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EDOS Operations Concept and Development Approach

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Abstract

The Earth Observing System (EOS) Data and Operations System (EDOS) is being developed by the National Aeronautics and Space Administration (NASA) Goddard Space Flight Center (GSFC) for the capture, level zero processing, distribution, and backup archiving of high speed telemetry data received from EOS spacecraft. All data received will conform to the Consultative Committee for Space Data Standards (CCSDS) recommendations. The major EDOS goals are to:

- Minimize EOS program costs to implement and operate EDOS
- Respond effectively to EOS growth requirements
- Maintain compatibility with existing and enhanced versions of NASA institutional systems required to support EOS spacecraft.

In order to meet these goals, the following objectives have been defined for EDOS:

- Standardize EDOS interfaces to maximize utility for future requirements
- Emphasize life-cycle cost (LCC) considerations (rather than procurement costs) in making design decisions and meeting reliability, maintainability, availability (RMA) and upgradability requirements
- Implement data-driven operations to the maximum extent possible to minimize staffing requirements and to maximize system responsiveness
- Provide a system capable of simultaneously supporting multiple spacecraft, each in different phases of their life-cycles
- Provide for technology insertion features to accommodate growth and future LCC reductions during the operations phase
- Provide a system that is sufficiently robust to accommodate incremental performance upgrades while supporting operations.

Operations concept working group meetings were facilitated to help develop the EDOS operations concept. This provided a cohesive concept that met with approval of responsible personnel from the start. This approach not only speeded up the development process by reducing review cycles, it also provided a medium for generating good ideas that were immediately molded into feasible concepts. The operations concept was then used as a basis for the EDOS specification. When it was felt that concept elements did not support detailed requirements, the facilitator process was used to resolve discrepancies or to add new concept elements to support the specification. This method provided an ongoing revisal of the operations concept and prevented large revisions at the end of the requirement analysis phase of system development.

1.0 Introduction

EDOS operations supports end-to-end data delivery for EOS spacecraft. The operations concept describes the strategic, tactical, execution and post-execution phases for EOS Ground System (EGS) elements, and describes the role of EDOS in each phase. In support of these phases, the concept describes EDOS operations in relation to current and future GSFC Mission Operations and Data System Directorate (MO&DSD) institutional systems and EOS systems. These include the Tracking and Data Relay Satellite System (TDRSS) Ground

Terminals (TGTs), the Network Control Center (NCC), EOS Communications (Ecom), as well as EOS Core System (ECS) facilities, including the EOS Operations Center (EOC), Distributed Active Archive Centers (DAACs), and other EGS elements.

