A MOS FOR ALL SEASONS

Larry Bryant

California Institute of Technology / Jet Propulsion Laboratory
Pasadena, California

ABSTRACT

From a systems perspective, this paper examines the challenges of a single system to support multiple Jet Propulsion Laboratory (JPL) space exploration missions and the need for unitary responsibility for the system. The focus is a Mission Operations System (MOS), which is effectively a mission management organization with direct authority over data system operations, command sequencing, flight operations control, data management, trajectory determination, telemetry and data acquisition, and spacecraft analysis. Stratagems for training and the approach to processes, procedures, and interfaces to facilitate the transition from the present situation to a truly multimission operational environment are developed.

The outcome is a paradigm for a MOS that is achievable, that can effectively support multiple projects, and that can take advantage of technological changes without perturbing the entire system.

Key Words: Mission Operations System, operations, customer focus

1. INTRODUCTION

In lean economic times, government expenditures receive close scrutiny. Certainly space programs where the benefit is not always intuitively obvious are subject to as close a look as any expense. One such project currently affected by cutbacks is Magellan, which is being terminated even though the spacecraft itself remains capable of operations for an extended period of time. This paper addresses one means by which a key factor in the Magellan demise may be mitigated for future projects, examines the Mission Operations System (MOS) for flight projects to see where change may be appropriate, and suggests a model for that potential change.

2. WHY CHANGE

It is clear from NASA's call for smaller, better, **CHEAPER** missions to explore space that costs are a major consideration in Jet Propulsion Laboratory (JPL) flight projects. The MOS is one prominent cost source that can be focused on for reduction. This is primarily due to the growth potential for these costs as we build better spacecraft that can and often must achieve longer missions. Magellan is a timely case in point. The projected costs of continuing the mission exceed the cost that can be justified by the anticipated return over the life of the spacecraft itself. Thus, endeavoring to reduce operational costs is an important aim in the continuation of space exploration. A contributing factor to the continuing accumulation of costs is the tendency of our interplanetary probes to substantially exceed their planned lifetimes. However, beyond the longevity of spacecraft, we find there are other significant operational cost drivers that can result in a relatively young mission, like Magellan, being phased out before the spacecraft is inoperable.

3. A SEASONAL MOS

An examination of the typical approach in establishing the MOS (or Ground System [GS], in Cassini's nomenclature) for a JPL flight project provides an insight into another cause of the significant growth of MOS costs. The MOS has traditionally been designed as a custom system to support a single project. The rationale for such an approach lies in the perception of the uniqueness of each project and its requirements for support. Further, we have only to look at the Voyager, Magellan, Ulysses, TOPEX, and Galileo projects to see that this approach has been successful in terms of mission performance. Each of these projects had or has a complete cadre of project-dedicated operational teams and support systems. Even though Magellan moved forward with the initial delivery of a multimission ground data system (MGDS), its version of the MGDS software is unique and incompatible with the software versions of the other projects that are making the transition to the newer system. Even JPL's newest major project, Cassini, while using institutional or multimission resources that are available, still maintains a project-unique organizational structure for its ground system. It is time to look closer at this approach to determine the factors that spawn substantial costs, especially in comparison to the return they provide.

3.1 Let's Reinvent the Wheel

In the effort to design a MOS to support a specific project, there is a significant duplication of previous efforts and costs, that is, a real tendency to reinvent the wheel. The basic reason for the duplication is that there does not exist any single organization at JPL to take the lead and develop standards for operational processes, procedures, and interfaces that can be used directly or adapted for successive missions. An example within JPL is the matrix organization with expertise in MOS design, space flight operations, navigation, etc. spread among the technical divisions and then drawn upon and managed by each project as the project perceives the need. Even the Mission Operations System Office (MOSO), whose name sounds as if they might have a global operational role, has limited responsibilities in the areas of ground system development, mission control, and data management, to develop narrowly defined multimission capabilities. Consequently, projects like Cassini, rather than taking advantage of a standard operations approach through an established organization, continue to duplicate earlier efforts by designing their own MOS and expending the resources for boards to review the designs and the delivery schedules for project software, procedures, plans, etc. Another drawback to the current approach, which a single organization would mitigate, is the potential for under utilization of valuable resources.

