EOS Ground Data Systems: A Description & Interface Overview

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ABSTRACT

The Earth Observing System (EOS) is planned as a space-based measurement system, earth-science research program, and data and information system (EOSDIS). It will consist of several high data rate spacecraft with multiple earth sensing instruments which provide investigators with a thorough, long-term view of the earth's environment. Up to seven spacecraft may be supported at once, either in operational, checkout, or testing phases; and the average data rate from the EOS satellites in orbit at any one time is expected to be from 18 to 60 Mbps.

Providing the data processing and flight operations support for EOS will be the EOSDIS Core System (ECS). The ECS will command and control the spacecraft; process and store the EOS data; provide access to the data for years; and support researchers. The data processing aspects of the ECS consist of a collection of Distributed Active Archive Centers (DAACs) which perform the product generation, data archive and distribution, and information management services. Flight operations aspects will be provided by the EOS Operations Center, by instrument control centers, and by widely distributed instrument support terminals. The communications and system management aspects will be provided by the EOSDIS Science Network and the System Management Center. In addition to the EOS satellite data, other data sets from earlier earth science missions are also to be added to designated DAACs.

Other ground data systems which will provide support to EOS for acquiring, transporting, processing, and distributing the transformed spacecraft data are currently being defined or are being upgraded for the EOS era. These systems include the Space Network consisting of the Tracking and Data Relay Satellite System (TDRSS), the TDRSS Ground Terminals, and the Network Control Center as well as the Flight Dynamics Facility, the EOS Data and Operations System, and EOS Communications.

This paper briefly describes data handling by the ECS, the support data systems, their interfaces, and their roles.

Key Words: Earth science, data systems, data processing, flight operations, communications, information systems

1. BACKGROUND

NASA's future role in space has been focused in the 1990s on planetary and astronomical investigations—Mission from Planet Earth—and on developing a detailed understanding of our own planet—Mission to Planet Earth (Fig. 1). This is NASA's response to the U.S. Global Change Research Program involving an integrated effort of nine U.S. Government agencies. The Mission to Planet Earth has many components including NASA's Earth Observing System (EOS). The EOS consists of space-based measurement systems, a data and information system, and scientific research programs.

Beginning in the late 1990s, EOS will utilize large, multi-instrument spacecraft to gather data about the earth in order to coordinate and extend investigations of the earth's atmosphere, oceans, ice caps, land, and water resources. Tens of megabits of data will be generated every second, and petabytes (10^{15} bytes) of data will be stored on the ground over years for access by investigators. Scientists will analyze observations from EOS, combine them to achieve interdiscipline synergism, and coordinate their findings with ground-based observations and other satellite measurements to expand the level of understanding of all earth science.

After observations are made by an EOS spacecraft and before the analyses are released, a variety of crucial data transformations will be made to the data to produce new information on earth phenomena. To do this for the volumes of data to be gathered will require an extensive ground support system to command and control the spacecraft and instruments, transport the observation data, process the data into standard products, store the data products, provide access to EOS information for years, and support researchers in their investigations. This ground support system is collectively known as the EOS Data and Information

