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Mission Control Center Enhancement Opportunities in the 1990s

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ABSTRACT

The purpose of this paper is to present a framework for understanding the major enhancement opportunities for Air Force Mission Control Centers/Test Support Centers (MCCs/TSCs) in the 1990s. Much of this paper is based on the findings of Study 232 and work currently underway in Study 2-6 for the Air Force Systems Command, Space Systems Division, Network Program Office. In this paper, we will address MCC/TSC enhancement needs primarily from the operator perspective, in terms of the increased capabilities required to improve space operations task performance.

INTRODUCTION

Study 232, "Enhancing MCC Operations Using Automation and Expert Systems Technology," was commissioned as a first step in defining the next generation of enhancements required to support MCC operations activities. Advances in technology (especially in the areas of telemetry servers, workstations, displays, graphical user interfaces, databases, hypermedia, and expert systems) provide many new opportunities for building systems and capabilities that can greatly enhance the ability of operations personnel to accomplish their assigned space operations tasks and activities.

The following sections address major operations functions and activities; current difficulties, limitations, and challenges; MCC enhancement opportunities; architecture constraints; and a framework for an Integrated Space Operations Support Environment (ISOSE).

MAJOR OPERATIONS FUNCTIONS AND ACTIVITIES

Time-, resource-, and experience-intensive tasks span the full spectrum of MCC operations functions and activities from: 1) requirements analysis, 2) to planning, 3) to scheduling, 4) to contact support, 5) to post-pass analysis (see Figure 1).

1. **Requirements analysis** involves consolidating program needs from the System Program Office, mission needs of various users, and vehicle needs from operations handbooks and directives as well as technical analyst inputs.

2. **Planning** involves translation of mission needs into planned mission activities, vehicle activity planning to translate consolidated needs into vehicle activities, and contact support plan generation to define what specific actions will be accomplished during each vehicle contact.

3. **Scheduling** involves identifying and requesting the resources necessary to accomplish MCC activities. Three levels of resources are involved. Internal MCC scheduling deals with the resources under direct control of the MCC. Personnel scheduling ensures that adequate personnel are available to accomplish scheduled operations activities. Air Force Satellite Control Network (AFSCN) scheduling deals with obtaining needed common user resources including communication links and remote tracking stations.

4. **Contact** activities include execution of contact support plans, tracking, commanding, telemetry monitoring, status monitoring, real-time telemetry analysis, contingency identification, and contingency plan execution. These occur in real time while the ground system is in contact with the space vehicle.

5. **Analysis** activities include state assessment, review of contact activities, telemetry analysis and trending, orbit analysis and determination, attitude determination, anomaly identification, anomaly analysis, and anomaly resolution. These activities are typically performed off-line.

BASIC NATURE OF OPERATIONS

MCC operations functions and activities are performed around-the-clock by military crews, primarily at Falcon Air Force Base (AFB). TSC operations activities are performed around-the-clock by contractor operations teams, primarily at Onizuka AFB. The major difference between the two is the Research and Development (R&D) emphasis and the accompanying greater need for engineering support for programs operated from the TSC. Both MCCs and TSCs require use of common communications and tracking station equipment that are a part of the AFSCN to contact and track their assigned vehicles.