3.2 Effective Personnel Utilization

Establishing project-dedicated teams, especially for nearly identical functions, can significantly under utilize a critical resource at JPL, namely, our people. The basis for this assertion is in the nature of mission operations that are continual but not continuous functions that must be executed in the conduct of operations. This means that during a normal workshift, a certain amount of dead time can exist between real-time supports, while a software routine is running, or while data is being recorded for later analysis. This time could be used for support of other projects or tasks, assuming the person is properly qualified and trained. A classic example, and one in which some progress is being made, is mission control. It is not too hard to conceive of having a single individual to monitor a data playback for one project and a non-commanding tracking pass for a second project, either serially or in parallel, rather than having a dedicated controller for each project, as is currently the norm. The potential for unnecessary waste of an important resource clearly exists with our existing approach to mission operations systems.

4. CUSTOMER FOCUS

A single MOS would, in theory, have definite advantages, but we must assess how such a global approach would work in reality and how the development and transition should be approached to be certain of its ultimate success. To define what the role of a single MOS should be, we must deal with a fundamental issue not often dealt with directly at JPL. This issue is what Dr. Stone refers to as "Customer Focus" (Ref. 1). Who are the customers, what do they really need, and what is the right way to give them the right product the first time? In mission operations, we have customers who are both external and internal to JPL. Flight projects have external customers who are scientists and other users of the data from the instruments we send into space. Internally, the flight projects themselves are customers who expect a set of properly functioning instruments to be delivered to a specific locus in space, the instruments to be operated successfully, and the data from those instruments to be returned to Earth and accessible to the intended users. By focusing on what these customers want, we can identify an approach to mission operations that will in the long run be better and more cost-effective than our present system, that is, we can be "doing the right thing right" (Ref. 1).

4.1 The Customer's Real Requirements

The return of scientific data is the essential driver for mission operations. The ultimate goal of mission operations is to ensure that the data collected from space is provided error-free to the user; that is what the customer really wants.

Timeliness, correct format, time correlation, etc., are additional requirements that support the primary goal and that facilitate the use of the data. To satisfy its customer, a project places requirements on its own operations system. While projects have traditionally identified detailed requirements, like 24-hour tracking coverage during the first 30 days of flight or a complete checkout of every combination of ground system configurations, these are not the real requirements. Such requirements prevent the MOS from looking at options that may better satisfy the project's real requirements. Take the instance in which checkout and configuration of the spacecraft is accomplished within a matter of days, and the injection is so accurate that the first planned maneuver would be superfluous. The real requirements for getting the spacecraft safely into space and on the proper trajectory have been satisfied, and a real need for continued 24-hour coverage is questionable. It is apparent that the traditional project requirements on a MOS are not the truly essential requirements.

4.2 Pointing to a Single MOS

When requirements are couched in terms of functional performance, a different way of viewing how we put a MOS together begins to emerge. Rather than the project deciding that dedicated teams with specific staffing levels are required to support the traditional requirements, the project can focus on its needs in the context of functional performance and levy the responsibility for working the details on the MOS. Following this through, for a system to have the capacity, knowledge, capabilities, and skills to best conduct mission operations at JPL, it must access the experience and talent base of JPL across all operational disciplines. To do less would invite implementation of a less than optimal operational process for a project. For example, if the interplanetary navigation experience at JPL were ignored, a tremendous cost would be incurred to redevelop adequate algorithms to process tracking data and accurately determine a spacecraft trajectory. Thus, utilizing all disciplines is crucial and points to establishing a singularly managed MOS for all projects.