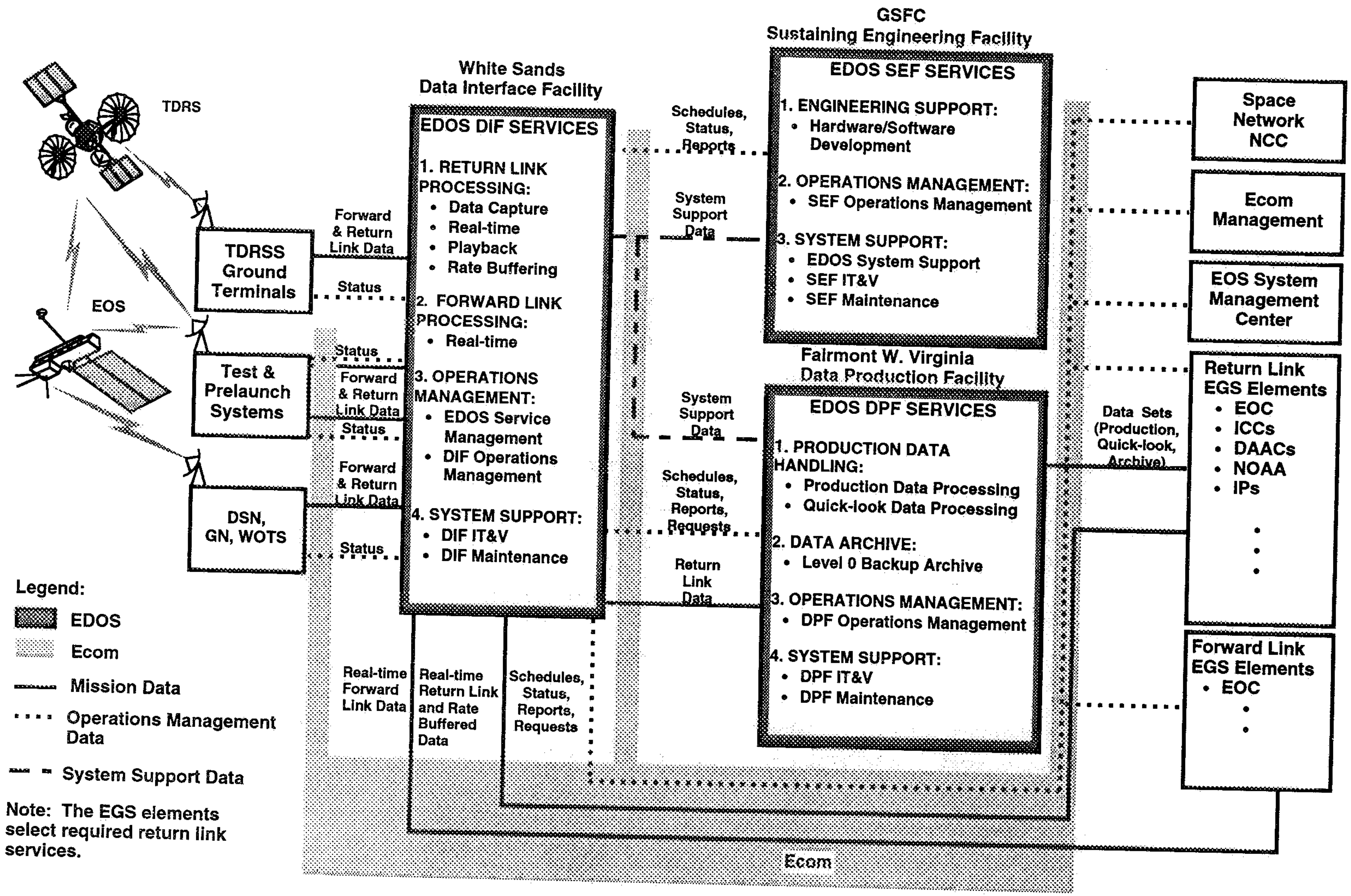
The approach used for developing an operations concept is almost as important as the concept itself. In order to be an effective concept, it must be well thought out and in agreement with the interested parties (systems engineers, interface organizations, and management). The approach must also allow change. This includes a discussion of the development of alternative concepts, and the tradeoff and other engineering analyses performed in selecting and developing the baseline operations concept. The significance of the operations concept in the development of the detailed EDOS functional and performance specification and interface requirements is described as the "proof of concept" of the development method.

