

# MULTI-MISSION GROUND DATA SYSTEMS: BREAKTHROUGHS AND CHALLENGES

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## ABSTRACT

Given the cost-constrained nature of JPL Flight Projects, especially Discovery Class missions, there is more and more pressure to reduce the costs associated with mission operations, particularly the costs for the Ground Data System. This paper explores the successes (and failures) of using the Mission Management Office (MMO) GDS team to provide a common set of services, tools, procedures, and products to JPL Flight Projects.

MMO provides a number of multi-project services to JPL Flight Projects, among them are Guidance and Navigation Control, Mission Planning and Sequencing, Ground Data System, Flight Control, Science Operations and Control, and DSN Allocation Planning. The MMO GDS Team provides system engineering, software engineering, network engineering, test engineering, and associated support services to JPL projects. Cost savings to these projects come from reuse of existing plans, requirements, architectures, products, and people. The MMO GDS engineers are multi-mission assets who are cross-trained in a variety of areas. This allows a project, which has limited funding for these areas to leverage off the capabilities of the entire MMO GDS team. So long as there is a balance in the needs of these projects and the staffing/funding to MMO, there is often a good opportunity for cost savings.

This paper will describe these cost savings areas in detail, and where appropriate use actual examples from previous Flight Projects, among them MGS, SDU, Mars ODY, GNS, MER, and MRO.

## 1. INTRODUCTION

JPL has been using a multi-mission Ground Data System (GDS) called Advanced Multi-Mission Operations System (AMMOS)<sup>1</sup> in support of Flight Projects since 1989, when the initial version of the system was successfully used to support the Magellan mission. Since that time, the system has been adapted to support over a

dozen other missions, including Mars Pathfinder, Mars Observer, Cassini, and Deep Space 1. Beginning with the MGS project in the mid-1990s, the Mission Management Office (MMO)<sup>2</sup> has been able to integrate, test, and deploy versions of this GDS for the following operational and/or Spacecraft Assembly, Test, and Launch Operations (ATLO) projects:

- Mars Global Surveyor (MGS)
- Stardust (SDU)
- Mars Polar Lander (MPL)
- Mars Climate Orbiter (MCO)
- Genesis (GNS)
- Mars Odyssey (Mars ODY)
- Mars Exploration Rover (MER) – Launch 2003
- Deep Impact – Launch 2004
- Mars Reconnaissance Orbiter (MRO) – Launch 2005

While the core technologies of this GDS are multi-mission in nature and for the most part funded institutionally by the Deep Space Mission System (DSMS) organization, these GDS elements by themselves are not ready for a project to use, since they require adaptation, integration, test, deployment, and operational support. These final phases, during which the integrated GDS (IGDS) is delivered by MMO, are necessary for successful project level testing and the transition to full operations. Figure 1 below shows how the IGDS comes together to support a particular project.

MMO GDS support for the flight projects is provided in the areas of system engineering, test engineering, software engineering, deployment, system administration, facility/network engineering, and configuration management. This support is negotiated with each project, based on their requirements. While not all projects have the same set of requirements, they are generally similar and need all of these GDS services in order to be successful. Projects can either provide these

<sup>1</sup>Formerly the Space Flight Operations Center (SFOC)

<sup>2</sup>Formerly the Mars Surveyor Operations Project (MSOP)

services themselves, or turn to a supporting organization such as MMO GDS.

