The Earth Observer

An EOS Periodical of Timely News and Events

Vol. 2, No.6 July 31, 1990

EDITOR'S CORNER

International Space University

The International Space University (ISU) is a three-year-old venture, currently holding classes in Toronto, Canada. Started by three young students with a gleam in their eye and a bold plan, the first classes were held the summer of 1988 at MIT, with a student body, faculty, and plan to launch a pilot effort to bring together an international group of scholars, in the broadest possible context. They organized in many fields: engineering, science, law, architecture, medicine, and business. The common theme was that everything be focused on efforts in ***space*** and in ***education***.

The first year was a smashing success! Encouraged to go for a second summer, they moved the whole infrastructure to Strasbourg, France, at the Institute de Pasteur. They combined the course work with a very elaborate project to design a lunar base, and ended up with a ***bigger*** success than the first time. The students of the second year asked to become the faculty for a third summer. This year, they are in Toronto with a larger effort than before, a very interested faculty, and over 150 students. Their project is *Earth Remote Science Satellites* — their version of an EOS.

The classes deal in all aspects of space activity. The students come from over 30 countries. Classes are in English, but languages flourish everywhere. Terrific youthful enthusiasm is always apparent, and no one ever seems to sleep — **conversation and creative ideas fill the air!**

Next summer, the whole campus moves to Moscow and the following year to Japan. There is talk of a permanent campus, but no decision yet as to what country or what architecture. Clearly, there is an opportunity here for our educators to learn from this group what it is that students want and where the future lies. NASA and other space agencies around the world have their eyes on them!

Jerry Soffen
Senior EOS Project Scientist

Message from HQ

Taking the Long Term, Broader View

NASA has been planning EOS for many years. During the past eight years, we have enlisted a large segment of the scientific community (through the NASA Advisory Structure and by incorporating numerous recommendations of many boards, committees, and panels put forth by the National Academy of Sciences/National Subgroups) to help formulate the EOS and Mission to Planet Earth Programs. We have pursued an Earth Probes initiative to complement and supplement the EOS measurement efforts. Examples of the planned Earth Probe missions are the NSCATT on Japanese ADEOS platform; a succession of TOMS measurements on a USSR Meteor-3 satellite, on a small dedicated satellite, on ADEOS, and on a subsequent follow-on mission; the Sea-WIFS ocean color data initiative, the TRMM mission as a joint U.S. - Japanese mission; and future cooperative missions including a Gravity Field Mission, a Magnetic Field Mission, a Topography Mapping Mission, and perhaps others which, as yet, have not been subject to a detailed study or review by the National Academy of Sciences.

Over the years, the current NASA contributions to the Global Change Research Program and some of its elements have been referred to as Earth System Science, Global Habitability, System Z, and others. All of these fit into a complex pattern, each with its strong advocates, and some with vocal "non-advocates" — especially some of those who feel that their particular hardware, or their particular science element, is the most important at this particular time — to the exclusion of the broader, long-term data and science requirements of the Global Change/Earth Science community as a whole. What **is** clear is that the interest in Earth sciences is growing, in the science community, the political arena, and the world community as a whole. We had over 300 requests from graduate students to participate in the Global Change EOS Graduate Fellowship program.

We are now at an important juncture — about to make recommendations to Dr. Fisk and the Agency concerning the complement of instruments to be a part of the first EOS platform. Everyone in my Division understands the importance of these recommendations. We represent a very large community, with very diverse ideas. Eventually, we hope that all of the good ideas which have been put forward will be executed. Clearly, however, at the present time we must adapt to fiscal and other resource limitations.

I know it's much easier for me to ask your patience than to have to be on the waiting end. However, if you, the science community, are going to achieve long-term goals in Earth System Science, an orderly process — in terms of implementing a broad comprehensive space and ground-based program — is required. In this process, if painful, individual "pushing and shoving" becomes the dominant element, I believe, that *you*, *your program*, *the science community*, and *the world as a whole*, will be cheated. We must try to learn to cooperate in the implementation of the Global Change Research Program.

Shelby Tilford
NASA Headquarters

Direct Transmissions of EOS Data to Worldwide Users

Introduction

The planned EOSDIS is a comprehensive, distributed system for handling the data output from the sensors and platforms of the Mission to Planet Earth series of NASA global change observatories. The data processed through the EOSDIS will receive extensive quality control and will be used in the calculation of numerous derived products for the use of all participants in global change research.

There is another community of potential users of a portion of the EOS data stream who would like to have their data either directly broadcast continuously for global reception at international ground stations or directly downlinked to suitable high-transmission-rate reception sites already available.

This article is a description of the current EOS capability for both the Direct Broadcast (DB) and the Direct Downlink (DD) data delivery techniques and includes current plans for the implementation of both systems.

The Potential Users

The potential users of the direct data transmissions include at least three types:

- EOS team participants and interdisciplinary scientists requiring real-time data for the conduct of validation field observations, aircraft vectoring, and phenomenon location while they are in the field.
- International meteorological and environmental agencies requiring real-time measurements of the atmosphere, storm and flood situations, water temperature and vegetation stress.
- Our international partners in the development of EOS who will desire periodic outputs from their high-volume sensors directly to their own analysis centers for engineering quality checks as well as local analysis of their own regions.

In the first category of users, one can easily foresee the value of having direct readouts of definitive EOS data during the conduct of the special field experiments, which are planned in order to understand the physical interactions between the the oceans, atmosphere, and land. Examples of these focused field experiments include the GEWEX activities in the Tropical Pacific, monsoon research programs in the Arabian Sea and Indian Ocean and near South-East Asia, land/vegetation/atmosphere interaction programs, and air/sea interaction experiments in the North Atlantic.

Many countries fall in the category of direct broadcast environmental data users. Today's users are taking advantage of the data being transmitted routinely from the AVHRR sensors on the NOAA satellites. Relatively low-cost ground stations can receive, process, and display the swath data as the satellite passes overhead. A similar but higher data rate, direct-broadcast system is being contemplated for the EOS platforms. It would require a more sophisticated ground reception and analysis system, but is well within today's state-of-the-art technology. Some of the countries having expressed interest in a direct broadcast system for EOS, or who have traditionally seized the opportunity to develop high-technology systems for using direct remote-sensing data, include Australia, Italy, Japan, Taiwan, Canada, the Philippines, Indonesia, Thailand, New Zealand, and Brazil. Other countries, including Bangladesh and Fiji, have seen the utility to be gained through real-time monitoring of disasters and resources and have requested aid to develop the technology.

The Direct Data System

The EOSDIS Project is conducting studies to evaluate the feasibility for implementation of both the DB and DD systems on EOS with no impact on the fundamental sensor complement scenario, described as the "Violet" Payload, and minimal impacts concerning weight, power, and onboard data system modification requirements. The currently manifested COMM package can be made fully capable of handling the data signal routing, RF modulation, and transmission functions that are required. Integration of the Wide-Band Data Collection System (WBDCS) and the COMM package to achieve more efficient use of resources and to achieve additional functionality, such as relaying of map analyses through EOS to the direct broadcast receiver for computer overlays on the image data, is also currently being considered.

