MISSION OPERATIONS UPDATE FOR THE RESTRUCTURED EARTH OBSERVING SYSTEM (EOS) MISSION

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1.0 INTRODUCTION

The National Aeronautics and Space Administration's (NASA) Earth Observing System (EOS) will provide a comprehensive, long term set of observations of the Earth to the Earth science research community. The data will aid in determining global changes caused both naturally and through human interaction. Understanding man's impact on the global environment will allow sound policy decisions to be made to protect our future.

EOS is a major component of the Mission to Planet Earth program, which is NASA's contribution to the U.S. Global Change Research Program. EOS consists of numerous instruments on multiple spacecraft and a distributed ground system. The EOS Data and Information System (EOSDIS) is the major ground system developed to support EOS. The EOSDIS will provide EOS spacecraft command and control, data processing, product generation, and data archival and distribution services for EOS spacecraft. Data from EOS instruments on other Earth science missions [e.g., Tropical Rainfall Measuring Mission (TRMM)] will also be processed, distributed, and archived in EOSDIS. The U.S. and various International Partners (IP) [e.g., the European Space Agency (ESA), the Ministry of International Trade and Industry (MITI) of Japan, and the Canadian Space Agency (CSA)] participate in and contribute to the international EOS program. The EOSDIS will also archive processed data from other designated NASA Earth science missions (e.g., UARS) that are under the broad umbrella of Mission to Planet Earth.

2.0 EOS RESTRUCTURING

Various events have resulted in the restructuring of the EOS program over the past year. The Congressional Committees on Appropriation directed NASA to restructure EOS based on three principal reasons: to focus the science objectives of EOS on global climate change, considered the most critical problem of global change; to increase the resiliency and flexibility of EOS by flying instruments on multiple smaller spacecraft rather than large platforms; and, to reduce the cost of the overall program. NASA, through internal and external reviews, discussions with the science community, and numerous engineering studies of spacecraft configurations and launch options, restructured EOS to meet congressional constraints and still satisfy the needs of the scientists investigating global climate change.

In addition to the above, NASA programmatic decisions resulted in an expanded scope for the EOSDIS. Original plans utilized two future NASA institutional elements: the Customer Data and Operations System (CDOS) and an upgrade version of the NASA Communications System (NASCOM II). These elements would provide the forward and return link processing services and mission critical communications functions for EOS and future NASA missions with high data rates. In the summer of 1991, NASA Headquarters transferred functional responsibilities for these future elements to the EOS Program Office; thus the EOS Data and Operations System (EDOS) and the EOS Communications System (ECOM) have been incorporated within EOSDIS.

In the spring of 1992, EOS was directed to include the Landsat-7 mission under the EOS umbrella. Landsat-7 is being procured under a joint Air Force/NASA contract. This includes the flight operations segment (operations control center) and the science processing software which will be used in the Landsat-7 ground processing system, the latter to be procured under a separate contract. The Landsat-7 operations control center will be physically located in the EOSDIS building at GSFC. Data archival and distribution will be provided under EOSDIS.

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3.0 EOS SPACECRAFT CHANGES

The major differences between the original and restructured spacecraft configuration are highlighted in Table 1.

CHARACTERISTICS	ORIGINAL CONFIGURATION	RESTRUCTURED CONFIGURATION
Number of Series/Total Number of Spacecraft	2/6	5/17
Nodal Crossing Time	EOS-A: 1:30 PM ascending EOS-B: TBD	EOS AM: 10:30 AM descending EOS PM: 1:30 PM ascending EOS CHEM, ALT, AERO: TBD
Number of Instruments per Spacecraft	EOS A: 15 EOS B: approx. 14	EOS AM: 5 EOS PM: 5 to 6 EOS AERO: 1 EOS CHEM: 4 EOS ALT : 3
Launch Vehicle	Titan IV	EOS AM, PM, CHEM: ATLAS IIAS class EOS ALT: Delta class EOS AERO: Scout class or Pegasus
Forward Link Data Rate	1 to 100 Kbps	1 to 10 Kbps
Return Link Data Rate	up to 300 Mbps	up to 150 Mbps
Spacecraft Design	Common design and modularity of subsystem components	Commonality within series

Table 1 - Original vs. Restructured Spacecraft Configuration

The original EOS spacecraft configuration consisted of two series of large platforms, EOS-A and EOS-B. Each series had a large number of instruments and three spacecraft per series, with each spacecraft having a five-year lifetime and an identical instrument complement.