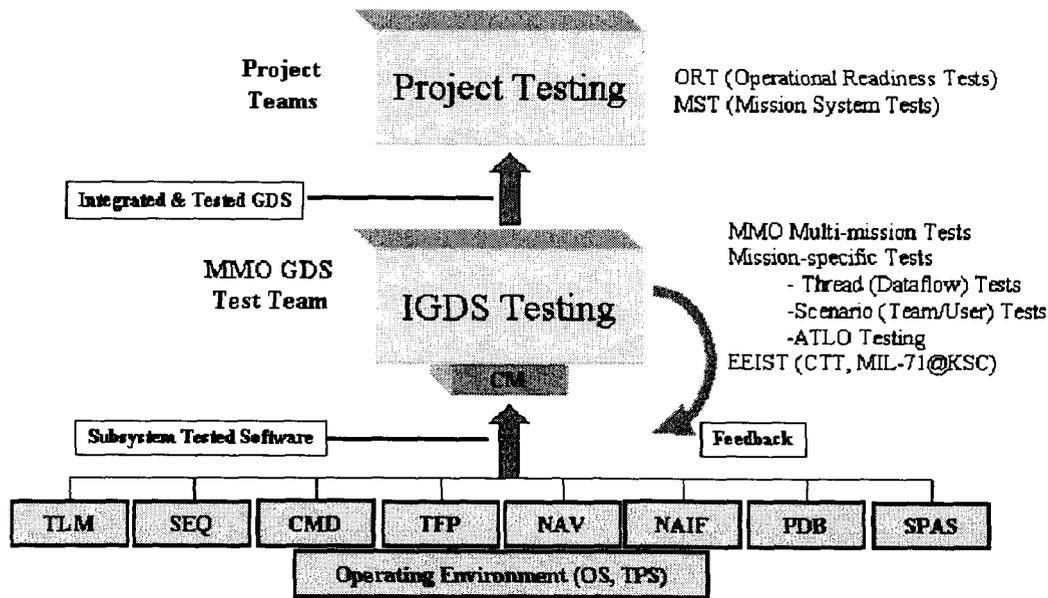


Figure 1: IGDS Test & Deployment

2. “ONE STOP SHOPPING” FOR DISCOVERY PROJECTS

Discovery missions are common at JPL and are often associated with limited science and/or technology objectives. As a result, they are smaller in scope and limited in funding. Most of the attention, interest, and funding is focused on the flight system, namely the spacecraft and instruments – therefore it is inevitable that the Mission Operations System (MOS) and GDS will suffer. Often, the result of this is that the GDS must accommodate whatever technical decisions are made early in the design process – which can then lead to costly (and unexpected) impacts to the project.

To mitigate against these cost drivers, it is important that the proper level of flight/ground system engineering is done so that an integrated flight/ground architecture is achieved with proper technical and cost tradeoffs. MMO GDS provides a single model that can support a flight project in various ways:

- Cradle to Grave Support: Pre-Project, Phase A-D, Phase E Operations
- Standard Reusable GDS Templates: Requirements, Design, Test, Review, Training, Security
- Institutional Support: Testbeds, EEIS Engineering, Test Automation, Mission Support Areas (MSAs), Ground Support Equipment (GSE) interfaces and software, Uplink/Downlink Support Toolkits
- Standard Procedures and Documentation

The MMO GDS “One Stop Shopping” model provides for many of these areas that can be quite costly if supported in a piecemeal fashion. For example, after MMO GDS support of the MGS and SDU missions, the Testbed infrastructure was in place to support ODY and GNS with minimal project cost. Standard system engineering products (requirements, design, testing, training, procedures, interface agreements, etc) could be reused for these new missions with only small adaptations. The

result was that both ODY and GNS were able to reduce their GDS costs by leveraging against prior missions.

However, it would be a mistake to assume that all projects are the same, or that by simplifying the flight system (spacecraft/instruments) for a discovery mission, the corresponding GDS costs can be reduced. The truth is that there are basic GDS capabilities that are required for all projects, regardless of how simple and streamlined they may be. These GDS capabilities (Command, Telemetry, Data Analysis, ATLO, Launch Support, Science Support, Operations Troubleshooting) cannot be reused like a cookie cutter – they require adaptation by the MMO GDS team. An example of this would be one of the upcoming Mars Scout missions, which assumed that a previous ground system configuration from many years ago could be reused ‘as is’ with little or no changes. The reality was that the previous system had very little heritage to current GDS hardware/software, perhaps only an initial Command/Telemetry Dictionary. This assumption, if not addressed early in the project, could have led to significant cost uncertainty.

### 3. DOES MULTIMISSION WORK?

In the early years of AMMOS, asking this question would have made no sense. Prior to Magellan in 1989, each JPL project would design, build, and deploy a mission unique GDS to meet its own requirements. There was no need for inheritance between projects, since a project GDS was only intended to support a single mission, and then be discarded. With the advent of AMMOS for the Magellan project, the concept of ‘adapting’ a multi-mission GDS in support of new projects became a reality. The missions that immediately followed Magellan greatly benefited from the multi-mission concepts. Even projects that had previously deployed unique GDSs (VGR, GLL) were eventually convinced to replace them with AMMOS multi-mission versions. As more and more projects were developed, each realized some level of cost savings from the predecessors – problems were found and fixed, automation was introduced, processes and procedures got better.