While numerous options have been studied, it appears that it is well within the current platform constraints to be able to transmit all of the data from the prototype operational instruments, as well as the data from one moderately high data-rate instrument, via a continuously broadcast transmission at about 15 Mbits/sec. This implies that potentially, for the EOS-A series platforms, all the data from the AIRS (including AMSU) sounder, the MIMR/AMSR/HIMSS passive microwave imager, the lightning imaging sensor (LIS) and all of the MODIS-N data could be broadcast continuously for reception around the world. This particular combination of sensor data is appropriate for direct broadcast since its information value contains a large real-time component. Those data which are of more value when consolidated globally, and calibrated precisely, to yield global-change detection quality records should be obtained through the EOSDIS after all advanced data processing has been applied. This is also true for *in-situ* space environment monitors, which are better viewed in the global environment frame rather than locally. Directly broadcast data should be those which have near-term regional impact for warning or assessment, or which help to conduct local physical process investigations. The particular sensor complement of AIRS, LIS, MIMR, and MODIS-N provides a spectrum of data which extends the current NOAA DB system by providing more channels of higher resolution for the refinement of regional analyses of atmospheric temperature profiles, atmospheric moisture profiles, land- and sea-surface temperature distributions, ocean color near coastlines, wetlands flooding distribution, forest fire occurrence, regional volcano eruption, nearby severe storm locations, regional vegetation change distribution, lightning occurrence and related storm intensity characterization, rainfall rate estimation and areal coverage, and other regional geophysical measures to be developed with the advanced spectral data.

There is yet another class of users which cannot be satisfied with the quite comprehensive low data-rate DB transmissions. These are the high data-rate users, principally our international partners in Japan and Europe. For instance, the ITIR instrument has such a high data rate that if our Japanese partners wish direct transmission of the data to Japan, it will require a data bandpass of nearly 100 Mbits/sec. This is clearly outside the scope of a DB system involving continuous transmission and is now a candidate for a direct downlink system. The EOSDIS Project studies have shown that the type of direct transmission RF modulator/transmitter that the Canadians have offered is capable of simultaneous transmission at several combinations of data rates including 10 and 100 Mbits/sec. Reception of such high data-rate data would have to be accomplished at existing LANDSAT, SPOT, or similar X-band reception facilities because of the large antennas and volume-processing equipment required. As time progresses, payloads are finalized and international direct downlink data requirements are confirmed, agreements will have to be reached with the appropriate reception facilities for the periodic, scheduled reception, recording, and distribution of the specific data sets.

Another instrument which could have its data downlinked directly is HIRIS. Certain data swaths might be required for regional experiments near reception stations or for equipment deployment during physical process studies. No plans are currently being made for the broadcast of HIRIS data, which must be used for research purposes only, and its distribution must comply with existing laws. It is also likely that our Japanese and European partners would like to have access to the directly broadcast data for their own evaluation and regional use. Thus, their interest goes beyond mere access to the data from their own sensors.

While the likely payload for the EOS-B series is even less well-defined than for EOS-A, it suffices to note that if STIKSCAT and TES were onboard, their data could be used regionally, either operationally or in research field experiments, so the direct broadcast capability of the EOS platforms could be employed if a strong enough case were made by the investigators for that functionality.

Ground Systems

As currently conceived, the high and low data-rate transmissions could use the same X-band transmitting frequency near 8 GHz, but the high data-rate transmissions could be received only by LANDSAT, SPOT, or similar large facilities and would only be scheduled upon the request and agreement of all parties. The low data-rate transmissions (up to 15 Mbits/sec.) would be broadcast continuously for all the world to receive.

Specifications for appropriate systems for the reception of the direct broadcast signal would be developed by NASA and made available, upon request, to potential builders of reception systems. Perhaps two or three relocatable receiving/recording/display systems would be developed by NASA for use in specific regional field experiments where real-time data was essential. These would be treated as a NASA resource and proposals would have to be written for their deployment and use. In addition, a library of appropriate software would be developed by NASA for the reception, packet decoding, calibration, local navigation, overlay, display, and evaluation of the quantitative direct broadcast data.

Use of the directly broadcast data will imply no obligation on the part of the recipient concerning return of locally-generated products to the EOSDIS archives. However, as with any system developed for the good of a variety of users, NASA would appreciate receiving examples of regional usages of the data, novel new interpretation techniques, and published papers related to the use of the data.

Conclusion

NASA is evaluating a minimal impact system for broadcasting and downlinking moderate and high data-rate segments, respectively, of its full EOS data flow directly to users worldwide. The purpose is to take advantage of the real-time value of some of the data being observed for long-term remote measurements of environmental data for the study of global-change processes and eventual modeling of the interacting system. This direct broadcast/downlink system represents a spin-off from the overall grand plan to measure and study environmental evolution, but it should help numerous people in many countries around the world to plan for regional events on a much shorter time scale.

James C. Dodge
NASA Headquarters

The Earth Observer is a monthly publication of the EOS Project Science Office, Code 900, NASA/Goddard Space Flight Center, Greenbelt, MD 20771, telephone (301) 286-3411, FAX (301) 286-3884. Correspondence may be directed to Charlotte Griner at the above address. Articles, contributions to the meeting calendar, and suggestions are welcomed. Contributions to the meeting calendar should contain location, person to contact, and telephone number. Deadline for all submissions is the 20th of each month.

Team Meetings

HIRDLS Science Team Efforts

The High Resolution Dynamics Limb Sounder (HIRDLS) science team met May 21-24 in Lexington, Massachusetts to complete work on the Phase B design and to prepare for the EOS-A Conceptual Design and Cost Review (CDCR) in July. John Gille (NCAR) and John Barnett (Oxford University), dual Principal Investigators, chaired the meeting.

HIRDLS Origins

Dr. Barnett and his colleagues proposed the Dynamics Limb Sounder (DLS) in response to the EOS AO; at the same time Dr. Gille and his group proposed the High Resolution Research Limb Sounder (HIRRLS). Subsequent review showed that the scientific objectives and basic measurement approaches were very similar, although there were differences in the proposed instrumentation.

With encouragement from the British National Space Centre and NASA, the PI's and their teams began to discuss the merger of the two investigations. During a meeting in December, 1989, the basis for the collaboration was established. Under this, the two teams combined to produce a single design to satisfy the scientific requirements of both investigations. The dual PI's will lead an equal partnership in which each side will provide half of the instrument and perform half of the associated tasks. The instrumental details were worked out in subsequent meetings.

The instrument now weighs 120 kg (less than in either original proposal) and consumes 125 watts of power; data rate is 35 kbits/sec. Heat rejection is to the Observatory cooling loop. 21 detectors, each with a separate infrared passband, share a single focal plane, which is cooled by twin Stirling cycle coolers.

Measurement Improvements

HIRDLS extends previous measurements. It takes advantage of the inherent characteristics of infrared limb scanning — day and night (including polar night) observations, ability to measure small amounts of emitting material (thus small concentrations of trace gases), and high vertical resolution. Its measurements will be significant advances over earlier instruments (such as the LIMS and SAMS on Nimbus 7, or the ISAMS and CLAES to be launched on UARS).

More importantly, HIRDLS addresses global change problems that are just emerging. In addition to having lower noise levels and a longer lifetime, this requires improving upon earlier measurements in the following ways:

Improved Observation of the Tropopause Region:

One goal is to observe the lower stratospheric and upper tropospheric structure and composition. These are the critical levels through which trace gases, notably those reduced gases produced by biogenic processes at the surface, are transported into the stratosphere and their oxidized products are returned to the troposphere. These levels also couple the dynamics of the two regions. This goal will be achieved through the use of more transparent spectral channels for the gases that become opaque at the centers of their bands, e.g., CO_2 (for measuring temperature), O_3, H_2O. These channels obtain measurements for the upper troposphere with larger signal-to-noise ratio and improved vertical resolution.