4.3 Moving Towards Cost Effectiveness

By melding the operational disciplines into a single entity responsible for delivering individual customer needs in terms of functional performance, a more effective and efficient MOS can be achieved than is apparent in our current situation, in which several project MOSs compete for the best talent and resources. The reason is clear: sharing resources and talent provides each project access to the best concepts and an equitable share of support targeted at satisfying actual performance requirements. If, for instance, the planning and scheduling of tracking and commanding support is an integrated activity, then the supports can be distributed into a sequence of events that meets performance requirements and spreads the necessary workload around the clock. Unitary management of a MOS to support all projects leads to more effective and efficient operations and brings us to the point of addressing what the role and structure of the MOS should be.

5. A MOS FOR ALL SEASONS

The necessity of accessing a broad spectrum of talent and skills within JPL implies a broad role for the MOS to integrate mission operations across the range of JPL projects more efficiently and effectively. This role would appropriately cover all aspects of operations from the pre-launch tests and launch operations through the entire mission until delivery of all the captured data to the science community. Such a broad scope of coverage provides operational continuity during the entire opportunity for significant contact and interaction with the spacecraft under operational or quasi-operational conditions. Responsibilities of the MOS would encompass managing the delivery of ground data system capabilities that can support each mission and that provide an integrated capability so as not to adversely affect the ability or cost for the MOS to support all projects. The planning of operations and spacecraft sequencing in response to mission plans and endeavoring to reduce interference or conflicts between support requirements and distribute the workload to make staffing management easier is also within the purview of the MOS. Resource scheduling for both flight projects and external requirements would be a MOS task to provide a single clearinghouse that can make decisions to resolve potential conflicts. The direction and implementation of all aspects of operations, including operating the ground system, commanding the spacecraft, trajectory determination and prediction, telemetry processing, spacecraft health and status analysis, data archiving and distribution, with associated support processes, are clearly within the charter of this MOS.

Additionally, development of standard processes and procedures as well as operational interfaces to simplify and facilitate the capability of supporting all projects effectively, and the dissemination of these good operational practices through formal training are significant elements of the MOS role. This latter aspect of standardization and training is particularly important in achieving cost effectiveness across all projects and can be seen to be quite practical once one looks at what the functional performance requirements are for operations versus the current approach for specifying MOS requirements. Embracing such a broad scope for the MOS role is needed to ensure the efficiency and effectiveness of the MOS to satisfy the real operational requirements—that of safely delivering a set of instruments to space and returning the scientific data they collect in a usable form to the science community.

5.1 Looks Like . . .

The selected structure (see Figure 1) of the MOS must complement the breadth of its role. This implies an organizational level on a par with that of flight projects to facilitate communication and a cooperative effort to best achieve the primary goal of each project. To further facilitate effective cooperation and equitable treatment, a dedicated project mission manager is an invaluable member of the MOS staff. Other elements of a single MOS would parallel those of existing MOSs except that they would all be responsible for the full range of JPL flight projects. Some of these elements are either in place or being implemented in the areas of mission control, data system operations, and telemetry and data acquisition operations. Others, like data management and navigation, have the capability already and merely require the formal organizational realignment to achieve full multimission capability within a single element. The design and generation of command sequences would be handled by a single element, although there would surely be some pockets of expertise for any essential project-unique applications. Still, the basic concepts, especially as processes are standardized, are similar, if not identical, which makes support of distinct projects a practical matter. A planning and integration element is vital to the unified MOS. The need to distribute supports and coordinate and integrate activities to apportion workload and resource utilization equitably is fundamental and can only be achieved through a single element with the responsibility and authority to develop operational plans and to allocate resources accordingly. Perhaps the most challenging domain for consolidation is the analysis of spacecraft health and status and contingency responses. This would, in fact, involve spacecraft dedicated effort during critical events. A team of spacecraft subsystem experts would be routinely involved in daily health and status, event verification, and command planning and review activities. Each individual would have received vehicle-specific training in more than one of our spacecraft to provide for backup during high activity and coverage during absences. Additionally, during and immediately following launch and until the spacecraft is safely configured and characterized, personnel with an in-depth knowledge of the spacecraft gained during development, test, and launch preparation activities would supplement the primary analysis element. Additional expertise would also be identified for support during selected critical activities as identified by a project's mission manager. The concept for this organizational structure is intended to ensure that each project's actual requirements can and are met in a safe and timely manner while utilizing available workpower and other resources effectively and efficiently. An essential element to achieve this efficiency is a structured training and certification effort that promulgates the standardization and implementation of good operational practices as well as addresses those areas of knowledge and capabilities that are really project-unique. The result of this organizational approach is a MOS that can satisfy the functional performance requirements of existing JPL projects and make the necessary adjustments or growth to do the same for future projects.