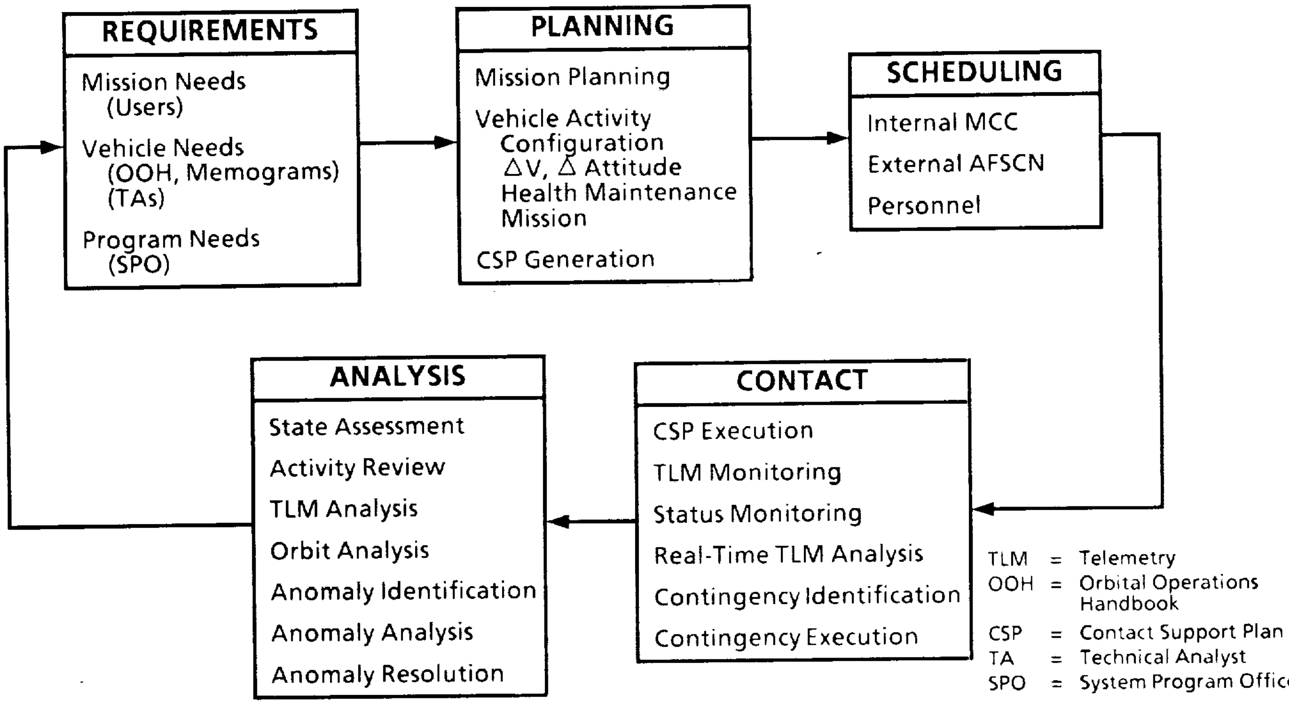

Figure 1. Major Operations Functions/Activities

NEED FOR IMPROVED CAPABILITIES

Extensive interactions with AFSCN MCC and TSC operational personnel during the conduct of Study 232 led to the identification of several categories of possible enhancements to the capabilities of the existing system. Explicit needs have been documented and appear in Reference 2. These capabilities would allow the operators to accomplish their typical tasks more quickly and/or allow operators to be more effective with less training than is currently required. Many of these capabilities started appearing on systems designed in the late 1980s. Specific examples of such capabilities include:

- Ability to use general-purpose utility and analysis software on mission data without having to re-enter data or use totally off-line processing.
- Ability to make changes in selected database parameters quickly and easily, without requiring any software code recompilation.
- Ability to do speed data entry and enhance the automated checking and user prompts to ease use for the operator and minimize data entry errors.
- Ability to provide context-sensitive help, activity support aids, and decision support aids.
- Ability to do historical and trend analysis.
- Ability to customize displays readily and add graphical elements, as appropriate, to support changing operational needs effectively.

MCC ENHANCEMENT OPPORTUNITIES

Overcoming the difficulties, limitations, and challenges identified through discussions with operational personnel is the primary source for MCC enhancement opportunities. Basic automation of time-intensive processes and activities is a crucial first step. This needs to be followed with tools and capabilities that allow operators to accomplish their operations tasks more effectively, with less training, and with personnel that have lower technical skill levels.

On-line documentation, enhanced telemetry server capabilities, improved display and user interface capabilities, activity support aids, and decision support aids are the key elements needed to provide MCC operations improvements. Figure 2 maps these elements to the operations functions and activities previously discussed.

Requirements analysis can be enhanced by providing on-line access to needs documentation and decision support aids that assist in needs prioritization.

Planning can be enhanced by providing on-line access to technical data and procedure information, activity support aids that help in translating needs into corresponding vehicle activity and in building Contact Support Plans (CSPs), and support aids that facilitate mission decisions and selection and ordering of specific vehicle activities.