The two additional coupled measurement goals are to observe atmospheric temperature and composition at horizontal scales of 400 km or less, closer to scales at which critical dissipative and mixing processes take place. The vertical scales must then be measured to about 1 km or less, to be consistent with the aspect ratios of the primary mid-latitude wave disturbances that act in these processes. Gravity waves, critical to the circulation in the upper stratosphere and mesosphere and probably to the mixing at lower levels, can also be seen at this resolution.

Higher Horizontal and Vertical Resolution:

Horizontal resolution finer than the orbital spacing is obtained by scanning at multiple azimuths from the spacecraft. The nominal spacing is 4° longitude by 4° latitude achieved by scanning at 6 azimuths, but higher resolution is planned on a research basis. This gives a swath of measurements across the satellite track of the same type that nadir sounders obtain; they could be aligned with those of AIRS.

Higher vertical resolution is achieved through a 1 km vertical field of view, plus the use of deconvolution techniques on the measured radiance profiles during the data processing.

Geopotential Height Gradients:

Winds have been derived from previous limb-scanner results by integrating the vertical temperature profiles to obtain thicknesses which were added to the conventionally determined geopotential height of a low altitude pressure surface to get the height of higher altitude surfaces. These heights can then be used in geopotential or higher order approximations to derive the dominant non-divergent component of the wind. Conventional analyses may not be adequate at the HIRDLS horizontal resolution, especially in data sparse regions. HIRDLS will use carefully calibrated encoders and a gyroscope package to measure the horizontal variation of the heights of geopotential surfaces. Away from the equator, this is equivalent to measuring the dominant component of the wind at the base of the stratosphere, and may have a significant impact on tropospheric analyses as well.

Experiment Capabilities:

HIRDLS capabilities have been estimated, based on detailed simulations of the measurement and retrieval process. The HIRDLS capabilities are briefly summarized in Figure 1, which is based on the results of statistics on a small set of retrievals under clear conditions. Important points to note are that the retrievals cover the range from the mesopause down into the upper troposphere, with quite high precision. LIMS or SAMS on Nimbus 7 have measured all of these species except CFC 11 and 12 and N_2O_5; HIRDLS results will improve on the previous ones. All the species will be measured by instruments on UARS, so that HIRDLS observations will extend those data for the purpose of trend detection during a critical period of middle atmospheric change.

It should also be pointed out that the Polar Stratospheric Cloud (PSC) locations and cloud top height bars are based on LIMS results and indicate the altitude range over which the tops are expected; cloud top altitudes will be measured to about 200-400 meters. The open box for aerosols indicates that they can be measured when they are optically dense enough, which is usually in the troposphere and lower stratosphere, but could be higher after a volcanic eruption.

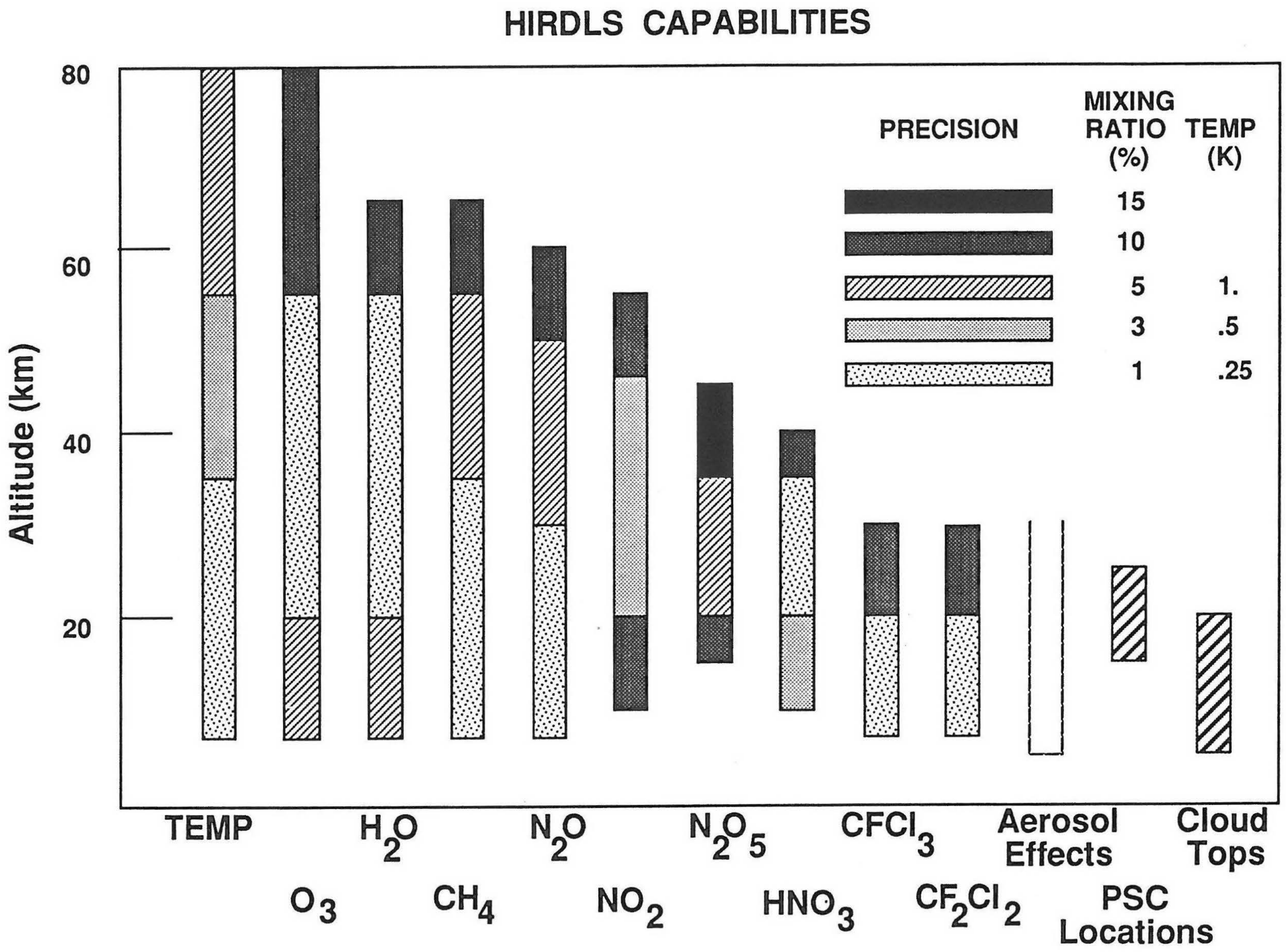
HIRDLS and Global Change

HIRDLS will make contributions to several areas of global change study. The major application of the data will be to research on the middle atmosphere, where the only well-documented, long-term atmospheric changes are taking place. Observations show that ozone is decreasing on a global basis and at a very rapid rate in the Antarctic spring, where field expeditions have shown that (mostly anthropogenic) chlorine is the cause. Models and dynamical arguments suggest that chlorine, directly or indirectly, is behind the global decrease as well. HIRDLS will play two complementary roles in these studies.