2.0 EDOS Operations Concept

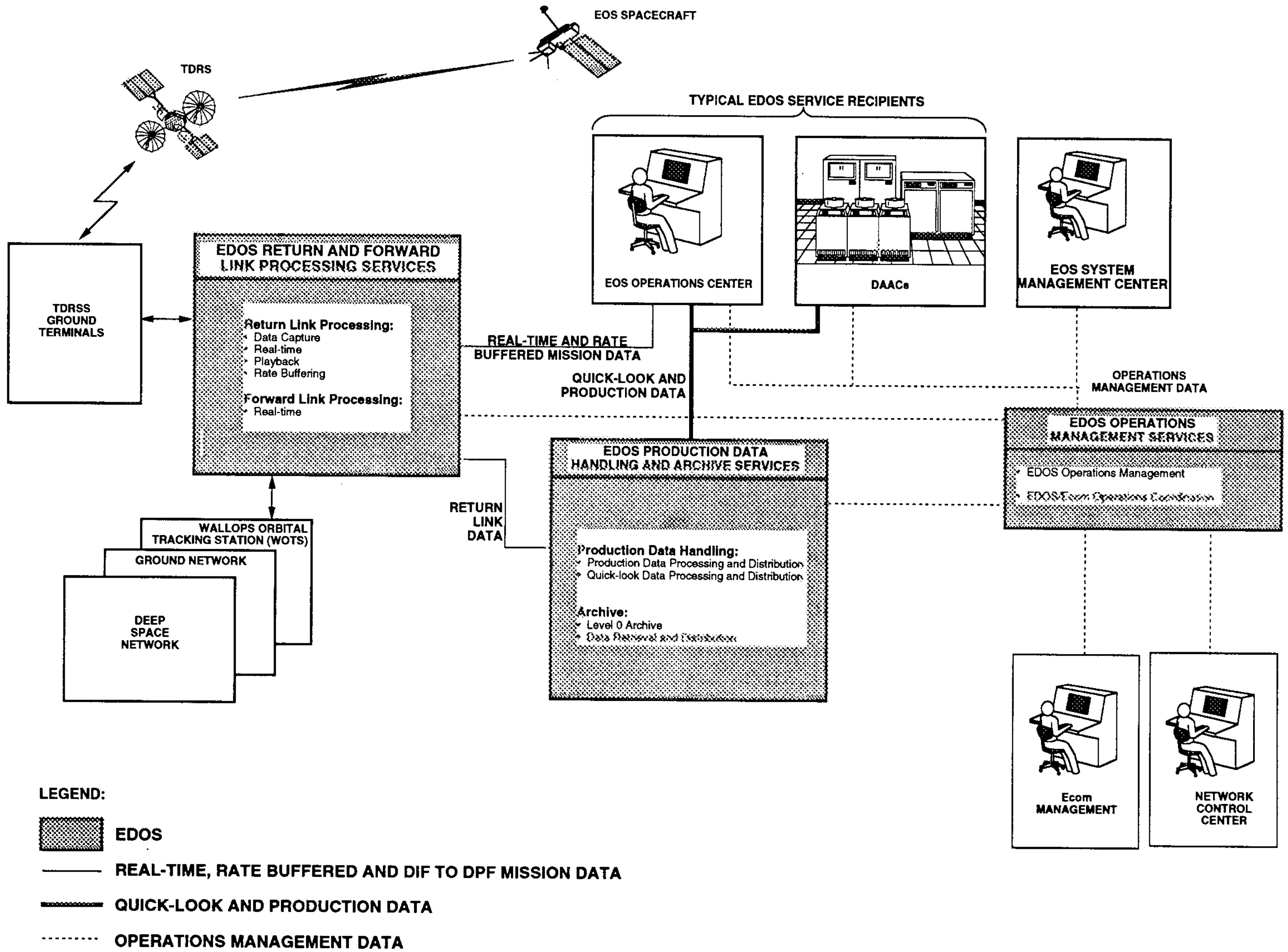
EDOS is the EOS data handling and delivery system maintained and operated by the MO&DSD. The development and implementation is being managed by the Information Processing Division (IPD), Code 560, of the MO&DSD at the GSFC. EDOS provides capabilities for handling data for EOS spacecraft that adhere to recommendations established by the CCSDS. Specifically, EDOS provides capabilities for return link data capture, data handling, data distribution, backup archival data storage, and forward link data handling. EDOS supports ground to ground data communications for data delivery using a set of approved protocols. Reliance of EDOS on these space/ground and ground to ground standards facilitates mission interoperability and will result in lower life-cycle costs for NASA. EDOS supports all levels of MO&DSD and EOS end-to-end testing in preparation for EOS spacecraft launch readiness, by utilizing the operational system without interrupting on-going operations. Data delivery is provided by the SN, EDOS, and Ecom. SN provides space/ground data communications. The SN consists of the Tracking and Data Relay Satellite (TDRS) constellation, the TGTs, and the NCC. The TGTs include the White Sands Ground Terminal (WSGT) and the Second TDRSS Ground Terminal (STGT). Space/ground data communications for emergency operations are provided by the Ground Network (GN), Wallops Orbital Tracking Station (WOTS), and the Deep Space Network (DSN). Ecom includes the wide area network and the Ecom Management capability, which provide ground to ground data communications support for the SN, EDOS, and EGS elements. EGS elements include the EOS Operations Center (EOC), the Distributed Active Archive Centers (DAACs), or other associated data handling facilities, such as the National Oceanic and Atmospheric Administration (NOAA).