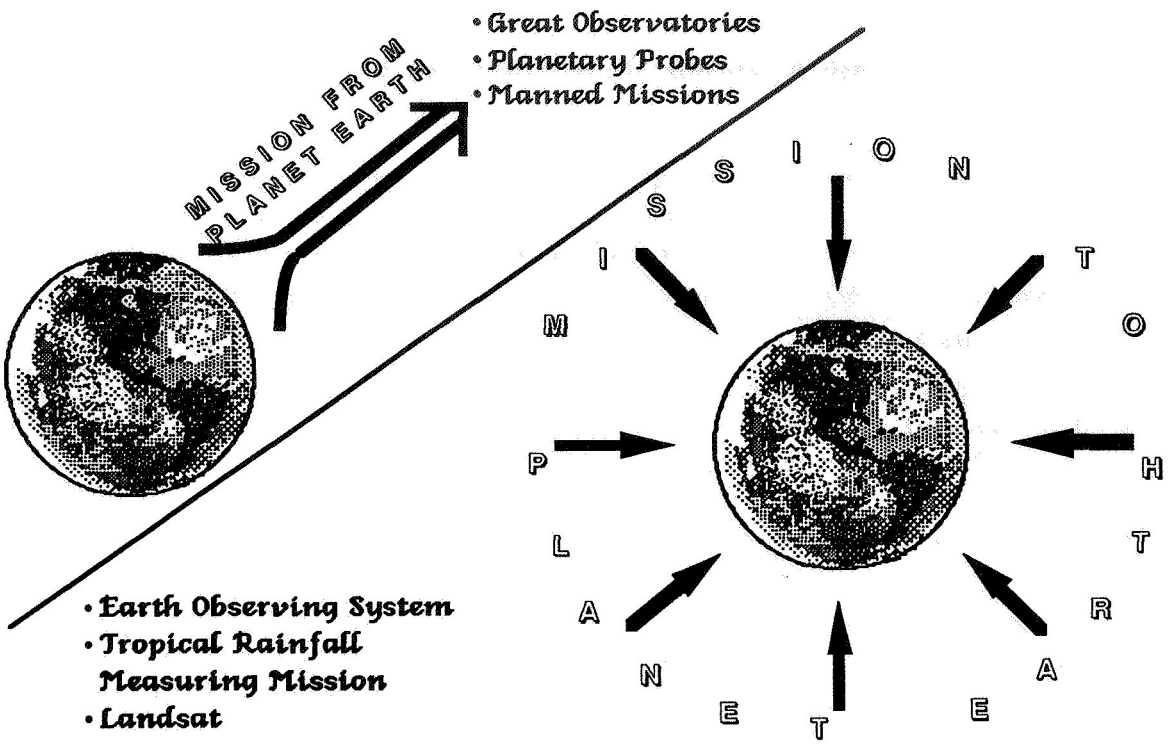

Fig. 1 — NASA Missions

System (EOSDIS) and will consist of a distributed network of facilities and functions. Providing standard EOSDIS services and products to the earth science community will be the EOSDIS Core System (ECS). NASA institutional facilities will also be utilized to provide standard NASA services to the ECS.

The ECS will consist of three segments: Flight operations, science data processing, and communications and system management. These are divided into elements which are to perform related functions distributed to a number of sites at centers of scientific expertise.

2. EOS DATA HANDLING

2.1 The EOS On-Board Data System

The EOS on-board data system collects data packets from the instruments and spacecraft sensors at asynchronous rates. These packets contain radiance measurements, image scan lines, or other sensor-unique observations. The on-board data system merges low-rate packets into virtual data channels by breaking each merged data stream into synchronous frames with a set number of bits, adding framing headers and providing error protection encoding of each frame. The low-rate instrument virtual channels are further merged with high-rate instrument virtual channels for transmission to the ground or for recording for later transmission.

Uplink data (commands and memory loads) arrive at the spacecraft in coded virtual channels. Then the virtual channel formatting is removed, the data decoded, and the commands are sent to the appropriate instrument or spacecraft subsystem for interpretation.

The average data rate for the EOS A.M. spacecraft is 18 Mbps with first launch scheduled for mid-1998. Subsequent spacecraft in the A.M. series (three spacecraft at five year intervals) and the spacecraft in the P.M. series (three spacecraft at five year intervals beginning in late 2000) are expected to produce equal or greater amounts of data. Additional EOS spacecraft are the Chem, Aero, and Alt series with fewer instruments and lower aggregate data rates. The EOS is planned for 15-20 years of active data collection; and support for access to the EOS data archives could continue indefinitely, depending on user interest and funding. Landsat 7 and subsequent Landsat flights are also planning to utilize the EOSDIS ground data systems.