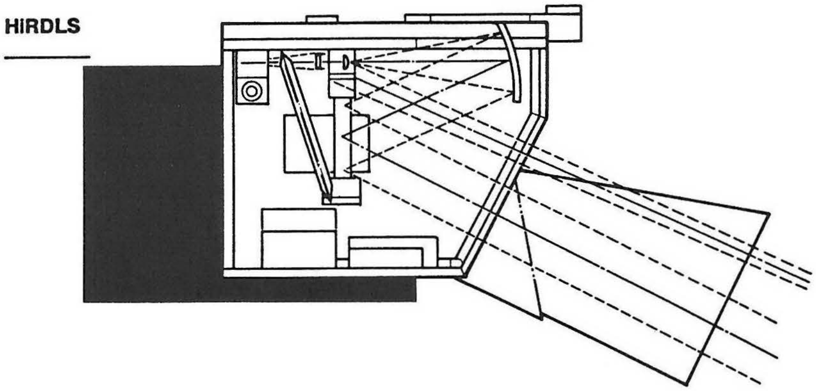
First, it will provide measurements of most of the ozone column, and indicate changes in the ozone amount not only at 40 km but also in the lower stratosphere, over the 15-year life of EOS. The upper region is where the theories predict a large decrease, the lower is where a large part of the observed global change must be taking place. Note that these data can be related to the UARS data, and back to the data from Nimbus 7 (1978), so that there will be a total span of over three solar cycles.

Second, its measurements will provide an understanding of the chemical and dynamical processes that may be responsible for such a change. For instance, through measurements of the concentrations of key constituents of the active nitrogen family of species, and sources of the hydrogen and chlorine families, it will be possible to identify, or at least constrain, chemical causes of ozone changes.

Other areas where HIRDLS will make major contributions include tropospheric chemistry, a discipline of great importance for global change. HIRDLS can-


HIRDLS CAPABILITIES
Altitude (km)
80
60
40
20
PRECISION
MIXING RATIO (%)
TEMP (K)
15
10
5
1.
3
.5
1
.25
TEMP
O3
H2O
CH4
N2O
NO2
N2O5
HNO3
CFCl3
CF2Cl2
Aerosol Effects
PSC Locations
Cloud Tops

not see down to the surface, but its observations of upper tropospheric CH_4, N_2O, and the CFC's are good indications of the concentrations of these well-mixed gases in the lower troposphere, down to the boundary layer. In addition, the fate of many of the biogenic gases emitted at the surface depends on the oxidizing capacity of the atmosphere, which is closely related to the concentration of the extremely reactive hydroxyl radical, OH. Therefore, it is exciting that HIRDLS measurements of upper tropospheric O_3 and H_2O will allow estimation of the production rate of OH there. Further, NO_2 controls the recycling of OH and HO_2, and CH_4 is one of the sinks of OH. If measurements of CO, another major sink, are available from another instrument (MOPITT or TRACER), the major species controlling the OH concentration will be observed, and it will be possible to estimate its local concentration.



HIRDLS observations are also very important for the Earth's radiation budget. H_2O and O_3 are two of the most important gases for the radiative budget of the troposphere, and both are highly variable in space and time. Their concentration in the upper troposphere has not been observed with good temporal and spatial coverage to date. Such data will be extremely important for calculations of the radiative budget and for monitoring changes. In particular, the observations of stratospheric temperature will allow a search for the decrease in stratospheric temperature expected to accompany both increased greenhouse gases and an ozone decrease. HIRDLS high vertical resolution will be significant in differentiating between these effects.

Additionally, a limb-scanning instrument gives a unique view of clouds, since it is sensitive to small concentrations of cloud particles at the topmost levels. Thus, it determines the *physical* cloud top, as opposed to the *radiative* cloud top, determined from measurements of outgoing long-wave radiation. Assuming that HIRDLS is flown on the same platform as AIRS and MODIS, data from the three instruments will be sufficiently coincident in time to allow multiple views of the same clouds, which could tell much about the physical processes at cloud tops.

Polar Ozone Destruction

Even if CFC production is halted by the turn of the century, the amount of chlorine in the stratosphere will increase over the EOS period. Field measurements have also shown that the chemistry of the Arctic stratosphere is quite perturbed, with some evidence of ozone decrease. The Arctic is much more important because of its proximity to areas of dense human habitation. As the Antarctic ozone "hole" phenomenon has shown, present models may not be good guides to what can happen at high chlorine levels. In addition, models have not yet shown an ability to tell how the polar regions affect the rest of the globe. We do not yet know, reliably, whether the winter Antarctic vortex acts as a containment vessel with a consequent limit to the amount of ozone that can be destroyed each year, or as a continuous flow reactor, exchanging air with other latitudes and, hence, with much greater potential for ozone depletion.

HIRDLS, with its ability to observe the lower stratosphere, and measure O_3, PSC's, HNO_3 and H_2O, all at the small scales close to those at which mixing across the vortex boundary takes place, will provide continuous, real-time observations of the changes in the polar stratosphere in a critical region in which observations must lead the way for the foreseeable future.

John Gille
Principal Investigator

EOS SAR Team Meeting

An EOS SAR Team Meeting was held June 5-6, 1990 at Caltech. All 13 team members were in attendance or represented. EOSDIS investigators in attendance were Jeff Dozier and Dale Winebrenner for Drew Rothrock. The meeting goals as presented by JoBea Way were to continue to refine the science requirements, and outline and coordinate FY91 activities. Both the Science Requirements and the Algorithm Development Plan Documents are essential to providing the project the necessary criteria for designing the instrument and all system components. (A first draft of the Science Requirements Document is expected to be completed by this October.)

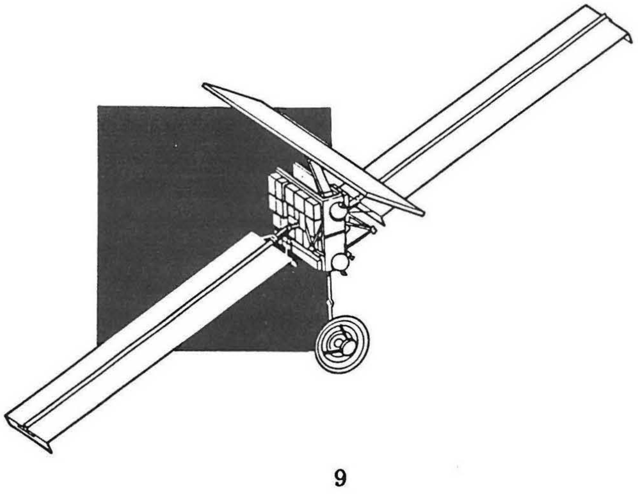
Most of the team members are actively involved with field experiments involving AIRSAR overflights that will provide results on the combinations of frequency, polarization and system sensitivities that are required to produce the geophysical parameters listed in the SAR products table. As an example, Fawwaz Ulaby of the University of Michigan discussed the detection of soil moisture in bare soil and low vegetation cover. In bare soil, it is necessary to determine the surface roughness in order to separate out the moisture conditions and may require the use of both C- and L-bands. With a low vegetative cover, it is more straightforward to separate the contributions to the signal from the vegetation and soil moisture by using information in the polarization ratios and phase difference from a single frequency.