There are three EDOS facilities. The Data Interface Facility (DIF) is located at the White Sands Complex (WSC) near Las Cruces, New Mexico. The Data Production Facility (DPF) is located in Fairmont, West Virginia. The Sustaining Engineering Facility (SEF) is located in the Data Operations Facility (DOF), Building 28 at GSFC in Greenbelt, Maryland.

The capabilities that EDOS provides are grouped into categories of services. These services are allocated to the three EDOS facilities. EDOS services include the data delivery services outlined in the previous section and the services that support EDOS operations. The service categories are designated as return link processing, forward link processing, operations management, production data handling, data archive, system support, and engineering support. The DIF provides return and forward link processing services. The DIF also provides operations management services for DIF processing services and for the centralized EDOS operations management. The DPF provides production data handling, data archive, and DPF operations management services. Return link services are provided according to mission-specific requirements. The SEF provides sustaining engineering services, the EDOS system support coordination services and operations monitoring. System support services are provided at



EDOS Services and Interfaces



Representative EDOS Services

each of the three facilities to support the operations at the respective facility.

2.1 Return and Forward Link Processing Operations

The DIF return and forward link processing services provide for the receipt, capture, processing, and transfer of digital data that conform to applicable CCSDS communication services recommendations. EDOS acts as an interface between the EGS and the SN. Return link processing removes communications artifacts and provides computer ready data sets to the EGS. Telecommand link and physical layer services are provided for forward link data received via Ecom from the EOC and delivered to the EOS spacecraft via the TDRSS. Data capture is provided for return link data received from spacecraft via the TDRSS. Return link services include real-time and rate buffered Path and VCDU services. Return link data can be delivered to any appropriate EGS destination. All data handling services, return and forward link, include data quality assurance and accounting.

The DIF processing services are highly automated data-driven services using management information provided by the DIF operations management service. The management information represents service requirements for data processing and defines the parameters the DIF will use to process and deliver data. The DIF incorporates built-in test capabilities in support of on-line operations.

The DIF provides the following capabilities for the processing and delivery of mission data:

Data Capture. All return link data, including fill data, are captured and stored for 30 days after receipt by EDOS for use in recovery processing.

Return Link Real-time Processing. Real-time processing receives and processes all return link data, and delivers CCSDS Service Data Units (SDUs) (e.g., Virtual Channel Data Units (VCDUs), CCSDS packets) to EGS elements with minimized processing delay through EDOS, as required.

Playback Processing. Playback processing restores "as recorded order" to spacecraft tape recorded data received by the frame synchronization function in reverse order. Playback data received in forward order are processed and stored as received. Transfer of playback data commences after the completion of the TDRSS Service Session (TSS).

Rate Buffering. Rate buffering is the process in which data from an EOS spacecraft, transmitted to the ground during a TSS, are completely received by EDOS at one data rate and transmitted to destinations at negotiated reduced data rates.

Forward Link Real-time Processing. The DIF provides the capability to process forward link data in support of CCSDS Telecommand services.

2.2 Production Data Processing Operations

The DPF provides production data handling services for return link mission data received from the DIF. Production data handling services annotate and remove, when possible, communications artifacts and data anomalies due to spacecraft operations. These services include production data processing and quick-look data processing.