The restructured EOS spacecraft configuration consists of five series of spacecraft, each with a different flight configuration based on scientific measurement objectives. Table 2 summarizes the EOS series and planned launch dates.

4.0 EOS GROUND SEGMENT UPDATE

The EOS ground segment and hence the ground operations concepts have undergone a number of changes as a result of changes to the spacecraft configuration and NASA management decisions. As stated earlier, EOSDIS has been expanded to include two new elements, the EDOS and ECOM. Consequently, mission operations concepts have been revisited in response to the restructured configuration (e.g., the increase in the number of on-orbit spacecraft).

4.1 Forward and Return Link Operations

Figure 1 on the next page provides an overview of the current EOS mission concept. EDOS and ECOM provide the interface between the EOSDIS Core System (ECS) and the spacecraft utilizing NASA institutional systems. EOS spacecraft use the Tracking and Data Relay Satellite System (TDRSS) for normal spacecraft operations and science data acquisition. The Deep Space Network (DSN), the Ground Network (GN), and the Wallops Orbital Tracking Station (WOTS) are used for contingency operations. EDOS and ECOM elements are located at White Sands, NM, Fairmont, WV, and the GSFC.

Delivery of mission critical data is the responsibility of ECOM. ECOM will transport forward link data from the EOS Operations Center (EOC) to the EDOS/White Sands facility and from EDOS to the TDRSS Ground Terminals (TGT) for uplink to the spacecraft through the TDRS. ECOM will transport the return link data from the TGTs to EDOS at White Sands, from where realtime housekeeping data will be sent to the EOSDIS control center [i.e., the EOS Operations Center (EOC)] for

U.S. EARTH OBSERVING SYSTEM (EOS)				
Spacecraft Series	No. of Spacecraft	Launches * (Tentative)	Nominal Lifetime (Years)	
			Per Spacecraft	Series
AM	3	June 1998, 2003, & 2008	5	15
PM	3	December 2000, 2005, & 2010	5	15
AERO	5	September 2000, 2003, 2006, 2009, & 2012	3	15
ALT	3	June 2002, 2007, & 2012	5	15
CHEM	3	December 2002, 2007, & 2012	5	15

* Launch dates after AM1 are for planning purposes.