5.2 Not a Yellow Brick Road

To get to such a MOS organization is not an overnight task. It will require extensive planning and even cultural changes. Just as it is not an overnight task, neither is it a perpetual task. The approach is straightforward and doable if the commitment is forthcoming. The initial effort involves establishing a core organization with operational, project, and training expertise to lay the foundation. This foundation involves establishing standard approaches to operations, chronicling good operational practices, drafting interface control documents, and developing positional and scenario operational training. Once this foundation is developed and codified, the next

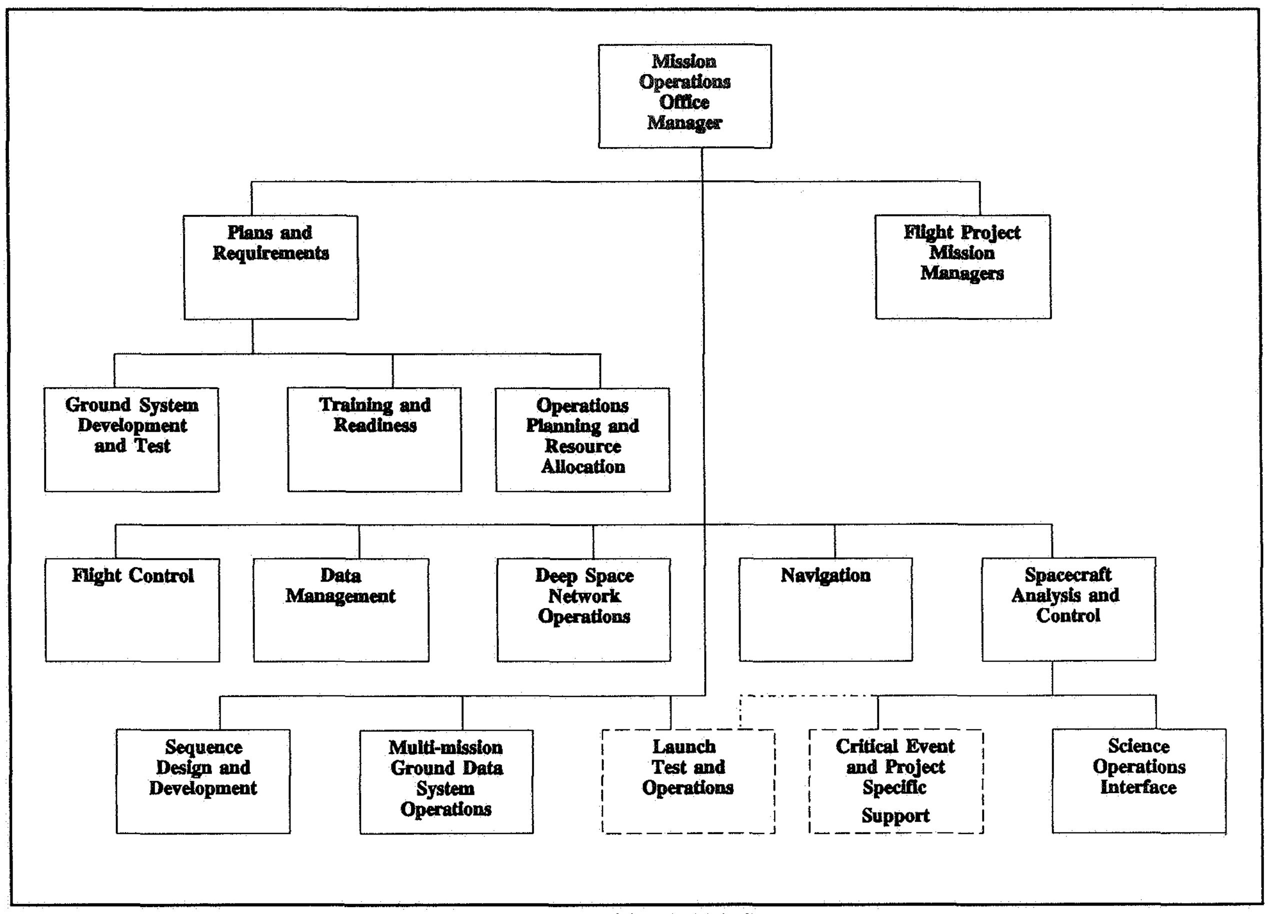

Figure 1 - Candidate MOS Structure

phase, the implementation of the training programs, begins. This activity prepares the existing project-dedicated teams to merge personnel and expand their scope of responsibilities. When this phase has been accomplished, the staffing can be adjusted to match the operational workload. Finally, the process is established for incorporation of new projects. This process includes development of training, delivery of the training, implementation of operations, and adjustment of staffing.

Another point needs to be made regarding the MOS and the implementation of standard processes, procedures, and interfaces. One might logically assume that taking such an approach and controlling these items could lead to stagnation within the MOS with respect to new techniques and technology. Such is not the case. In fact, such an approach actually facilitates change and improvement. First, through the control process, proposed changes and modifications are assessed as to their benefit and cost to the MOS as a whole. Then, because interfaces are controlled, it is possible to implement a new technique within a subsystem or element or to apply a technological advance, such as tools utilizing expert systems, without disrupting the entire system. To the rest of the system, with proper interface control, a changed element or subsystem need not look any different. Improvements can be made and even interfaces changed if there is a proper cost-benefit ratio. The crucial factors are that the change is controlled and documented and that the effects of the change are incorporated into the operational training whenever appropriate.

5.3 A Cornerstone