We are at a point now where new projects expect significant cost savings from the multi-mission AMMOS heritage, but do not expect the ongoing, relatively constant GDS costs for adapting, maintaining, and operating the system. In addition, there is a price for being a member of the JPL ‘multi-mission’ family of projects. This price consists of accepting procedures, regular GDS upgrades, project ‘keep out’ zones, and other undesired (from the project viewpoint) GDS constraints. For example, there may be regular GDS upgrades that are required, in order to maintain a consistent operations support structure for all missions – and yet a particular

mission may not want (or need) the upgrade. In such cases, the project is forced to abide by the multi-mission guidelines and accept the upgrade. It is difficult to define the cost for this multi-mission support, but it involves significant support from MMO.

The answer, of course, is that multi-mission does work, but the responsibilities and associated costs are often not clearly identified for a project. For existing projects that have experience with the MMO value-added services and products, this understanding comes gradually and is generally accepted. For new projects, especially those with project managers who have little experience with AMMOS or MMO, early consulting and briefings are going to be necessary.

### 4. LESSONS LEARNED

In order for MMO GDS to continue to provide value-added services to the projects, and to continue to reduce costs, we will have to get better at what we do. We have made great progress in a number of areas, several of which will result in direct cost savings to the projects. On the other hand, there are areas that are not properly engineered, or take too much time, or are otherwise too costly. These ‘breakthrough’ areas are summarized in Figure 2 below.

### 5. FUTURE WORK

In the future, MMO GDS has a strategy to provide additional cost savings services to the flight projects. Some of these concepts are already in limited use, others are planned for the near future:

- Standard Dictionary Management, using XML technology
- Data Quality Monitors
- Web-based Remote Science Operations
- Deployment Automation
- Daily Telemetry Summary Database
- Automated Test Tools
- Scenario-based Training
- Operations Metrics
- Improved Documentation

All of these enhancements are intended to make MMO a more effective provider of MOS/GDS products and services to the flight projects. The improvement areas are the result of many years of experience working with JPL projects, and the AMMOS multimission system. For additional information on MMO and the MMO GDS team at JPL, please refer to these URLs:

<http://mmo.jpl.nasa.gov> (MMO Organization)  
<http://mmogds.jpl.nasa.gov> (MMO GDS Team)  
<http://quill.jpl.nasa.gov> (MMO GDS Development)

Note: Sites may be password protected, and/or not accessible from outside JPL

<b>BREAKTHROUGH</b> (MMO Multi-Projects)	<b>STANDARD</b> (Single Project)	<b>CHALLENGE</b>
<b>Generic Project Testbeds</b> for Development, Test, Deployment; Reduced Cost; Heritage GSE	Project-unique Testbeds	Shared Testbed resources; Forced use of multi-mission GDS software and servers
<b>Common GDS for Operations</b> ; Reduced Cost; Shared Development/Operations Personnel	Project-unique GDS; Project-unique Development, People, Infrastructure	Coordinate common GDS deployment and capabilities for multiple projects; Enforce strong CM rules
<b>Common MOS for Operations</b> ; Reduced Cost; Shared Operations Personnel, Procedures, Scripts, Interface Agreements	Project-unique MOS; Dedicated Operations Personnel	Design and develop common MOS and GDS products to be easily adaptable for new projects.
<b>Cross Trained GDS Team</b> (Generalists)	Project-unique GDS Team (Specialists)	Cross training of GDS team to support various areas (System Engineering, Software, Test, OPS Support, etc)
<b>Common Integration &amp; Test</b> ; Automated Testing, Plans, Scripts, Bug Tracking, Reports, Development Interfaces	Develop from scratch, based on previous experience of team	Design and develop multi-project test program that is expandable to support new projects with little work
<b>GDS Deployment</b> ; Use of JumpStart Server, Common Target Architecture; Reduce deployment time by 90%	Develop from scratch, based on previous experience of team	Enforce common architecture; Define procedures for CM and System Administration
<b>Common GDS Templates</b> ; Better GDS Products; Reduced Cost	Develop from scratch, based on previous experience of team	Design and development of good, multi-project products that can be used as templates

Figure 2: BREAKTHROUGH vs CHALLENGE

## 6. ACKNOWLEDGEMENTS

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