Scheduling activities can be enhanced by providing displays of schedule information,

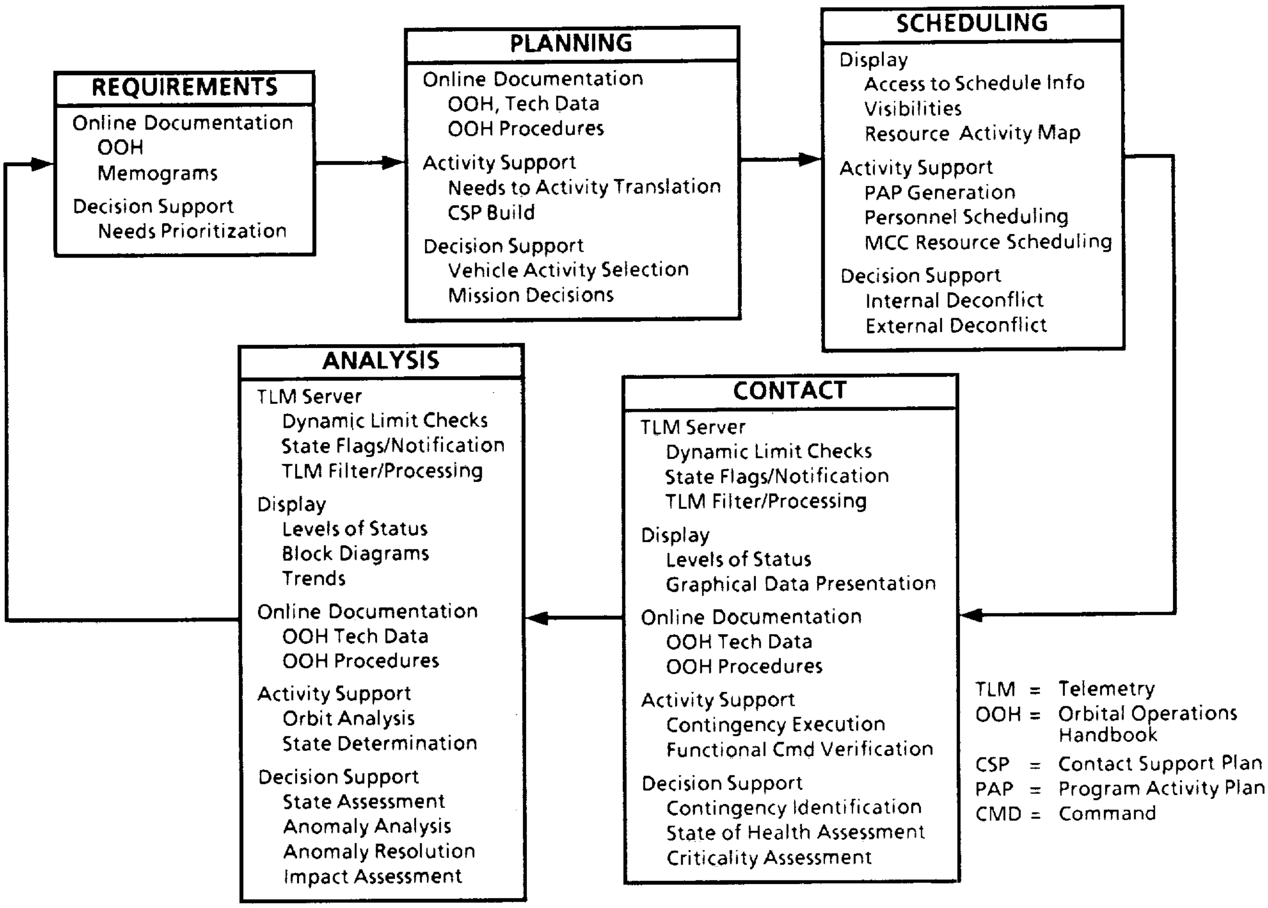

Figure 2. MCC Enhancement Opportunities

satellite/Remote Tracking Station (RTS) visibilities, and resource activity maps; activity support aids that assist in Program Activity Plan (PAP) generation, personnel scheduling, and MCC resource scheduling; and decision support aids that assist with both internal and external resource deconfliction.

Contact activities can be enhanced by providing additional telemetry server functions that provide better limit checking, pattern recognition, and filter/processing capabilities; displays that provide hierarchical levels of status and more graphical presentation of data and procedure information; activity support aids that assist in contingency execution and functional command validation; and decision support aids that assist with contingency identification, state of health assessment, and criticality assessment.