Production Data Processing. Production data processing of return link CCSDS packet data is the process in which packets from one or more TSSs are sorted by applications process identifier (APID), forward ordered by packet sequence count and time, and quality-checked. A production data set (PDS) consists of production data processed packets, quality and accounting summary information. Production data sets have redundant and previously processed packets deleted, and may be delimited by time interval, number of packets, number of octets of data, or TSS boundary.

Quick-look Data Processing. Quick-look data processing is similar to production data processing except redundant packets are not removed and the content of a quick-look data set (QDS) is limited to either all packets received for a single APID during one TSS or all packets in one TSS in which the quick-look flag is set in the packet secondary header. Quick-look data processing may be performed on up to five percent of return link data received over a 24-hour period. Quick-look data processing demands in excess of five percent will be detected and the EOS System Management Center (SMC) will be notified about possible degradation in EDOS support. The packets contained in a QDS are included in production data processing. Specific operational requirements for quick-look data processing will be contained in the Operations Agreement (OA) document between the EGS element and EDOS.

2.3 Data Archive Operations

The DPF data archive service provides a long-term storage capability as a Level 0 data backup to the DAACs. The PDSs created by EDOS are stored for the life of EOS plus 3 years. Retrieval of archived data is expected to occur infrequently. Retrieved PDSs together with quality and accounting information are delivered to the requesting DAAC as Archive Data Sets (ADSs). The data archive service can recover from lost or damaged PDSs by receiving and storing DAAC to EDOS Data Sets (DEDSs) from a DAAC.

2.4 Operations Management

EDOS operations management services provide the management capability for all EDOS resources and services. These services provide highly automated system monitoring and control capabilities and manage the operation of EDOS services.

The DIF and DPF operations management (OM) capabilities monitor and control the systems that implement the services of the respective facility. These management capabilities receive, consolidate, and analyze system performance data as well as respond to service requests received by the EDOS service management (SM) capability. The DIF and DPF OM capabilities transfer service status information to the EDOS SM capability for service reporting.

2.5 System Support Operations

System support services are provided at all three EDOS facilities. These services include the capabilities for integration, test, and verification (IT&V), fault isolation support, and maintenance support for the processing services at each facility.

The EDOS IT&V capability provides tools to support EDOS and external testing. Maintenance support capabilities at each facility provide tools for managing the maintenance of systems at the respective facility. The EDOS IT&V and maintenance activities are coordinated by the system support service at the SEF.

2.6 Sustaining Engineering Operations

The EDOS sustaining engineering capability provides an environment for the development of system enhancements, trouble-shooting and hardware and software updates to the operational system. The environment supports tracking of the operational system performance and maintenance history, and the development and evaluation of system changes and the evaluation of new technologies and requirements.

3.0 Operations Scenarios

The EDOS operations concept includes several operations scenarios to clarify system and interface functional interactions. A typical scenario describes real-time return link operations during a TSS.

3.1 Real-time Return Link Data Processing Scenario

a. TGT transfers Channel Access Data Units (CADUs) from each TDRSS service channel to the designated DIF TGT ports. Data capture recognizes data are present and starts storing CADUs, including fill CADUs. (The following steps apply to each TDRSS service channel)

b. VCDU service. The return link processing (RLP) service frame synchronizer recognizes CADU frame sync pattern, performing bit inversion and CADU reversal as required. The frame sync is stripped off, status data is collected and sent to the DIF OM, and the VCDU is passed to the Reed Solomon (R-S) decoder. The R-S decoder decodes the applicable portion of the VCDU (header and/or entire VCDU),and strips off the R-S code. The RLP deletes fill VCDUs, generates an EDOS Service Header (ESH), collects status data for the ESH and sends status data to the DIF OM. Time and date of CADU receipt by the DIF is added to the ESH and the ESH is appended to the VCDU, creating a VCDU EDOS Data Unit (EDU). Services for the VCDU are determined in the RLP by checking the service requirements for the VCDU-ID [spacecraft ID (SCID) and virtual channel ID (VCID) located in the VCDU header]. Command Link Control Words (CLCWs) are extracted from VCDUs and transferred in real-time with the source VCDU ESH to the EOC. VCDU EDUs not requiring Path service are stored. VCDU EDUs requiring real-time service are transferred to the requesting EGS elements. VCDU EDUs requiring Path service are sent to the Path service processor.