Other presentations included the following: Herwig Ottl of DLF in Germany discussed the status of the X-band SAR system being studied by DLR and Dornier in Italy; Wu-Yang Tsai presented details of the characteristics of the wide swath mode, which is a critical mode for sea ice, soil moisture and vegetation studies; Marguerite Schier presented the current status of IDS input product requirements; Ben Holt discussed the SAR team output products; Holt presented the proposed DAAC SAR-related activities and pre-EOS SAR data requirements; Tony Freeman presented an overview of current activities for SAR calibration and a design for a calibration lab for EOS SAR; design ideas for the SAR science computing facilities were presented by John Curlander; Daren Casey discussed orbital issues and a plan for putting together a representative mission scenario; results of simulating different levels of radar system sensitivities using calibrated AIRSAR imagery over land were shown by Howard Zekber; and an outline for the algorithm development plan was presented by Holt.

After the presentations, the team broke into working groups to discuss in more detail plans for FY91, key instrument design issues, and to develop a list of action items. There was general consensus as to the course of action needed for the next year to produce clear and adequate science requirements, and a high level of enthusiasm was expressed for accomplishing these tasks.

The next team meeting will be held October 2-4, 1990, at JPL where the draft of the Science Requirements Document will be discussed in detail and team members will present plans for FY91. We encourage participation at all future meetings by any interested members of the EOS community.

Benjamin Holt
Jet Propulsion Laboratory



Development and Implementation of EOSDIS

Overview and Philosophy

A view that EOSDIS is a *thing*, a piece of hardware supported by software, is fundamentally mistaken. EOSDIS is not a collection of hardware and software, it is a "place" where scientists communicate with each other and with the data they have collected with the help of their professional colleagues from the engineering and operations disciplines. At the time of launch, EOSDIS will also require a capability to process, store, and make visible large streams of data. It may even be correct to view EOSDIS as *the place where the scientists produce information to be used by other scientists*. EOSDIS must be run **by** scientists, **for** scientists.

Implementation Approach

The approach to implementing EOSDIS is governed by the following general needs:

- Long-term service to the scientific community: 15-year data sets imply 15 years' collection of data from the EOS observatory instruments, but about 18 years of data processing after EOS-A launch, to account for reprocessing and other contingencies.

- Serving a multi-disciplinary scientific community: Data systems knowledge must be incorporated from many disciplines, but a unified Earth system view must be provided to users.

- Access to non-EOS data sets: Scientists would like to have one-stop shopping for all data sets, whether they are from EOS or other sources. EOSDIS will serve a major benefit to the scientific community even if the launches of EOS platforms are delayed.

- Large data volumes: Data from the mission, from all platforms, average more than 50 Mbits/sec and must be processed without a backlog. Standard data production must be timely, and archives must be conveniently accessible.

The first three needs identified above imply that the system be developed in a flexible, evolutionary way, starting immediately, while the last implies that the system be large, robust, and reliable. The key, therefore, is to identify the parts of the system that can be well-specified to handle the data efficiently while maintaining enough flexibility, especially in user-sensitive areas where requirements evolve and grow. Therefore, EOSDIS will evolve, based on existing expertise and systems at the DAACs (Distributed Active Archive Centers) through a series of versions with increasing capability.

Plans for Version 0

Starting immediately, through the cooperative efforts of the DAACs, a Version 0 EOSDIS will be developed. Each subsequent version will incorporate the results from the previous versions through user feedback and documented development experience, hardware, software, standards, etc. Changes in versions will result from new concepts tried out through prototypes and innovations in computer science and technology.

The goals of the Version 0 development are to:

- Develop pathfinder data sets, existing large-scale, moderate-volume, long-term data sets that need to be processed into community-consensus data products.

- Provide at least the present level of service to the respective scientific users of the data systems at the DAACs.

- Develop commonality among the data systems at the DAACs to provide a unified Earth System view to users.

- Use the experience with the multiple data systems users to evolve user-sensitive requirements.

- Examine prototype technologies relevant to EOSDIS.

Version 0 will be based primarily on existing data systems at the DAACs with augmentations to hardware and software to improve the Earth system view and to ensure that EOSDIS functions are demonstrated. Initially we will concentrate on the Information Management Service (IMS) and the Data Archive and Distribution System (DADS). Product Generation Service (PGS) will begin, and networking among scientists' computing facilities will be substantial.

The transition to Version 1 and later versions will be graceful, with no degradation in service during transition. Version 1 will provide PGS, IMS, and DADS functions, but will be limited in capacity to handling of the data sets supported by Version 0. The DAACs will support migration and testing of algorithms for standard products, and will examine prototype planning and scheduling functions for the EOS instruments.

Version 2 will be the EOS-A launch-ready system, with full functionality and capacities in all areas. Version 3 will be the EOS-B launch-ready system. Further versions of EOSDIS will be defined and developed to accommodate changes in requirements after the launch of EOS-B.

Functional Objectives

The key functional objectives of EOSDIS are:

1. *Command and control of NASA polar platforms:* The first platform, EOS-A, is planned for launch in 1998. The second, EOS-B, is planned to be launched 2 1/2 years later. Each will have an expected life of 5 years. So as to ensure a 15-year data set, each will be replaced twice.

2. *Command and control of EOS instruments:* The instruments to be flown on EOS-A and -B will be selected by NASA Headquarters in 1990 and 1991. Currently, there are 9 candidate "Facility Instruments" and 23 "Principal Investigator" instruments under study. Brief descriptions are given in the EOS Reference Handbook. Because of its unique requirements, the EOS SAR will be flown on a separate platform, slated for an independent new-funding start in 1993 or 1994, and a 1999 or 2000 launch.

3. *Processing and reprocessing of EOS data:* EOSDIS must support the generation of data products at levels 1 through 4. There are both standard and special products. Standard products are of wide research utility, are routinely produced by a peer-reviewed algorithm, and are available anywhere the input data are available. Special products are produced on limited subsets of data, by algorithms that may still be under development. At present, the EOS investigators have defined several hundred candidate standard products.

4. *Data archival, storage, and distribution:* EOSDIS must be able to store all computed standard and special products during the mission life, and distribute requested subsets of them to users. Data from non-EOS sources that are needed for the generation of products will also be available through EOSDIS. Moreover, algorithmic software, documentation, calibration data, engineering and other ancillary data will be available, and backup storage of either Level 0 or Level 1A data will allow recovery from catastrophic loss.

5. *Information Management:* EOSDIS must provide information about data (metadata) at adequate granularity and richness to permit easy location and selection of data of interest to users, so that they may decide which data to analyze more intensively. Convenient means include user-friendly interfaces and browsing and visualization tools.

6. *Networks:* EOSDIS must provide electronic access to data and information, so that scientists can communicate with each other and with the system.

7. *Transfer to permanent archives:* At the end of the mission, the data held by EOSDIS should be transferred to control of permanent archival agencies, namely NOAA and USGS, through sharing of budgets rather than physical movement of the data.

8. *Exchange of data, commands, algorithms, etc.:* EOSDIS needs to develop interfaces with NOAA, ESA, NASDA, CCRS, and other agencies to exchange data, commands, algorithms, metadata, etc.

Policy on Availability of Data

NASA policy specifies that all EOS data and derived products be available to all users, with no preference given to EOS investigators and no proprietary period. Research users in the U.S. and participating countries will pay only the marginal costs for data reproduction and distribution; they will have to agree to publish their results and to make available supporting information, including methods of analysis and code implementing the algorithms. Research users in other countries may have the same access to EOS data by proposing cooperative projects and associated contributions — similar access to their satellite, aircraft, and surface data. For all data products, the documented scientific software that produced them will also be available.