Analysis activities can be enhanced using the same telemetry server, display, and on-line documentation enhancements identified for contact activities, and by providing activity support aids that assist with orbital and attitude analysis and determination; and providing decision support aids that assist with maneuver planning, state assessment, impact assessment, anomaly analysis, and anomaly resolution.

APPLICABLE TECHNOLOGY AREAS

The technology areas applicable to enhancing MCC operations include:

Hypermedia for providing on-line access to space vehicle technical information and procedures.

Telemetry Servers for providing improved telemetry processing and monitoring capabilities.

Advanced Workstations for providing environments for running enhanced support applications.

Databases and Database Management for providing flexible storage and retrieval of a variety of information types.

Expert Systems for providing decision support capabilities.

Human-Computer Interfaces for providing improved display and interface capabilities.

Support Functions for providing basic capabilities such as word processing, spreadsheets, briefing packages, personal information management, and graphics; as well as more sophisticated analysis tools and training aids such as simulators.

OPERATIONS CONCEPT ISSUES AND ENHANCEMENT DRIVERS

Specific operations tasks vary widely from MCC to MCC, and even from one program to another within the same MCC. The criticality of the need for a particular enhancement is highly dependent on the specific nature, complexity, and difficulty of the planning, monitoring, assessment, and analysis activities supported by the enhancement.

Information overload is rapidly becoming unmanageable. Increasing complexity of space vehicles and increased raw telemetry rates are forcing MCCs to deal with more complex problems in smarter ways. Operators need aids that present information to them in a context that conveys meaning quickly and effectively. Raw telemetry must be converted into meaningful vehicle information that supports the analysis and decision processes.

ARCHITECTURE CONSTRAINTS

Current MCC Architecture

The current MCC architecture was designed in the late 1970s. Its chief features include a closed architecture with alphanumeric workstations tied to planning and evaluation and contact support mainframes. Processing is heavily centralized and display capabilities are limited (see Figure 3).

Transitional Architecture

There are efforts underway to open the architecture (see Figure 4). Improved telemetry and command "front end" processing will free the main processors from some Central Processing Unit (CPU)-intensive functions. The addition of industry standard, high-speed Local Area Networks (LANs) further opens the architecture to decentralization of processing. New, high performance workstations enable critical operations enhancements and superior display capabilities and user interfaces. This also frees the main processors from time-intensive display processing.

Opening the architecture and distributing some of the processing now performed by the main processors must not be done in an ad hoc nor haphazard way. What is required is the evolutionary development of an *integrated space operations support environment.*

INTEGRATED SPACE OPERATIONS SUPPORT ENVIRONMENT (ISOSE)

The major components of the ISOSE are the Environment Manager, Support Functions, Enhanced Display Capabilities, Hypermedia and On-line Documentation Capabilities, Enhanced Database Capabilities, Enhanced Telemetry Front-ends, and CCS Interfaces (reference Figure 5).

Environment Manager

The Environment Manager should provide an integrated environment for virtually seamless control and access to all applications that are a part of the ISOSE. The Human Machine Interface should be primarily graphical with heavy use of windows, menus, and icons--in an environment that supports an object-oriented, user-tailorable, multiple window desktop metaphor. The environment should allow the user to run multiple applications concurrently and provide an easy means for communication between applications.

