Risk Reduction Methodologies and Technologies for the Earth Observing System (EOS) Operations Center (EOC)

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ABSTRACT

This paper will discuss proposed Flight Operations methodologies and technologies for the Earth Observing System (EOS) Operations Center (EOC), to reduce risks associated with the operation of complex multi-instrument spacecraft in a multi-spacecraft environment. The EOC goals are to obtain 100% science data capture and maintain 100% spacecraft health, for each EOS spacecraft. Operations risks to the spacecraft and data loss due to operator command error, mission degradation due to mis-identification of an anomalous trend in component performance or mis-management of resources, and total mission loss due to improper subsystem configuration or mis-identification of an anomalous condition. This paper discusses automation of routine Flight Operations Team (FOT) responsibilities, Expert systems for real-time non-nominal condition decision support, and Telemetry analysis systems for in-depth playback data analysis and trending.

INTRODUCTION

The Flight Operations Segment (FOS) of the EOS Core System (ECS) is currently in early stages of the design process. The Preliminary Design Review (PDR) is scheduled for December 1994, and the concepts discussed in this paper will be refined as we progress with the development cycle.

The FOS will provide the command and control system for EOS instruments and spacecraft. The EOC will be located at NASA Goddard Space Flight Center (GSFC) to generate commands to the instruments and spacecraft of NASA within the International Earth Observing System (IEOS) as well as monitoring the health and performance of these flight elements.

International partners flying instruments on NASA EOS spacecraft will be able to provide these functions for their instrument from their own center. Principal Investigators (PIs) and facility instrument teams will participate in monitoring their instruments and in resolving instrument anomalies from their home institutions through use of an Instrument Support Terminal (IST) Toolkit, a special set of software that will be run on a local computer workstation.

AM-1 will be the first mission to be supported by the EOC FOT, it is scheduled for a June 1998 launch. Other missions currently scheduled to be supported from the EOC include: AERO-1 (9/00); PM-1 (12/00); ALT-1 (6/02); CHEM-1 (12/02), AM-2 (6/03); AERO-2 (9/03); PM-1 (12/05); AERO-3 (9/06); ALT-2 (6/07); CHEM-2 (12/07); AM-3 (6/08); AERO-4 (9/09); PM-3 (12/10); ALT-3 (6/12); AERO-5 (9/12); and

CHEM-3 (12/12). At full capacity the EOC FOT will be required to support up to 7 missions (five on-orbit, one in pre-launch stage, and one mission in a "decommissioning" stage).

Systems will be in place well before the launch of the first EOS satellite to provide the full functionality required to support it. The command and control functions will be brought on-line and fully tested with simulated EOS data in operational scenarios.

After the EOS missions are on-orbit and providing high volumes of data, the EOC will continue to evolve and add capabilities in response to new requirements and lessons learned through its use. This evolution will be in the form of planned EOC upgrades. Continued prototyping will occur, and development of EOC will be actively sought. This continuing evolution will enable the EOC to incorporate advances in data system technologies, as well as adapt to changing user requirements.

The FOT shall provide mission operations support with technical directives from the NASA Mission Operations Manager (MOM) and the EOS Project Scientist. Coordinated mission planning, scheduling, and commanding operations shall be performed by the FOT in accordance with the MOM's policy guidelines and directives. Instrument science planning and scheduling operations, including conflict resolution, shall be performed under the general high level direction and guidance of the Project Scientist. The FOT shall perform operations necessary at the EOC to ensure that the ECS FOS achieves the functional and performance requirement of the ECS specification. These functions include the following services: operation planning and scheduling; command management; commanding; telemetry processing; observatory and instrument monitoring and analysis; data management; element management; and user interface services.

With increased complexity of space and ground systems, and interactive science operations there will be an increase in the level of complexity of onboard resources and constraint management. Current tools for assessing the state of the system require that FOT members mentally convert alphanumeric data into a mental model and reason about the model. Automated logic checking is performed at the parameter level, leaving subsytem and system level assessment as a human task. Because of this FOT effectiveness is an issue that promises to grow in the future.

The ECS FOS will supply tools that reduce FOT sensory requirements. This will be accomplished through the development of automated routine FOT responsibilities. A Decision Support System, and the EOC Telemetry Analysis system will be the main tools used to automate these responsibilities. The goal of these systems is to aid in complex parameter checking, and system level reasoning checks for the FOT. These tools will also support real-time resource and constraint management. In the EOC these tools must effectively manage multiple payload sets in a dynamic resource allocation environment.

Automation of expected versus actual state analysis process will greatly aid the FOT. FOT productivity gains will also be achieved by visualization tools for assessing system status. These visualization tools will support graphical representations of system level data with the capability of rapidly expanding the displayed information down to the parameter level. The promise of improved visualization techniques is that the FOT will be able to monitor systems by exception, rather than through surveillance. Each of these methods has the promise of improving FOT efficiencies and reducing mission critical risks.

AUTOMATION OF ROUTINE FOT RESPONSIBILITIES

In traditional control centers significant labor is expended for routine operations, such as monitoring subsystem displays, and supporting poorly engineered interfaces for the negotiation of external services (e.g., communications, flight dynamics). An ECS FOS goal is to automate and standardize these interfaces. This will result in increased operational efficiency, lower system life-cycle costs, and reduced operational risk.