To the extent possible, we want to apply the same policy to non-EOS data. Other U.S. agencies involved in EOS, NOAA and U.S. Geological Survey, have agreed. For data from the international platforms, discussions are underway between NASA Headquarters and the appropriate foreign government agencies. Expectations are that they will agree to the same data policy. Availability of commercial data (Landsat and SPOT) under the same policy will require a change in legislation. The Landsat system, in particular, has priced data for full-cost recovery, but the usage declined dramatically when this policy was implemented.

System Architecture

Reasons for Distribution of EOSDIS Functions

Separation of product generation into different nodes within EOSDIS is consistent with scientific goals and interdisciplinary research. In order for a networked Information Management System to succeed, standards for operating systems and data formats are crucial, and a single common catalog is needed. Any user should be able to investigate the availability and characteristics of all archived data, without having to use separate catalogs for different instruments or to learn new access techniques.

Scientific functions of EOSDIS — distribution of instrument Level 1 data to investigators, information management, interaction among investigators, creation of geophysical and biological products, and archiving and distribution of data and information — should be separately optimized. Smooth interfaces are also important. Where centralization is appropriate, let us concentrate processing in a few institutional locations, but for those functions where more distributed processing is best, let us use EOSDIS to provide networks, occasional access to super-computers, standards, maintenance, and advice. Where processing can be routine, without continuous involvement of scientists, let us design a system to process efficiently, but where continuing scientific evaluation is needed in the creation of science products, let us not constrain this activity by an emphasis on "efficiency."

A major consideration in arriving at the distributed architecture is the existing reality of a distributed community of investigators and resources. EOSDIS will develop in an environment that is distributed. Proposed EOSDIS-related research facilities with associated computational resources are distributed across the continental U.S. and beyond. The investigators are broadly geographically distributed. Further, the Global Change community that will be a major user of EOSDIS is distributed. There are ten or more data centers that will supply non-EOS data and these are geographically distributed.

However, this geographic distribution of facilities and investigators is not now closely knit. Thus, we cannot take advantage of the great strengths of these investigators' skills and excellence. Indeed, their distribution without adequate attention to the requirements of scientific interaction has not served to extract the potential of the research enterprise. EOSDIS must become the logical integrator of these facilities by modifying the infrastructure and removing the roadblocks to effective remote use. It must be possible to remotely access and acquire data that are stored in widely disparate forms, thereby reducing the effort needed, before such data can be used in computer analyses. Networks for use in a distributed environment such as EOSDIS must evolve in capability, capacity and ubiquity. Individualized styles of research must be accommodated.

The greatest potential for knowledge from EOS comes from the fertilization that follows from the interactions among researchers with differing views of the data and different styles of data use. This fertilization requires that communication mechanisms improve and that EOS become a driving force in the initiation of the "Laboratory Without Walls." It must be far simpler to use and acquire data than it is now. EOSDIS must provide access to data and tools that allow the solution of the problems in understanding the Earth as a system. The existing centers of expertise and excellence should be incorporated into a distributed EOSDIS architecture to allow the best availability and interaction among all resources. A centralized view of EOSDIS assumes that one group has a monopoly on knowledge of how to manage Earth observations data.

Competition and Cooperation Among EOSDIS Sites

Distribution removes the problems associated with failures at a central or controlling site. With a proper distribution, if a single site fails, most EOSDIS facilities will remain operational; this would not be true with centralization.

The competition inherent in a distributed architecture will result in much better service to the EOSDIS user community. Site management will necessarily be more responsive to the user community if the sites are being judged competitively. Competition will provide a comparative basis under which funding decisions can be made. Many benefits will accrue for the EOSDIS community. Examples include: Sites will keep maintenance schedules as narrow as possible and maintain 24-hour-a-day operation with reasonable consulting schedules. Sites will attempt to tune the operating parameters to provide responsive service. Indeed, they will be judged on their *success*, not merely forgiven for their failures. There will be pressure to perform well whenever technological experimentation is undertaken. Moreover, sites will have to compete in the *scientific* arena as well as the *technical* arena.

EOSDIS must provide a large amount of computational power both in terms of GFLOPs and storage. No single system could provide the performance required. Multiple systems with different characteristics are needed. Distributing this computational power allows each site to concentrate on obtaining the best performance out of the class of equipment that has been selected, and to tune it to suit the requirements of the users of their data products. With care, equipment will be placed at sites where appropriate expertise and excellence exists. Perhaps a significant reason for the slow development of competing supercomputer architectures has been the attempt to operate these in environments where they were not expected to provide the major computational resource.

The eventual EOSDIS user base is estimated between 5,000 and 15,000 persons. Today's major supercomputer centers, which are operated for the non-classified U.S. research community, normally serve between 1,000 and 3,000 persons. The number projected for EOSDIS would present a formidable service task, if all were using one site or had to interface to EOSDIS through a single site or system.

Decentralization will loosen the grip of bureaucratic control. It will be more difficult to devise and enforce rules that inhibit easy interaction among EOSDIS elements and the community because the management itself will become distributed and find it in their own best interest to keep the system as responsive and functional as possible.

Communication Among Nodes

A challenge of EOSDIS will be to augment the communications infrastructure to further interconnect the research community to itself and the various EOS elements. This augmentation has to occur whether EOSDIS is functionally distributed or centralized. It is more likely to be effective if it is realized at the onset that this augmentation is a key to EOSDIS success, instead of something that is merely an expensive frill to be added when funding is not tight.

EOSDIS is not an isolated system. It exists to help the research community flourish and return useful knowledge about the Earth. It cannot provide resources only to the small segment of the community implied by centralization, but instead must assure that it encourages participation by as broadly based a community as possible.

During the first three decades of satellite observations of the Earth, we learned to put reliable instruments in space and began to make some progress at understanding how to use these new tools of understanding. However, we regarded data as a precious resource and hoarded them jealously. Each research group that obtained satellite data put them into a form that suited their own experience and current needs. As a result, these data are fragmented and dispersed.