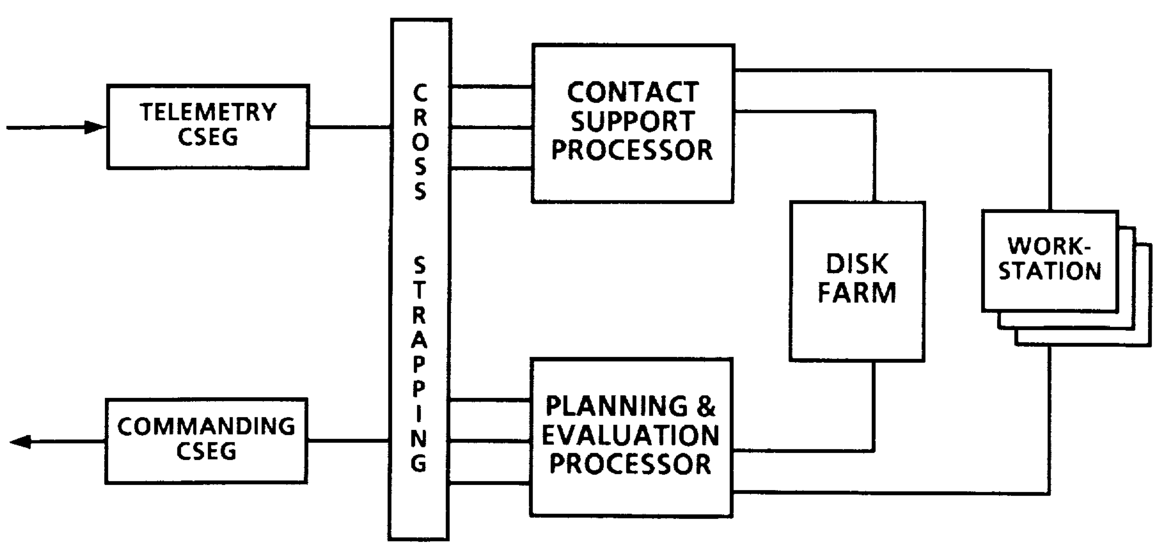

Figure 3. Baseline CCS System Architecture

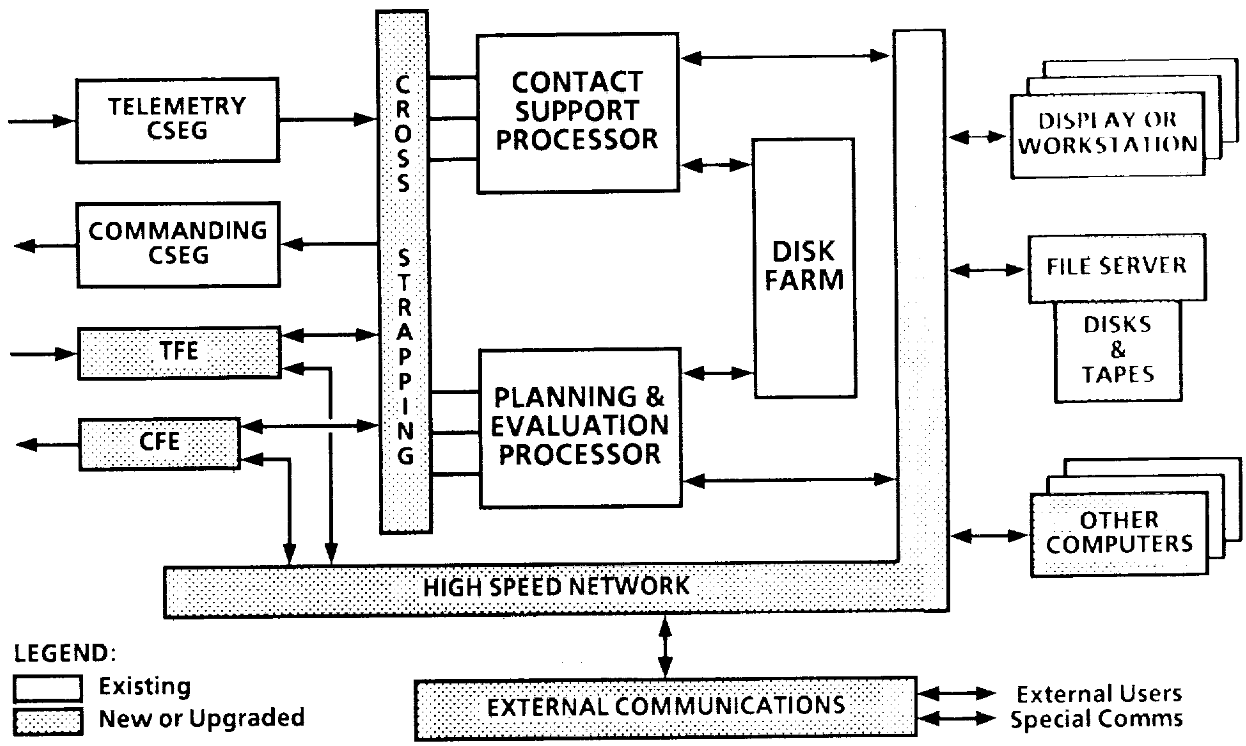

Figure 4. Transitional CCS System Architecture (5 Year Goal)

<u>Support Functions</u>

The major categories of support functions are: 1) Help, 2) General Aids, 3) Readiness Tools, 4) Analysis Tools, 5) Activity Support Aids, 6) and Decision Support Aids.