Table 2 - EOS Launch Schedule

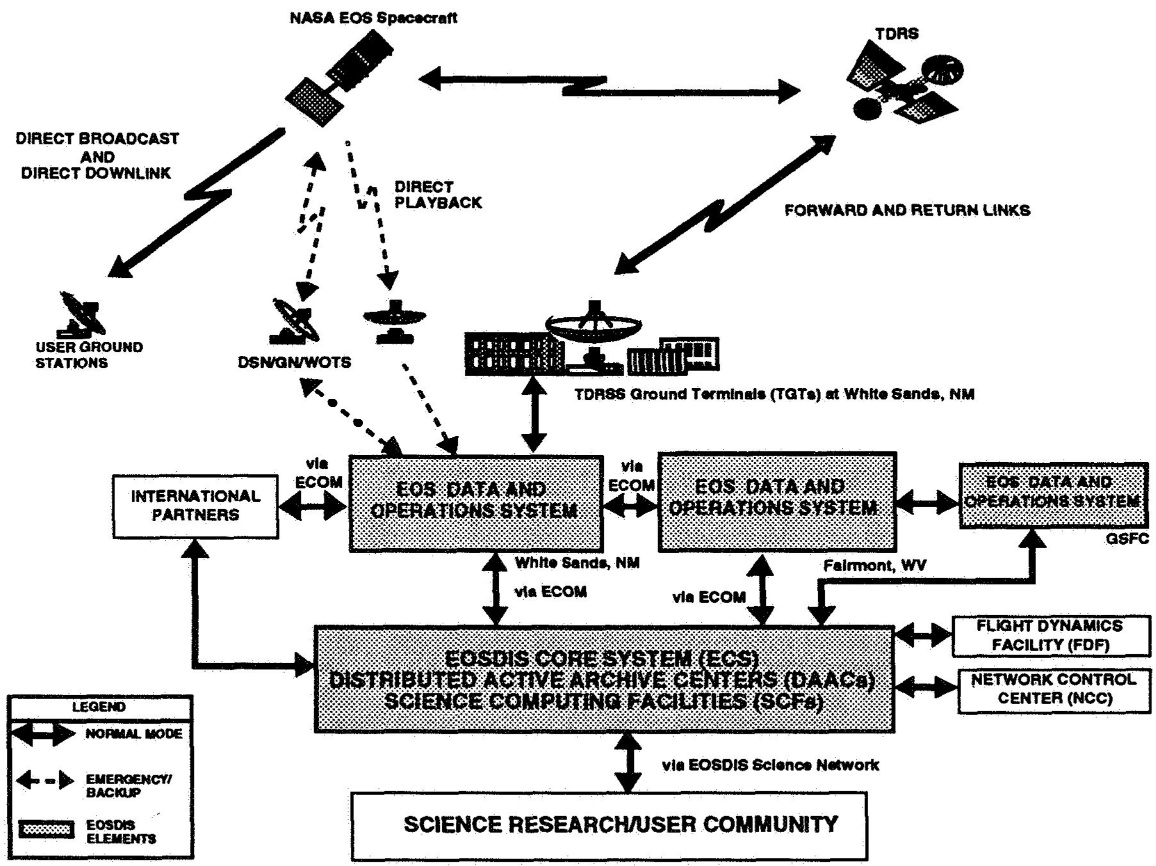

Figure 1 - EOS Mission Concept

health and safety and quicklook analysis; science data will be sent to the EDOS/Fairmont facility for Level 0 production processing. ECOM will transport production data sets to the designated EOSDIS data processing and archive centers or user facility for higher level processing.

5.0 MISSION OPERATIONS

Figure 2 on the next page compares the original operational profile to the restructured profile. During the 15 year plus operational lifetime of EOS, as many as five spacecraft will simultaneously be performing normal operations.

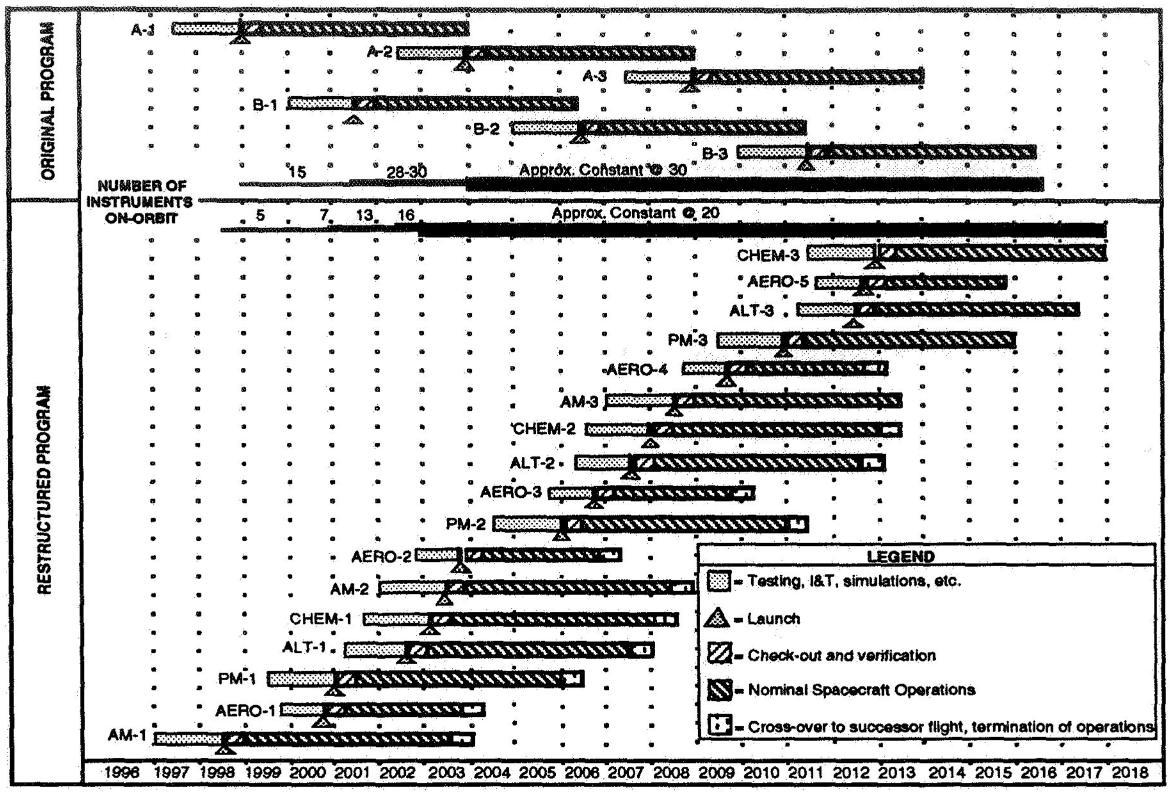

Figure 2 - EOS Operational Profile (Original vs Restructured)