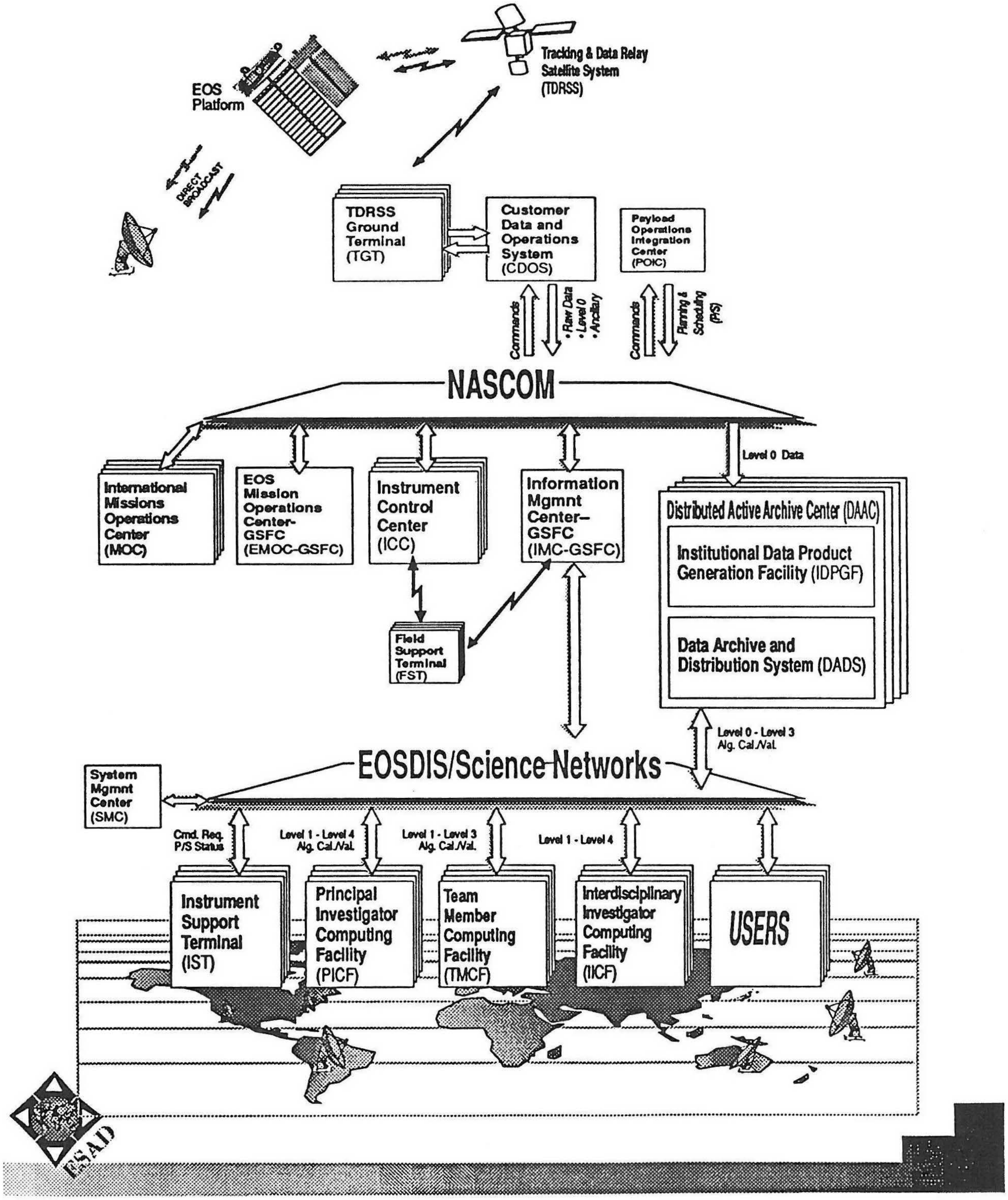
Specific Functions

The architecture of EOSDIS has evolved over the past three years through design studies and interaction with the science community. The present architecture is shown in Figure 2, which shows both the EOSDIS elements and the external elements with which EOSDIS interfaces. There are three segments to EOSDIS:

1. The Flight Operations Segment controls the platform and instruments, supports mission planning and scheduling, and monitors the health and safety of instruments. It consists of the EOS Operations Center, Instrument Control Centers, and Instrument Support Terminals.

    a. The EOS Operations Center coordinates EOS platform and instrument operations and monitors the accomplishment of mission objectives. It also maintains health and safety of the observatories, supports planning and scheduling of the resources on the EOS

EOSDIS Architecture



platforms, coordinates observations from all instruments to develop conflict-free schedules, accommodates unplanned schedule changes, and develops and implements contingency plans. It will normally have to support simultaneous operations of two U.S. platforms, but during replacement of platforms it will have to support simultaneous operation of three platforms over a nominal overlap period of about six months. It receives commands from the Instrument Control Centers, performs high-level command validation to ensure that there are no conflicts, and merges instrument and platform commands for total observatory operations. The EOS Operations Center also coordinates with the mission operations centers for the European and Japanese platforms and for Space Station Freedom.

b. EOSDIS has two Instrument Control Centers, one at NASA/Goddard Space Flight Center and one at the Jet Propulsion Laboratory (JPL). Their functions are to plan and schedule instrument operations, generate and validate instrument command sequences, forward commands in real time or store them for later transmission, and monitor health and safety of instruments. They create instrument-specific commands within the schedules provided for each instrument by the EOS Operations Center, and they review quick-look engineering and science data.

c. Instrument Support Terminals are provided to the instrument Principal Investigators and Facility Instrument Team Leaders to help monitor instrument status.

2. The Science Data Processing Segment is the part of EOSDIS of most interest to the investigators. The current concept of EOSDIS is that several Distributed Active Archive Centers (DAACs) will fulfill all processing needs except algorithm development and individual scientists' investigations. At present, seven DAACs have been designated by NASA, and there are Affiliated Data Centers (ADCs) with which EOSDIS has interfaces. The seven DAACs and the presently identified ADCs are shown in Table 1:

Table 1

DAACs

Alaska SAR
Fairbanks, Alaska

Jet Propulsion Laboratory
Pasadena, California

NASA/Goddard Spaced Flight Center
Greenbelt, Maryland

NASA/Langley Research Center
Hampton, Virginia

NASA/Marshall Space Flight Center
Huntsville, Alabama

National Snow and Ice Data Center
Boulder, Colorado

U.S. Geological Survey
EROS Data Center
Sioux Falls, South Dakota

AFFILIATED DATA CENTERS

Consortium for International Earth
Science Information Network
Ann Arbor, Michigan

National Center for Atmospheric Research
Boulder, Colorado

University of Wisconsin
Madison, Wisconsin

Each will have a PGS that will generate standard products, DADS that will distribute data sets to investigators, and that will be accessed by an IMS. Explicit in this concept is that multiple facilities and generic classes of facilities can best fulfill these functions. The ADCs will not have responsibility for generation of level two geophysical or biological products from EOS data, but instead will organize large data sets from other sensors and incorporate large-scale models. In the next year, each potential DAAC will identify appropriate current and previous data and promote their rapid development. They will also acquire experience with currently active data processing centers and archives and begin development of interfaces between DAACs and between EOSDIS and other national and international archives.

a. The Product Generation System is responsible for the generation of standard data products. The combined capacity at the PGS nodes must be great enough to generate all standard products at a rate fast enough to cope with the incoming data stream and to allow for reprocessing. Algorithmic software for product generation is designed and implemented by the responsible scientists, who also define contents of metadata and browse products associated with the standard products.

b. The Data Archive and Distribution System archives instrument and interdisciplinary data products, ancillary data, radiometric and geometric calibrations, metadata, command history, correlative data (including those from pre-EOS sensors, surface measurements, and non-EOS data used in product generation), algorithms, and documentation. An estimate of the data volumes to be stored by the DADS is shown in Table 2.

c. The primary function of the Information Management System is to provide information about the data holdings in EOSDIS and access to other (external) archives. The IMS will be distributed, to take advantage of the diversity in experience at the DAACs and to permit DAAC-specific features. The degree of distribution of functionality and the configuration will depend on the state of data base management technology and network responsiveness. Regardless of which DAAC a user interacts with, the IMS will provide uniform, seamless access to all data held by EOSDIS, through convenient, easy user interfaces for novices and experts. It will be possible to access data by simple search criteria, such as instrument name, product name, time of collection,

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Table 2

Platform	Rate Mbits/sec	Data Levels Gigabytes per day					
		0	1A	1B	2	3	TOTAL
EOS-A	21.6	233.1	341.6	341.6	83.5	15.3	1,015.1
EOS-B	10.6	114.7	168.2	19.6	0.3	0.2	302.8
European	0.02	0.2	0.3	0.3	0.2	0.5	1.5
Space Stn	0.03	0.3	0.5	0.2	0.1	0.4	1.5
Japanese	2.0	21.6	23.8	1.4	0.1	0.0	46.9
EOS SAR	20.0	216.0	316.8	28.2	14.1	7.0	582.2
	54.3						1950.0

Total data over a 15-year mission is estimated to be about 11 PB. The data are distributed on request to EOS scientists, other DAACs and the general community, via either electronic networks or on media such as optical disks or magnetic tapes.

and spatial coordinates. Moreover, other modes of searching should be provided to permit cross-instrument and cross-disciplinary searches by enriching the metadata with summaries of the data sets. The IMS is the element through which data are ordered by users.

   d. A User Support Office at each DAAC consists of scientific experts and support staff to assist users in understanding the data products specific to that DAAC. Each works closely with the scientific community through science advisory groups in its own discipline and the EOSDIS Advisory Panel. Activities are coordinated through the EOS Science Processing Support Office.