Because effective training is fundamental to the success of the implementation of a single MOS, it is appropriate to consider the training approach to be implemented. The approach would be systematic and based upon the operational jobs to be performed. It would differ from other approaches to technical training in that the emphasis is on how the system functions (Ref. 2) and the cognitive involvement of operations personnel as opposed to a structured set of tasks typically associated with technical training. In developing the training for the cognitive involvement, our operational training would also rely upon network analyses of operational and system experts' models (Ref. 3) of the spacecraft, the ground systems, and the operational processes. The results of these analyses would be used to structure both the positional and scenario training for operations with the content based on the job performance requirements. The training process also involves validation through MOS-level rehearsals and readiness testing as well as updating to improve effectiveness and incorporate new projects. By using this systematic approach, the training element can in fact effectively provide the foundation upon which to build a MOS for all seasons.

6. OPINION

With the need to hold the line on budgets, operations costs are a valid arena to examine, as demonstrated by the Magellan project. By addressing the real performance requirements, it is possible to identify a MOS structure that can be effective without being dedicated exclusively to a single flight project. The role of a single MOS would necessarily span all of operations, from pre-launch through mission operations to project termination. To be effective, the MOS would be a distinct organization with authority to make and implement the decisions that are the organization's responsibility. The foundation for such an organization is assured in the development of standard processes, procedures, and interfaces and, of utmost importance, in a formal training process to propagate these standards and good operational practices. It would also prepare the system for new projects as they develop. With the application of the necessary effort, JPL can achieve a single MOS management structure that draws from the matrix organization to support all flight projects cost effectively and to stand the projects in good stead whatever the season.

7. ACKNOWLEDGMENT

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