CONNECTING SCIENCE AND OPERATIONS: THE OPERATIONS COORDINATOR

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ABSTRACT

For a current space mission under development at the Applied Physics Laboratory, the Mission Operations staff includes a team of "Operations Coordinators" who have been working with the Mission Science and Spacecraft Development teams since completion of mission conceptual design. The Operations Coordinators are responsible for bringing knowledge of the spacecraft to the Mission Science team, and bringing knowledge of the experiment requirements to the Spacecraft Development and Mission Operations teams. Once on-orbit operations begin, the Operations Coordinators will be responsible for implementation of specific science experiments from analysis through scheduling, generation of spacecraft command sequences, delivery of science data to the end user and operations assessment. The Operations Coordinator concept is proving very effective during the development phase of the current mission.

1. INTRODUCTION

From March through December 1989, the "Delta Star" spacecraft provided scientists with a multi-spectrum suite of scientific instruments in low earth orbit that could be positioned for observation of both moving and stationary targets of interest. Science data recorded on flight recorders were downlinked to ground stations, made available for review and analysis at a science data center, and then forwarded to a central archive for future use. During the on-orbit phase of operations, over thirty Principal Investigators proposed experiments for the Delta Star spacecraft. Many of these experiments, which evolved as the mission progressed, involved cooperative ground operations. For the Mission Operations team to effectively implement these experiments and make efficient use of spacecraft and ground resources, it became clear that each Principal Investigator needed a partner in Operations who would be responsible for their experiment from inception through delivery of data to the end user. This "partner" needed both a clear understanding of the spacecraft and ground system capabilities as well as the technical background necessary to grasp the science objectives and translate them into spacecraft and ground system operations. Additionally, the "partner" would provide a single point-of-contact in Mission Operations for a Principal Investigator and, as a member of the Mission Operations team, could provide schedule coordination for experiments that required the use of other ground or airborne sensors in conjunction with spacecraft observation of a particular phenomena. Thus, the concept of an Operations Coordinator emerged.

Informal tests of the Operations Coordinator concept during the latter stages of the Delta Star mission indicated that, not only was the concept effective, but it also provided very interesting and challenging work for senior level operations staff members. The decision was made to implement this concept at the outset for the next mission that resembled Delta Star in terms of spacecraft complexity and user variety. The Mission Operations system for the current space mission under development employs the Operations Coordinator concept.

2. THE MISSION OPERATIONS SYSTEM

The Mission Operations system consists of the ground system, the Mission Operations teams and the processes in which the teams and the ground system engage to operate the spacecraft. The "concept of operations" describes the Mission Operations system teams and processes based on the ground system design. Functionally, the system is divided into three major areas: Operations Planning, Operations Control and Operations Assessment. The Operations Planning function is concerned with analyzing and scheduling spacecraft operations and generating command sequences; the Operations Control function is concerned with communication of command and telemetry data to and from the spacecraft and data distribution; and the Operations Assessment function is concerned with evaluation of the performance of the spacecraft