2.2 NASA Institutional Facilities

Several NASA institutional facilities contribute to getting the data packets created by the instruments to the ECS for extensive processing and to moving the commands and memory loads from the ECS to the spacecraft. These facilities include the Space Network (SN), NASA Communications (Nascom), and the Flight Dynamics Facility (FDF).

The SN consists of the Tracking and Data Relay Satellite System (TDRSS) and a Network Control Center (NCC). The TDRSS acquires the EOS spacecraft data transmissions at one of its synchronous-altitude satellites (TDRS) from an EOS spacecraft and retransmits the data to one of two TDRS Ground Terminals (TGTs) at White Sands, New Mexico. Transmission artifacts are removed at the TGT. In addition, commands are uplinked through the TDRSS to the spacecraft. The NCC schedules and controls the TDRSS links and the data traffic through them. Development of an advanced TDRSS (TDRSS II) is now underway for enhanced operation in the next decade.

The Flight Dynamics Facility (FDF) will provide orbit support for EOS by developing and managing the TDRS On-board Navigation System (TONS). TONS will compute the EOS spacecraft position, velocity, and time parameters on-board the spacecraft from two-way coherent tracking measurements and Doppler extraction between the spacecraft and the TDRSS satellites. In addition, the FDF will provide and maintain attitude sensor calibrations for on-board attitude determination. The FDF will monitor the on-board position and attitude computations, determine any corrections to be made to the on-board algorithms, and provide spacecraft attitude and orbit control information to the EOS Operations Center.

Nascom is a worldwide complex of communication circuits and systems which support NASA programs. For EOS, a dedicated communications network (affiliated with Nascom) provides the ground communication circuits for the spacecraft telemetry data and the command data. Nascom supplies voice circuits between systems and provides the circuits for communication by the EOS Operations Center with the NCC and FDF.

2.3 EOSDIS Elements

The EOSDIS will be developed in an incremental and evolutionary manner. In addition to the ECS, it will include an early phase (Version 0), a testing component for Independent Verification and Validation, and a dedicated data capture and processing service—the EOS Data and Operations System (EDOS). A dedicated communications network for telemetry and command data—EOS Communications (Ecom), interconnection with institutional data transport systems, and science data product algorithm development—Scientific Computing Facilities (SCFs) will also be included in the EOSDIS. The relationship of the ECS to other EOS Ground Systems is shown in Fig. 2.

EOSDIS Version 0 was initiated in 1991, using existing earth science data systems to provide interoperability and improve access to existing earth science data. Version 0 will be developed prior to and outside the ECS contract with development of data sets derived from past and current earth science missions. It will also develop a substantial information management service, provide limited product generation, and develop substantial data archive and distribution capabilities. It will support commonality among cooperating data systems; develop prototype technologies; implement standards, protocols, and guidelines; and provide a unified earth sciences view to its users. Results from these activities will be available in the development of the ECS.

The EDOS will decode the data, flag error conditions, remove virtual channel framing artifacts, and reassemble the packets at White Sands, New Mexico —collocated with the TDRSS Ground Terminals. The packets are transmitted to Fairmont, West Virginia, for further processing. At Fairmont, the EDOS will produce data sets of time-ordered, nonredundant data packets for each instrument; transmit the data sets to the ECS; and archive all data sets for protection. If faster throughput is required for some instrument data, a reduced set of operations may be selected. In addition, commands arrive from the ECS in packet streams. These packets are formatted into virtual channels and passed to the ground station for uplink to an EOS spacecraft.

Ecom will transmit the data sets from White Sands to Fairmont, West Virginia, and from Fairmont to the appropriate ECS processing sites and will transmit command packets from the ECS to White Sands.

The primary functions of EDOS and Ecom are shown in Fig. 3.