The FOT will depend heavily on the accuracy and quality of spacecraft manufacturer and FOS documentation and information. Deficiencies in either spacecraft or FOS documentation or ground system test results will increase the level of mission risk, reduced mission effectiveness, and result in higher life-cycle costs. These deficiencies will lessen the FOTs ability to provide accurate responses to anomalies.

The amount of information required for operating a spacecraft is staggering. In a traditional control center this data is stored on paper in an ad hoc manner. This information is usually not organized in a way that allows quick access by the FOT for real time operations. Frequently this data is not kept on paper at all, but is retained in the minds of experienced FOT members.

We have proposed an extensive on-line technical information database for the missions controlled from the EOC. This system would allow for rapid information access through keywords, such as: subsystem name, and telemetry or command mnemonics. The information stored within this database will be integrated to the system level. The database will also serve as a repository of system specification, drawings, simulation and test data, historical data, operations procedures, and contingency plans.

Traditional control center operations involve a large number of alphanumeric displays monitored routinely by subsystem specialists with relatively little automatic checking of data, except for simple limit checks. The EOC operations concepts for FOT real-time monitoring calls for most monitoring to be performed by exception when specified rules are violated, when telemetry does not match predictive models, or when telemetry behavior is similar to previously known anomalous patterns.

The EOC telemetry displays will be at a system level, integrating pictures and hierarchical diagrams of spacecraft subsystems with detailed presentation of subsystem data. Both "idiot lights" and dense information displays will be provided and further integrated with analytic tools that provide data exploration capabilities.

With the insertion of more powerful

workstations and operating systems, complex analytic tasks will be performed in real time on a non interfering basis. This will result in lessening the traditional distinction between on-line and off-line systems. As an example, upon the detection of a major system event or anomaly, the FOS software might formulate a list of information relevant to the problem at hand and automatically provide pop-up windows displaying and organizing this information along with appropriate recommendations.

EOC DECISION SUPPORT SYSTEM (DSS)

The EOC FOT will utilize the proposed DSS to provide long-term analysis support and reduce mission critical risk factors.

The EOC DSS should encapsulate knowledge from previous missions. Spacecraft knowledge is often lost from mission to mission. In the life of a single long duration mission key operations knowledge may be lost due to personnel attrition. The EOC DSS is envisioned to disseminate this knowledge across the missions supported by the EOC.

The FOS DSS will have the following characteristics:

a. Access to comprehensive detailed spacecraft and operations knowledge to provide a systems perspective.
b. A library of extensive tools that are readily adaptable to a number of problem-solving activities.
c. A robust pattern-matching capability for matching experience to new problems.

The DSS will provide the following functions:

a. Support in-depth spacecraft and ground system long-term analysis. This will use the DSS integrated knowledge base subsystem in a graphical nature.
b. Assist in identifying and resolving space and ground system problems in a proactive manner.
c. Assist in developing plans for correcting current and future problems through consistent application of domain knowledge.

EOC TELEMETRY ANALYSIS SYSTEM

An often neglected, but important aspect of risk reduction in FOT activities is off-line analysis. In traditional control centers this is principally supported through relatively primitive trending and data analysis tools. These primarily include paper listings of trend data that are analyzed by subsystem engineers to determine potential degradation of components.

Careful and continuous analyses of data can improve the lifetime of a spacecraft and reduce risks associated with catastrophic failures. The ECS FOS software will contain on-line and off-line support capabilities' tools that provide rapid analysis of real-time and post-pass spacecraft behavior, and more direct user management of spacecraft activities.

Heritage and lessons learned from NASA, and NOAA missions will be utilized in developing the EOC Telemetry Analysis System. Specifically these missions include Landsat, EP/EUVE, GOES, and HST.

The EOC Telemetry Analysis System,

includes increased use of workstation-oriented interactive data analysis and visualization tools to support both spacecraft and subsystem analysis. It will scan for anomaly signatures derived from component histories. For example, changes in battery charge/discharge ratios provide early warnings of battery failures. Such signatures would be stored in an operations knowledge base and used to predict component failures.

Proposed specifics of the EOC Telemetry Analysis System include:

a. Support of automatic searches for interesting data and couplings: Such as, problems caused by couplings between attitude and power/thermal subsystems. Unusual iterations would be automatically detected and presented for further analysis in our proposed system.

b. Comparison to recent trends and manufacturer's specifications: Sudden changes in trends or specification would be immediately presented for more detail analyses.

c. Graphical presentation of knowledge in discipline-relevant formats: This includes the presentation of analyses in understandable formats, overlaid on spacecraft diagrams or in multi-dimensional presentation that facilitate data understanding and exploration.

CONCLUSIONS

The EOS FOT will benefit by having the proposed FOS architecture and tools. These benefits include: improved system performance since FOS is more responsive to user needs; reduced risk of spacecraft and/or data loss; lowered operations costs; reduced time and cost of supporting new missions by enhancing the design of the existing ECS FOS software; reduced operator training time and providing for retention of experienced operations personnel knowledge; increased job satisfaction among FOT personnel by automating performance of routine actions; provide for the capability to insert new technologies/products into EOC faster; and provide a more transparent, less obstructive interface between science users and the instrument and science data they use.

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