c. Path service. VCDU EDUs are disassembled: packets are extracted and reassembled. Packet fragments with headers are filled out with fill data. The source VCDU ESH is retained, packet quality and accounting data are added to the ESH and the ESH is appended to each related packet, creating packet EDUs. Packet EDUs are then stored. Packet EDUs requiring real-time service are concurrently transferred to the requesting EGS elements.

d. VCDU EDUs and packet EDUs requiring TSS post-operations services are stored in a manner that facilitates rapid access, in order to start transferring multiple EDU files to destinations within 5 minutes. Stored files are identified for the type and priority of post-TSS processing needed: quick-look data processing, playback processing, rate buffering, and production data processing).

e. The DIF OM collects service processing status data from each of the DIF processing services during processing activities. During a TSS, the EDOS SM collects these data from the DIF OM and also Ecom's service status data, compiles the data into a customer operations data accounting (CODA) Report, and sends the report to the EOC, nominally every 5 seconds, during the TSS. SN performance messages are received from the NCC and used at the DIF along with other status data and SN schedule data by the operators for fault isolation. The DIF OM also does quantitative and quality determination for DIF operators and for TSS summary reporting. The EDOS SM also receives TGT performance data via the NCC. The EDOS SM operator compares TGT performance parameters with the RLP status data for fault isolation.

4.0 Operations Concept Development Approach

Traditionally, the responsibility for drafting an operations concept for a new system lies with one or two knowledgeable people who have had some experience in the past with such documentation and who have participated in high level requirements meetings and discussions with the system project personnel. The concept is drafted and distributed for review. After several draft revisions, the concept eventually gets honed into an acceptable product. At best this method is a compromise of ideas (concept features) of how the system should operate. At worst, the concept may be lacking in support of key requirements. This could be caused by reviewers misinterpreting the concept or the writers misinterpreting the reviewers' intentions in their comments. There is more chance for this to happen if a new system is different or more complex than existing systems. Reviewers may not be persistent enough in their reviews to ensure compliance with their change requests. The traditional method was initially tried in developing the EDOS operations concept. After several unsuccessful attempts to satisfy reviewers, a facilitator approach to the development was tried.

The EDOS Project formed an operations concept working group (OCWG) consisting of EDOS systems engineering team (SET) members. The OCWG was composed of government and contractor project support personnel who had participated in Phase B studies and were responsible for the requirements analyses for EDOS. The OCWG met regularly and representatives of systems with EDOS interfaces were invited to participate in the concept discussions. Each member was allowed to express his or her ideas and critique the other members' ideas. Members shared facilitating of the meetings. This avoided over dependence of any one person and also avoided the "leader" instinct of some of the members. It also increased the homogeneity of the meetings. Agendas were followed at each meeting. A member was delegated to write the minutes (including concepts developed). These minutes were reviewed in detail at the next meeting prior to proceeding with new business/concepts. This gave the members an opportunity to correct or improve the concept as recorded and reach further agreement. An important feature of this method is that a consensus was reached among the responsible project personnel before a draft document was started. This meant that the critical part of the concept development was basically finished before documentation began. Another feature was that each member's technical knowledge and familiarity with the system requirements were enhanced during the process. This was important during the next phase of system development which was the requirement analyses for the EDOS specification. During this phase, the operations concept was used to understand what requirements were needed for the specification. If the concept was found lacking, the facilitator method was used to develop new or improved concept features. Since this method had been used previously and by the same personnel, it was easy to re-institute the process.