3. ECS—GROUND DATA PROCESSING AND FLIGHT OPERATIONS

The ECS is the central feature of the EOSDIS. It will be designed, developed, built, and operated over the next ten years through a NASA contract to a team of aerospace corporations. The three ECS segments—flight operations, science data processing, and

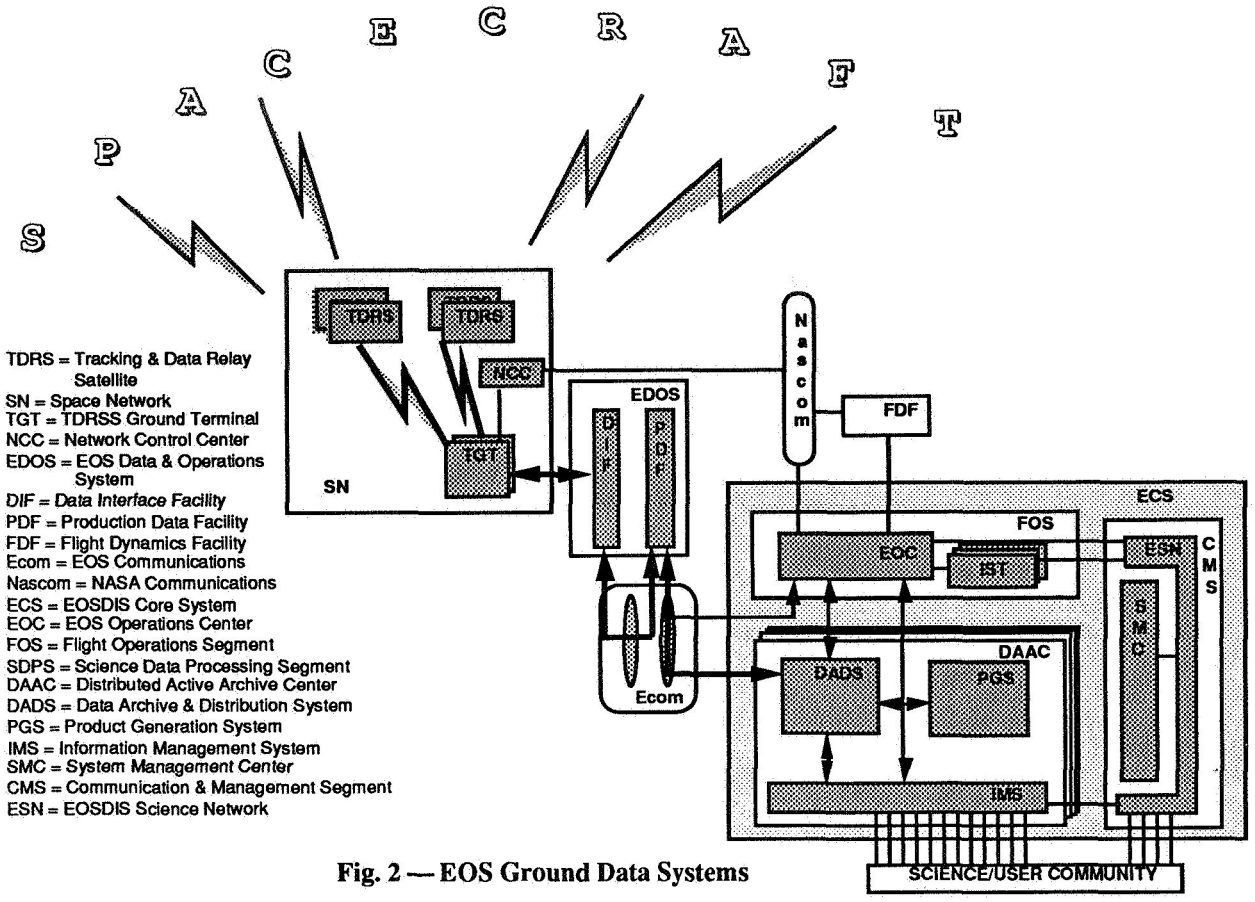

Fig. 2 — EOS Ground Data Systems

communications and system management—are divided into elements which perform related functions distributed to a number of sites at centers of scientific expertise.