During periods of cross-over operations (3 to 6 months), up to seven spacecraft (e.g., year 2003) will be on-orbit, all requiring planning and scheduling, command and control, and monitoring for health and safety and spacecraft performance. In addition, prelaunch operations (e.g., I&T, simulations, ground system compatibility, and operational readiness tests) for successor spacecraft must also be supported.

To determine the potential physical and personnel resources required to support multiple spacecraft operations, an in-depth analysis will be performed to determine the average and peak support requirements for normal and contingency operations. This analysis will consider setting priorities for scheduling mission support for the various spacecraft, specifying the additional resources required during contingency operations, and determining the requirements for reliability and maintainability of the ground system. The ground system will be "optimized" where possible to provide the necessary capabilities.

The EOC will be developed with the potential to expand and evolve as EOS progresses. The EOC will not require the capability for handling multiple spacecraft until two years after AM1 is launched. More elaborate planning and scheduling tools may be needed as coordinated operations increase among spacecraft. The EOC will be designed so that needed enhancements and capabilities can be added and tested with minimal impact to ongoing operations. The flight operations systems will also support prelaunch operations for successor spacecraft as well as ground system upgrades and maintenance.

5.1 Spacecraft Command and Control

The original EOSDIS flight operations system consisted of the EOC, Instrument Control Facilities/Instrument Control Centers (ICF/ICC), and Instrument Support Terminals (ISTs). The EOC was responsible for the spacecraft health and safety, integrated mission control, mission planning and scheduling, platform commanding, instrument command support, platform maintenance, and overall mission operations. Two ICFs were planned, each housing several ICCs. The ICCs were primarily responsible for instrument health and safety, planning and scheduling, command generation, and instrument maintenance activities. The ISTs were to be used by the Principal Investigators'/Team Leaders' (PI/TL) instrument team to support ICC operations.

The same functions remain in the revised operational concept; however, the functions have been redistributed among the elements. For example, the breakup of large platforms into many spacecraft, in conjunction with better knowledge of each instrument's operational complexity, has resulted in the elimination of the two-ICF concept and an increased role for the EOC in instrument operations support. Instrument operational complexity is judged by the amount of ground operation (i.e, planning and scheduling, command generation) required to perform the normal day-to-day instrument operations. Evaluating the current instrument manifest for all EOS spacecraft, only two to three instruments contain sufficient operational complexity to warrant development of an ICC for instrument operations. The ICCs for these instruments perform essentially the same role as that in the original ICC concept.

The operation of all simple or less complex instruments will be a coordinated effort between the EOC and an IST. The allocation of all aspects of instrument operations (e.g., planning and scheduling, command generation, health and safety and performance monitoring, etc.) will be negotiated for each instrument prior to launch. It is envisioned that instrument health and safety monitoring and command generation will be performed at the EOC with support from the IST. During periods of intensive instrument activities (i.e., instrument checkout, calibration periods, anomaly investigation, and instrument software loads), the instrument teams may take a more active role with the EOC providing support as needed.

5.2 Planning and Scheduling

Policy guidelines and the long term science plan for use of the instruments are set by the Program and Project Scientists and the EOS Investigator Working Group (IWG). The long term plan and guidelines form the basis for planning and scheduling at the EOC, ICCs, and ISTs. Since planning and scheduling for instruments that are not operationally complex will normally be minimal, the EOC will schedule daily activities for noncomplex instruments using a baseline instrument operations schedule. The baseline schedule may be periodically changed or updated by instrument teams through the IST. The daily planning and scheduling of complex instruments will be performed by the ICC in coordination with the EOC. The EOC integrates preliminary spacecraft subsystems and instrument activity schedules to determine the Space Network (SN) resource requirements. Upon completion of negotiations for SN resources with the Network Control Center (NCC), the EOC integrates detailed activity schedules for the instruments and subsystems into a spacecraft activity schedule used for command generation. Changes to the schedule may be made up to 1 hour prior to execution in response to Targets Of Opportunity (TOOs).