1. **Help:** Context-sensitive help should be available at all times. This help should be activated and presented in a manner that is consistent throughout all functions and activities supported by the ISOSE.

2. **General Aids:** General aids include an environment/applications/file manager, word processor, spreadsheet, briefing package, general information manager, form generator, and an object-oriented database access capability. These aids should work together in an integrated manner that supports the performance of operations tasks. Additional off-the-shelf software is anticipated, as the capabilities delivered by commercial vendors increase.

3. **Readiness Tools:** These include various training, development, and test tools such as simulators, probes, and database development aids that can assist operators in performing readiness activities.

4. **Analysis Aids:** These include tools that support trending, mathematical analysis, and engineering modeling. These should be easy to use and tailor. Technical analysts should be able to enter their own models without having to write computer code.

5. **Activity Support Aids:**

   a. **Activity Translation Support:** aid to assist operators in translating mission and vehicle needs into the specific vehicle activities necessary to meet those needs.

   b. **Contact Support Plan (CSP) Generation:** aid to automate the generation of specific CSPs that implement desired vehicle activities.

   c. **Program Activity Plan (PAP) Generation:** aid to automate the process involved in generating PAPs. Currently, extensive manual activity is required to transform data through a variety of MCC-specific forms to produce the inputs required for the PAP. This could be greatly simplified by having the forms generated automatically from user inputs, and by having data transcribed from one form to another automatically by the system.

   d. **Personnel Scheduling:** tool to support scheduling of MCC personnel. This task is currently done manually. MCCs typically operate around-the-clock, 365 days per year. This requires scheduling four to five crews under a variety of constraints that vary significantly depending on the nature of operations activities to be supported.

   e. **MCC Resource Scheduling:** tool to support scheduling of MCC resources. Most MCCs have a variety of equipment that can be used

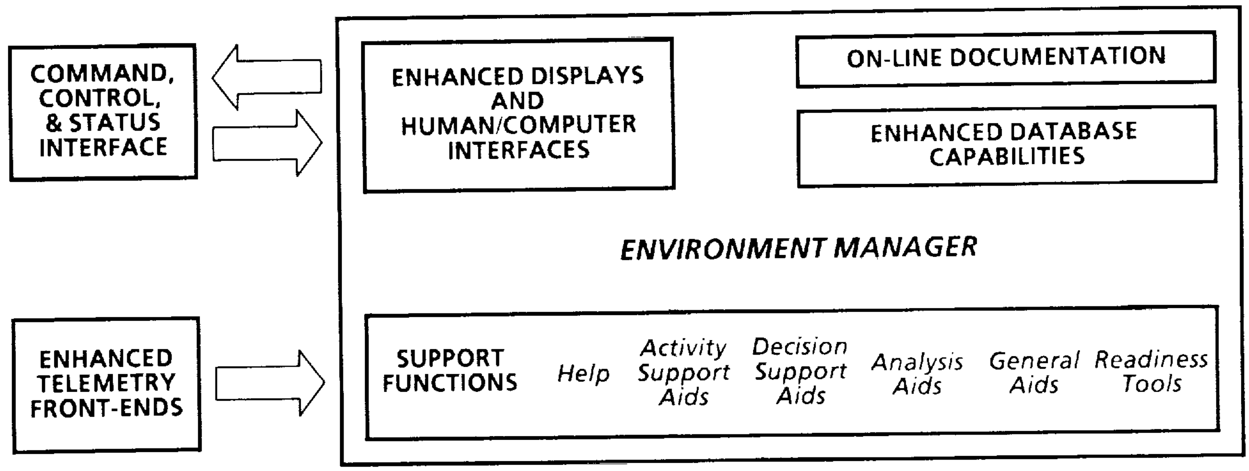

Figure 5. Integrated Space Operations Support Environment

to support multiple programs or crews. In addition, there may be complex dependencies between various modes of simultaneous use and the loading or performance of a particular resource. These common internal MCC resources need to be scheduled and allocated appropriately to the missions and contacts that need them. This task is currently performed manually.

