global change studies. The objectives of these committees should include

- providing for the dissemination of information about EOS and EOSDIS to the global change research community;
- evaluating the EOSDIS RFP and the EOS data requirements to determine whether they meet the needs of the user community and, if not, recommending specific modifications; and
- monitoring the continued evolution of EOSDIS throughout the contractor's development of the system to ensure that EOSDIS will meet the broad user community's needs.

Agency Comments

As requested, we did not provide a draft of this report to NASA for its review and comments. However, we discussed the report's contents with NASA officials, including the Deputy Director for Global Change and the Chief of the Modeling, Data, and Information Systems Program Office; and included their comments as appropriate. The NASA officials generally agreed with our findings and recommendation. Although the officials believe that NASA has been seeking substantial consultation with other federal agencies and international partners, they agreed that it would be beneficial to maintain an awareness of how the international community, other government agencies, and commercial users plan to use EOSDIS.

Our audit work was performed in accordance with generally accepted government auditing standards between July 1991 and March 1992. As arranged with your office, unless you publicly announce the contents of this report earlier, we plan no further distribution until 30 days from the date of this letter. We will then give copies to other appropriate congressional committees, the Administrator of NASA, and other interested parties upon request.

This work was performed under the direction of Samuel W. Bowlin, Director for Defense and Security Information Systems, who can be reached at (202) 336-6240. Other major contributors are listed in appendix II.

Sincerely yours,

A handwritten signature in cursive script that reads "Ralph V. Carlone".

Ralph V. Carlone
Assistant Comptroller General

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Abbreviations

AIAA	American Institute of Aeronautics and Astronautics
CEES	Committee on Earth and Environmental Sciences
DAAC	Distributed Active Archive Center
EOS	Earth Observing System
EOSDIS	EOS Data and Information System
GAO	General Accounting Office
IMTEC	Information Management and Technology Division
NASA	National Aeronautics and Space Administration
RFP	request for proposals

Objectives, Scope, and Methodology

The Committee on Science, Space, and Technology requested that we review various aspects of NASA's EOSDIS program. Based on this request and subsequent discussions with Committee representatives, we initiated separate studies on NASA's EOSDIS development approach, user input into EOSDIS requirements, and EOS data policy. A report on NASA's EOSDIS development approach was issued in February 1992.¹ This report covers the second topic on user input into EOSDIS requirements. Specifically, the Committee requested that we focus on the extent to which domestic and international users (both research and commercial) have provided input into the definition of EOSDIS requirements.

To obtain background on user involvement in past data systems planning, we reviewed reports by the National Academy of Sciences' National Research Council, including reports by the Committee on Data Management and Computation.

To determine the extent of user involvement in EOSDIS, we reviewed the NASA process for obtaining input during the early design and development phase of the system and also reviewed NASA's future plans for obtaining user involvement. To do this, we analyzed NASA EOS documents and interviewed NASA EOS program and project officials.

Specifically, we reviewed the process NASA used to develop the three main EOSDIS requirement and planning documents. These documents were

- the Functional and Performance Requirements Specification for the Earth Observing System Data and Information System Core System, July 1, 1991 (EOSDIS Functional and Performance Requirements);
- the Earth Observing System Output Data Products and Input Requirements, August 1991 (EOS Instrument Data Requirements); and the
- Science Data Plan for the EOS Data and Information System Version 0 And Beyond, (Draft) September 1991 (EOSDIS Data Plan).

To assess this process, as well as to identify the user and work load estimates and the role of EOSDIS users, we

- interviewed the EOS project officials responsible for each requirement and planning document and members of the EOSDIS Advisory Panel;

¹Earth Observing System: NASA's EOSDIS Development Approach Is Risky (GAO/IMTEC-92-24, Feb. 25, 1992).

- reviewed documentation to identify procedures or mechanisms for obtaining user input and to identify the user and work load estimates;
- obtained information on dates of meetings where EOSDIS requirements were to be reviewed by the user community and listings of the attendees; and
- obtained listings from the two NASA contractors regarding users contacted during their functional performance requirement studies.

Further, we interviewed scientists in the earth science research community regarding user input into EOSDIS. The scientists we interviewed were selected because we believe they represent a broad range of potential EOSDIS users, including NASA-affiliated, nonaffiliated, and commercial researchers. Among the scientists were

- members of EOS Engineering Review Committee;
- officials of the Office of Science and Technology Policy's Committee on Earth and Environmental Sciences (CEES);
- members of the CEES Interagency Working Group for Data Management and Global Change;
- representatives of the six key earth science professional associations and a major trade association of industrial users; and
- EOS investigators, DAAC representatives, and researchers involved in NASA's joint research efforts with other federal agencies.

To identify NASA's plans for future input, we interviewed the responsible EOS officials, obtained a listing of the members of each of the DAAC user working groups, and reviewed internal NASA documents. These documents included the

- EOS Configuration Management Plan, January 1990, and
- EOS Project Configuration Management Procedures Handbook, July 1991.

Our audit work was performed in accordance with generally accepted government auditing standards between July 1991 and March 1992 at various locations, including NASA headquarters in Washington, D.C.; the Goddard Space Flight Center in Greenbelt, Maryland; and the Jet Propulsion Laboratory in Pasadena, California.

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Related GAO Products

Earth Observing System: NASA Needs to Reassess Its EOSDIS Development Strategy (GAO/T-IMTEC-92-7, Feb. 26, 1992).

Earth Observing System: NASA's EOSDIS Development Approach Is Risky (GAO/IMTEC-92-24, Feb. 25, 1992).

Earth Observing System: Information on NASA's Selection of Data Centers (GAO/IMTEC-91-67, Sept. 18, 1991).

Space Data: NASA's Future Data Volumes Create Formidable Challenges (GAO/IMTEC-91-24, Apr. 8, 1991).

Space Data: Information on Data Storage Technologies (GAO/IMTEC-90-88FS, Sept. 12, 1990).

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