6.0 EOS AM1 UPDATE

As the first in the series of EOS spacecraft, EOS-AM1 is furthest along in development, with subsystem and instrument Preliminary Design Reviews (PDRs) currently in progress and an integrated spacecraft PDR scheduled for the fall of 1993.

The resource demands of other spacecraft using the SN-TDRSS will limit the amount of real time space-to-ground interaction available. Therefore, the EOS-AM1 spacecraft is being designed to require a minimum of ground control and interaction under normal spacecraft operations.

The AM1 spacecraft design incorporates Telemetry Monitoring (TMON) functions similar to those used on current spacecraft (e.g., UARS). Selected telemetry points (settable from the ground) from individual subsystem components are monitored by the spacecraft onboard computer. These points are compared to pre-established thresholds or limits, which are also settable or overridden, if necessary, via ground commands. Should an anomalous condition occur, the spacecraft will identify the likely cause and switch to a redundant path or function within the subsystem. If the anomaly continues, the spacecraft reverts to a degraded mode of operations. Subsystem housekeeping data are downlinked to allow ground-based evaluation of spacecraft performance and to identify and investigate the anomalous condition. Under certain conditions, when an anomaly jeopardizes the spacecraft life, the spacecraft will automatically place itself in a "safe mode," where only critical components are operating to maintain spacecraft viability and safety. After the anomaly has been resolved, the spacecraft can be returned to the normal operations mode via ground command.

AM1 spacecraft operations will normally be pre-planned. The AM1 spacecraft will use the S-band Single Access (SSA) link at 10 Kbps to load subsystem and instrument commands. The commands are uplinked to the spacecraft approximately 24 hours prior to execution.

Instrument activities are in general initiated via time-tagged commands stored in the spacecraft onboard computers and/or command tables loaded within an instrument microprocessor. The science data are normally recorded onboard for later transmission to the ground via the TDRSS (normally two 15-minute dumps per orbit). The AM1 instruments and their data rates are listed in Table 4.

Instrument Name	Power Consumption (w)		Data Rate (Kbps)		Science Objectives
	Average	Peak	Average	Peak	
ASTER	495	720	8300.0	89200.0	Provide high resolution images of the land surface and clouds for climatological, hydrological, biological, and geological studies.
CERES (2)	95	145	20.0	20.0	Provide continued long-term measurement of the Earth's radiation budget through observation of short and long wave radiation.
MISR	80	135	3800.0	7800.0	Provide continuous multi-angle imagery of the Earth at wavelengths of 440, 550, 670 and 860 mm.
MODIS	295	295	6200.0	11000.0	Provide measurements of biological and physical processes on a 1 km x 1 km scale with emphasis on the study of oceanic, terrestrial, and atmospheric phenomena.
MOPITT	250	250	6.0	6.0	Measure carbon monoxide and methane concentrations in the troposphere to enhance knowledge of the lower atmosphere.
Totals for AM1	1215	1545	18326.0	108026.0	

Table 4 - EOS-AM1 Instruments

The AM1 spacecraft provides an alternate source of data retrieval through an X-band Direct Access System (DAS). The DAS provides three services: the Direct Broadcast (DB) mode, which transmits data from the Moderate Resolution Imaging Spectrometer (MODIS) instrument at 15 Mbps; the Direct Downlink (DDL) mode, which transmits data from the Advanced Spaceborne Thermal Emission and Reflection Radiometer (ASTER) at 105 Mbps: and the Direct Playback (DP) mode, which transmits all data recorded on the high data rate recorder(s). The DP mode will be used as a backup mode to recover science data in case of extended or total loss of the TDRSS high rate data link (i.e., loss of the HGA or the loss or permanent curtailment of TDRSS support).

7.0 CONCLUSION

The restructured EOS mission is progressing well in all areas. EOS is a long term mission which will provide a comprehensive data base on global climate change. The first spacecraft, AM1, is in preliminary design review stage. Procurement of the EOSDIS is underway. The impacts of the restructuring on mission operations concepts have been evaluated; adjustments have been made to accommodate the restructured program. Some of the concepts are addressed in this paper. More detail can be found in Reference 5.

8.0 ACKNOWLEDGEMENTS

This paper includes relevant information on the EOS program contained in project presentations and preliminary design review material on EOS-AM1. Special thanks go to the EOSDIS flight operations development personnel headed by Steve Tompkins. Thanks also to Gregg Einfalt for his support in preparing this paper.

9.0 REFERENCES

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