3.1 The Flight Operations Segment

The Flight Operations Segment of the ECS will control the spacecraft, provide mission planning and scheduling, and monitor the health and safety of the spacecraft and instruments. The primary element of this segment is the EOS Operations Center, which will be responsible for the health and safety of each spacecraft; support planning and scheduling of platform resources; coordinate instrument observation requests; and validate commands to instruments. It will also serve as the U.S. Instrument Control Center (ICC) to plan and schedule each instrument's operations and to generate appropriate commands. It will also be responsible for instrument health and safety. For the International Partner (IP) instruments on U.S. spacecraft, additional ICCs may be located at the IP sites as negotiated. These would be linked to the EOC through Ecom. The Instrument Support Terminal element is distributed to key investigator facilities to perform instrument calibration; monitor instrument performance, health, and safety; resolve performance anomalies; and contribute to instrument planning.

3.2 The Science Data Processing Segment

The Science Data Processing Segment of the ECS processes the incoming science packet data sets into information in which spectral, temporal, and spatial observations are transformed and combined to obtain new parameters, images, or maps. There have been eight sites selected to perform this science data processing and other data services. They are Distributed Active Archive Centers (DAACs). Each DAAC has three elements. A Product Generation System (PGS) produces standard data products from approved algorithms. A Data Archive and Distribution System (DADS) stores the data products, distributes them to investigators, and makes the data available for decades for subsequent research. An Information Management System (IMS) monitors additions to and status of the data products in