f. **Contingency Plan Execution:** aid to assist and guide operators in the execution of contingency plans, especially for complex contingency plans. The aid should step the operator through the plan, informing the operator of the specific actions he is expected to perform and providing appropriate guidance and recommendations.

g. **Functional Command Verification:** aid to assist operators in monitoring telemetry and identifying functional command verification. This aid should operate synchronously with the CSP being executed.

h. **Orbit Analysis:** specific orbit/attitude analysis improvement needs are being addressed in detail by projects currently underway. Once these projects are completed, an assessment should be made as to whether any additional support is needed for orbit analysis activities.

i. **Status Determination:** aid to assist operators in quickly determining the status and configuration of the ground system and of space vehicle subsystems. Various levels of abstraction should be supported in a manner that allows the operator to navigate easily through the levels to get to the area of interest at the moment. Notifications should be provided to inform operators of specified conditions.

6. **Decision Support Aids:** Decision support aids may be implemented in a variety of ways. In most cases, it is enough to provide an aid that guides the operator through the decision process in a way that facilitates making correct operations decisions. In some cases, the decisions may be straightforward enough that the system can recommend the specific solution and provide a rationale for that choice. The following types of decision support aids are needed:

a. **Needs Prioritization:** aid to assist operators in prioritizing the various mission, health and status, and vehicle needs imposed on them.

b. **Vehicle Activity Selection:** aid to assist operators in selecting particular vehicle activities that can meet various needs, objectives, and operations constraints.

c. **Mission Optimization:** aid to assist operators in optimizing mission performance given a current or expected condition, a set of applicable constraints, and a time limit for coming up with an acceptable solution.

d. **Internal Schedule Deconfliction:** aid to assist operators in removing conflicts from the internal MCC schedule. These conflicts typically require shifting planned activities, rescheduling, and reallocating resources. The deconfliction aid should assist operators in finding acceptable solutions that can be achieved without drastic changes to current planned activities.

e. **External Schedule Deconfliction:** aid to assist operators in removing conflicts from the external AFSCN schedule. These conflicts typically require shifting planned activities, rescheduling, and reallocating resources. The deconfliction aid should assist operators in finding acceptable solutions that can be achieved without drastic changes to current planned activities.

f. **Contingency Identification:** aid to assist operators in categorizing the current operations situation and identifying the appropriate contingency that applies. Typically, the operator needs to deduce something about the nature of the problem before a contingency procedure can be selected. This deduction is not always obvious from the telemetry indications.

g. **State of Health Assessment:** aid to assist operators in assessing the state of health of the systems for which they are responsible. This aid should automatically monitor appropriate telemetry parameters and notify the operator of any anomalous indications and what they may mean. This aid should permit the creation of hierarchies of notification that assist the operator in identifying and paying attention to what is most critical at the current time.

h. **Criticality Assessment:** aid to assist operators in assessing the criticality of an anomalous situation. It should help operators to decide what operations options are most appropriate (fix, diagnose, collect data, mitigate impacts, wait, call experts).

i. **Impact Assessment:** aid to assist operators in assessing the impacts of a current situation or planned course of action. It should help to identify what risks are involved as well as what benefits and degradations should be expected.

j. **Anomaly Analysis:** aid to help operators through the analysis process for various anomalies. It is expected that these aids need to be tailored to the diagnosis and analysis processes required for specific kinds or categories of anomalies or for specific kinds of vehicle subsystems.

k. **Anomaly Resolution:** aid to help operators through the anomaly resolution process. These should work in conjunction with aids that support the anomaly analysis process. It is expected that these aids need to be tailored to the resolution processes required for specific kinds or categories of anomalies or for specific kinds of vehicle subsystems.

Enhanced Display Capabilities

Enhanced display capabilities include user tailorable telemetry displays, graphics capabilities, and standard window and menu capabilities. These capabilities should allow the operators to generate custom displays that include text, graphics, and user interaction.