3. Communications and System Management Segment services the DAACs and the scientists' computing facilities with the connectivity and management functions to ensure appropriate data flows, management of production schedules, and resource usage.

   a. The EOSDIS Science Network, possibly a combination of NASA institutional and other existing or new networks, will electronically distribute data among DAACs and scientists' computing facilities, and with the international community. It is anticipated that at least 45 Mbits/sec will be needed among DAACs and from 56 Kbits/sec to 1.5 Mbits/sec between the DAACs and the scientists.

   b. The Systems Management Center has as its functions configuration management, high-level scheduling of system, site, and element activities, monitoring production and performance, resolving faults, establishing security, accounting, and billing.

4. Field Support Terminals (FST) provide scientists in field campaigns with mobile communications to permit coordination of platform data with field experiments.

5. Scientific Computing Facilities (SCF) are the scientists' facilities to develop and maintain algorithms and software for producing scientific products, control quality of the standard products, support data set validation, instrument calibration and analysis, generate special products, and provide needed resources for the scientists' research. A set of software tools is provided to the SCFs to help them interact with each other and with other EOSDIS elements.

Near-Term Activities

The immediate task of the EOSDIS Advisory Panel is to help draft the Request for Proposal (RFP) for the EOSDIS Phase C/D (i.e., the design and fabrication of EOSDIS) and to guide the EOSDIS Project and DAACs in their near-term efforts.

August 1990
Next Draft of Statement of Work (SOW) and Requirements Specifications Completed

August 13-14, 1990
EOSDIS Advisory Panel Reviews SOW and Requirements

September 1990
Draft RFP Released to Science Community for Comments

November 1990
Comments on Draft RFP Collected

January 1991
Formal RFP Released

April 1991
EOSDIS Phase C/D Proposals Due

November 1991
Evaluation of Proposals Completed and Contractor Selected

May 1992
Phase C/D Contract Begins

Jeff Dozier
University of California, Santa Barbara and
Universities Space Research Association,
NASA Goddard Space Flight Center

Common Instrument Interface Study (CIIS) Status Update

A joint NASA/ESA/NOAA meeting was held June 14-15 at ESA/ESTEC to review the recent progress made on the CIIS and to determine the future direction for the effort. While past CIIS efforts have resulted in increased commonality in the basic ESA and NASA platform designs, it became evident that refinements in the potential common instrument complement yield a limited number of candidates. As a result of the joint meeting, ESA and NASA have developed ground rules for completion of the CIIS activity, which take advantage of the present direction of both platform programs. The CIIS activity will recommence in September 1990 with the selection of the EOS-A and ESA Polar Platform payloads.

First, a comprehensive compilation of the differences in requirements between the two programs will be prepared. Utilizing this documentation and the common instrument list, the top-level interface differences will be delineated for each candidate common payload. This activity will allow both NASA and ESA to quantify the impacts of flying the same instrument on both platforms and will complete the CIIS effort.

Transition to common instrument accommodation implementation will begin with the establishment of a management structure for the incorporation of a cost-effective accommodation design. In support of this effort, image interface control documents (ICDs) will be developed for each common instrument by July 1991. As it is now apparent that development of common ICDs is not practical, the instrument-unique ICDs, after being finalized in late 1991, will permit the efficient accommodation of those instruments selected for flight on both platforms.

Rick Obenschain
EOS Platforms Project Manager

SIXTH CATALOG INTEROPERABILITY WORKSHOP

On October 1-3 the Sixth Catal;og Interoperability Workshop will be held at the NOAA Silver Spring Metro Center 2 facility at 1325 East West Highway, Silver Spring, Maryland. The workshop will bring together government, academic, and international representatives to discuss the progress in creating a world-wide interoperable Earth and space science data information system. EOSDIS is expected to play a major role in this system. The meeting is open to all. For further information or to register your attendance, please contact Janis Shipe (301-794-5186) or Jim Thieman (301-286-9790).

Global Change Meetings

October 1-3	Catalog Interoperability Workshop, NOAA, Silver Spring, Maryland. Contact Jim Thieman, (301) 286-9790.
October 6-13	41st Congress of the International Astronautical Federation, Dresden, German Democratic Republic. Contact Dale deMatteo at AIAA (202) 646-7451.
October 16-19	NOAA Conference, Operational Satellites: Sentinels for the Monitoring of Climate and Global Change, Hotel Washington, Washington, D.C. Call Beverly Poe at (301) 220-1877 or Don Lipinski at (301) 220-2019, ext. 219.
October 23-24	Earth Observations & Global Change Decision Making: A National Partnership Fall Conference, National Press Club, Washington, D.C. Contact Nancy Wallman, ERIM/Global Change Conference, (313) 994-1200, ext. 3234.
January 13-18	2nd Symposium on Global Change Studies, New Orleans. Contact Eric Barron, (814) 865-1619.
Jan. 29-Feb. 1	Fourth Airborne Geoscience Workshop, Techniques, Results, and Future Needs, LaJolla, California. Contact Debby Critchfield (202) 479-0360, or FAX (202) 479-2743

Future EOS Science Meetings

October 2-4	SAR Team Meeting, Jet Propulsion Laboratory (JPL), Pasadena, California
November 6	AIRS Science Team Meeting, Langley Research Center, Hampton, Virginia
November 6-9	IWG, Langley Research Center, Hampton, Virginia

EOS Science Meetings 1990

	Monday	Tuesday	Wednesday	Thursday	Friday	Sat/Sun
AUGUST			1 ← ALT CDCR → ← LAWS Team Meeting, Boulder, Colorado →	2	3	4 5
	6	7	8	9 ← POEMS CDCR →	10	11 12
	13 ← EOSDIS Advisory Panel, Snowmass → Panel Members Only ← LIS CDCR →	14	15	16	17	18 19
	20	21	22	23	24	25 26
	27	28 ← Payload Advisory Panel and SEC Meetings, Durham, New Hampshire →	29	30	31	1 2
SEPTEMBER	3	4	5	6	7	8 9
	10	11 ← Calibration Advisory Panel Meeting, University of Arizona, Tucson, Arizona →	12	13	14	15 16
	17	18	19	20	21	22 23
	24 ← MODIS Science Team Meeting, NASA/GSFC →	25	26	27	28	29 30
OCTOBER	1	2 ← SAR Team Meeting, JPL, Pasadena, California →	3	4	5	6 7
	8	9	10	11	12	13 14
	15	16	17	18	19	20 21
	22	23 ← TES Science Team Meeting Cambridge, Massachusetts →	24	25	26	27 28
	29	30	31			

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Space Administration

Goddard Space Flight Center
Greenbelt, Maryland
20771