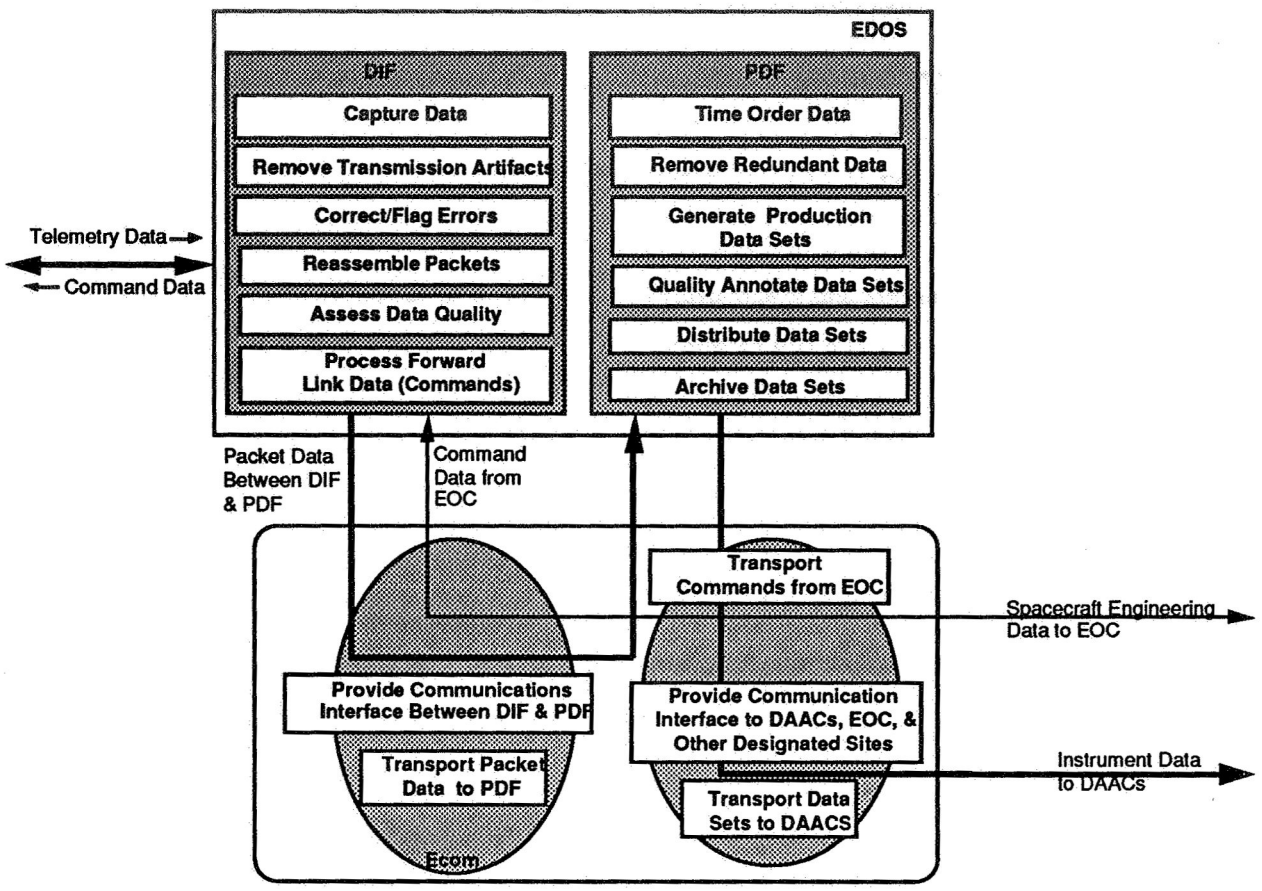

Fig.3—EOS Data & Operations System and EOS Communications Functions

the archive, makes the data product and data inventory information available for access by local and remote users, and provides these services for all DAAC archives through access to any DAAC. Technical assistance and automated help support will be provided to assist users requesting information. The highlights of Science Data Processing functions are shown in Fig. 4.

3.3 The Communications and System Management Segment

The Communications and System Management Segment has two elements. The EOSDIS Science Network distributes data among the DAACs and to users over NASA-provided circuits while the System Management Center provides on-line system status information of all ECS elements; configuration and performance management; high-level ECS scheduling, monitoring, and accounting; security management; and user authorization and billing. The Science Network also provides network management and user assistance. Related to the EOSDIS Science Network but outside the ECS and serving to support ECS services is the NASA Science Internet to interconnect users with the DAACs.

3.4 ECS Goals

These elements serve to provide the functionality required of the ECS to support the EOS instrument investigators, earth scientists, and other researchers. Included in the ECS archives will be the EOS spacecraft data and other earth research satellite data sets to provide the investigators with a rich mixture of information. Through these elements, the EOSDIS and the ECS will meet the goals of supporting system evolution; providing elegant access by investigators to massive, growing data stores; facilitating interdisciplinary research, and enabling increased understanding of our earth and its environment.