Hypermedia and On-line Documentation Capabilities

Hypermedia provides a means for electronically capturing and accessing text, graphics, video, and sound in a flexible and intuitive manner. It permits very fast and flexible access to the captured data. Some of the operations data that should be accessible electronically includes:

Space Vehicle Technical Data:
- Orbital Operations Handbooks
- Memograms
- Other Technical Data

Interactive Information:
- Procedures
- Contingency Plans
- Generic Contact Support Plans

Enhanced Database Capabilities

Database capabilities provide the means for storing and retrieving a variety of kinds of information. As a minimum, the ISOSE should provide flexible capabilities for operators and applications to generate, modify, and access data from the following:

Telemetry Databases:
- Telemetry format database per program
- Telemetry history database per vehicle
- Telemetry constraints and checks per vehicle

Command Databases:
- Command format database per program
- Command history database per vehicle
- Command sequence constraints and checks per vehicle

Activity Database:
- Contact support plans per contact
- Activity log data per contact
- Special limit checking and notification data
- Special activity and decision support aid definitions

Display Database:
- Operator telemetry display definitions
- Help display definitions
- Activity support display definitions
- Decision support display definitions

Enhanced Telemetry Front-Ends

Enhanced telemetry front-end capabilities should provide dynamic, user-tailorable limit checking, state flags and notifications, telemetry filtering and processing, pattern detection, and dynamic user-selectable monitoring and display of telemetry parameters.

Command, Control, and Status Interface (C/C/S)

The ISOSE will have to use current C/C/S links, or their equivalents, to get control directives out to AFSCN communications and RTS equipment; to get commands out to the RTSs for transmission to the space vehicle; and to observe status information from various AFSCN resources.

CONCLUSIONS

There is an overwhelming need for a variety of MCC/TSC enhancements in the 1990s. Basic automation of time-intensive manual processes is a crucial first step. This needs to be followed with tools and capabilities that allow operators to accomplish their operations tasks much more effectively.

The technology areas most applicable to developing needed MCC/TSC enhancements include hypermedia, telemetry servers, advanced workstations, database and database management, expert systems, human-computer interfaces, and a variety of support functions.

The Integrated Space Operations Support Environment provides a conceptual architecture that addresses key enhancement requirements. The major components of this enhanced operations environment are an environment manager; enhanced display capabilities; hypermedia and on-line documentation capabilities; enhanced database capabilities; enhanced telemetry front-ends; enhanced C/C/S interfaces; and a variety of support functions integrated into the environment. These support functions include help, general aids, readiness tools, analysis aids, activity support aids, and decision support aids.

Most of the MCC/TSC enhancements identified are well within the state of current technology. The challenge is to apply these technologies to specific space operations improvement needs in a manner that results in low-risk, cost-effective, new capabilities that can be integrated into the AFSCN Command and Control System Architecture.

REFERENCES

1. Bannister, J. A., Frazier, Jr., E. R., and Lee, C. A., The Aerospace Corporation, "Guidelines for the Evolution of the CCS Architecture," Contract F04701-88-C-0089, Aerospace Report No. TOR-0091 (6489-05)-1, Revision 1, El Segundo, California, 4 April 1991.

2. Golden, M., Hartman, W., Monosoff, S., and McDaid, P., Loral Space & Range Systems, "Enhancing Mission Control Center Operations Using Automation and Expert Systems Technology," Contract F04690-86-C-001, CDRL 023A2, Loral Report No. CUE-TR-90-135, Sunnyvale, California, 31 January 1991, (Study 232 Report).

SOAR
Wed, May 22, 1991

The Real Time Data System (RTDS) project of the Mission Operations Directorate (MOD) of NASA's Johnson Space Center has been developing real-time expert systems to support flight critical decision-making in the Mission Control Center for the past four years. These expert systems provide deterministic and heuristic analysis of Space Shuttle telemetry data and provide the results to flight controller operators at consoles in Mission Control. The primary purpose of these expert systems is fault diagnosis, isolation and recovery. The primary goal of these expert systems is to increase the quality of flight decision making.

The initial goal of the RTDS project was to demonstrate the viability of expert systems and advanced automation in a real operations environment. As a technology demonstration project, RTDS has been a clear success for NASA and an indicator that expert systems can and should play an important role in critical operations such as manned space flight. After four years of use as operator assistant tools, these applications are now being transferred to operational status and are becoming main-line items critical to mission success. With the RTDS project, NASA has demonstrated the ability to transfer leading edge technologies from a laboratory environment and place them on line in a mission critical environment at a reasonable cost.