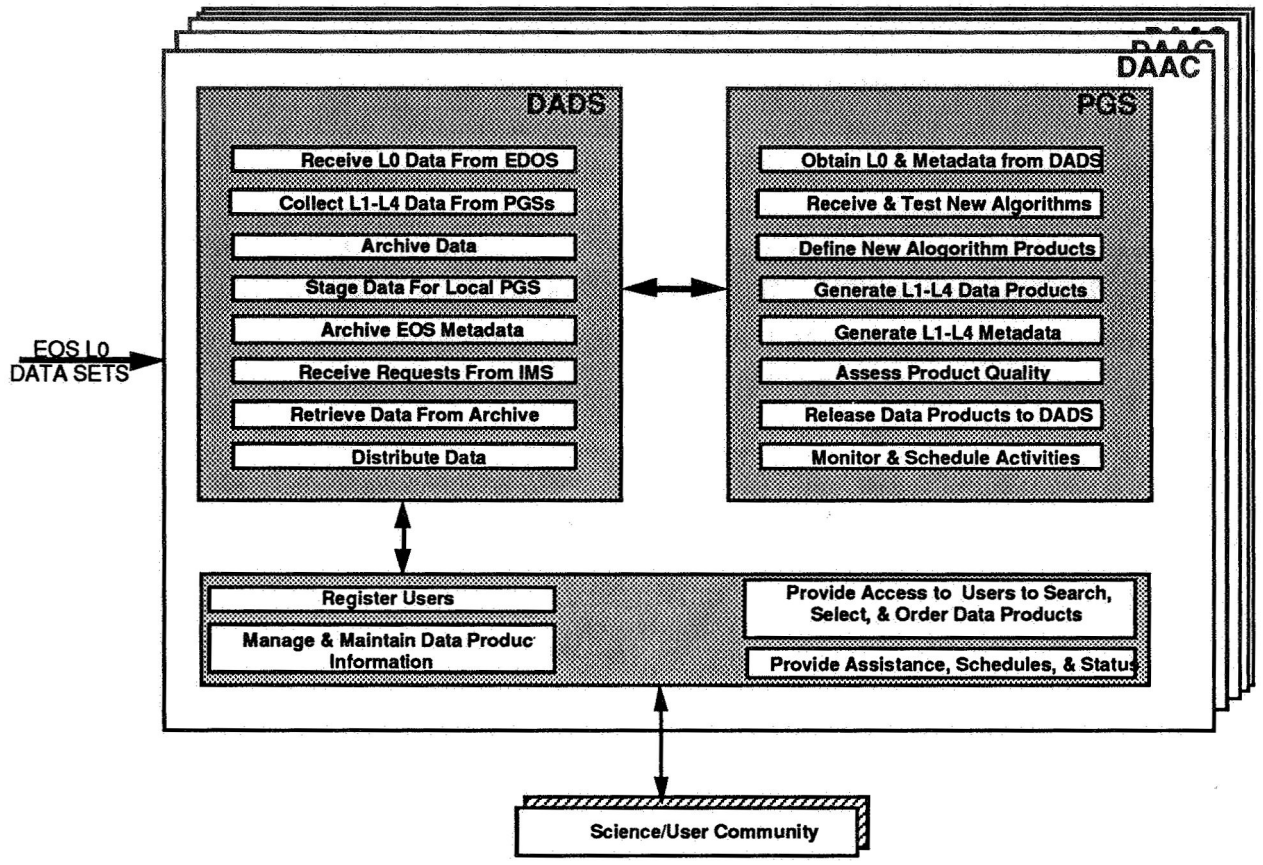

Fig. 4 — Science Data Processing

5. OUTLOOK

The ECS prime contract winner was announced in October after a lengthy procurement process. The award of contract is expected in January after completion of negotiations. The ECS contract is for ten years and will provide system design and development, system integration and testing, and operations and maintenance support. Another procurement process will begin shortly with the release of the EDOS Request for Proposal (RFP). THE EDOS is planned to be ready for operation a year before support for Landsat 7 is required. Similarly, an RFP for the EOS Ground System Independent Verification and Validation (IV&V) contract will be released soon.

6. ACRONYMS

CSMS	Communication & System Management Segment
DAAC	Distributed Active Archive Center
DADS	Data Archive & Distribution System
DIF	Data Interface Facility
Ecom	EOS Communications
ECS	EOSDIS Core System
EDOS	EOS Data & Operations System
EOC	EOS Operations Center
EOS	Earth Observing System
EOSDIS	EOS Data & Information System
ESN	EOSDIS Science Network
FDF	Flight Dynamics Facility
FOS	Flight Operations Segment
ICC	Instrument Control Center
IMS	Information Management System
IP	International Partner
NASA	National Air & Space Administration
Nascom	NASA Communications
NCC	Network Control Center
PDF	Production Data Facility
PGS	Product Generation System
SDPS	Science Data Processing Segment
SMC	System Management Center
SN	Space Network
TDRS	Tracking & Data Relay Satellite
TGT	TDRSS Ground Terminal