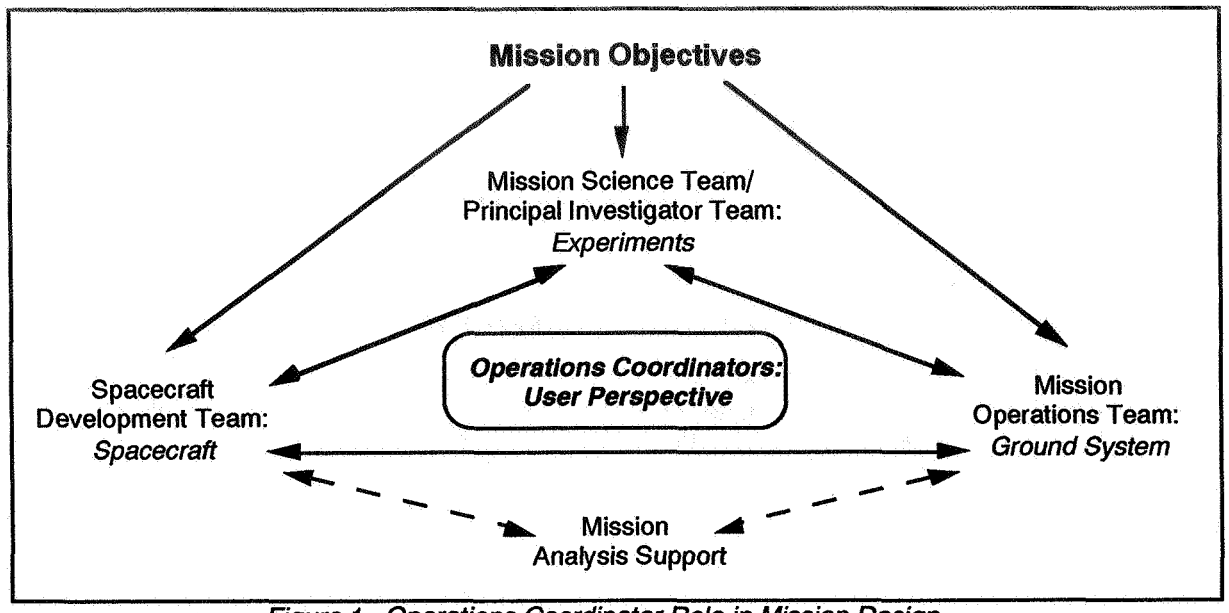

Figure 1. Operations Coordinator Role in Mission Design

and of the Mission Operations system. Each functional area is the responsibility of an operations team; each team is supported by elements of the ground system.

The Operations Coordinators are considered members of the Operations Planning Team. For the current mission, this team includes four Operations Coordinators representing eight Principal Investigator teams, and eight "Operations Analysts" who provide analytical support for operations planning activities. Each Operations Coordinator is assigned from one to three Principal Investigator teams depending on commonality of science objectives.

3. THE OPERATIONS COORDINATOR ROLE IN MISSION DESIGN

The space mission design process (Figure 1) requires the balancing of mission objectives with spacecraft system capability and ground system capability. For a scientific mission, translation of mission objectives into experiments or tests that will use the spacecraft and ground system is the responsibility of the Mission Science, or Principal Investigator team. The Spacecraft Development team and the Mission Operations team develop complementary system designs that will support execution of the experiments or tests proposed by the Principal Investigator team. Both spacecraft and mission operations engineers require analytical support to interpret science requirements in terms of system capability and to set design parameters.

Although the role of the Operations Coordinator as it evolved during the Delta Star mission concentrated on the on-orbit interface between science and operations, this connection is essential from the beginning of the mission design process. Typically the Mission Operations team that is identified at this time includes a ground system engineer with some level of mission analyst support. All team members are charged with understanding the science objectives as they apply to their system. However, properly defined, the Operations Coordinator role can bring a unique perspective to this process--that of the real user of the spacecraft and the ground system. If the Operations Coordinators are charged with the responsibility of translating science experiments into operations and following those operations through delivery of data back to the science teams, then they must be concerned with the integrated usability of the spacecraft and ground systems in the execution of science experiments.

For the current mission, eight Principal Investigator teams were chartered early in the mission design process, each with their own class of targets or phenomena to be observed. Two Operations Coordinators were designated as part of the core Mission Operations team and charged with taking the system "user " perspective as they developed both an understanding of the Principal Investigators' experiment proposals and the design of the spacecraft and ground systems. In this role they provided the user point-of-view in design

sessions and were also tasked with developing the "concept of operations" for the current mission.

4. THE OPERATIONS COORDINATOR ROLE IN SYSTEM DEVELOPMENT

Following the conceptual design reviews for both the spacecraft and ground systems, core members of each operations team were named to assist the ground system engineer in developing detailed specifications for the ground system elements that would be used by that team. As spacecraft system development began in earnest and the Principal Investigator teams actively moved forward with experiment scenario design, additional Operations Coordinators were identified to handle an expanding role. For each Principal Investigator team, the Operations Coordinator was tasked with instructing the team in the use of the spacecraft and, for each proposed experiment, assessing whether or not that experiment was feasible. This process (Figure 2) is iterative, as modifications to the experiment, the spacecraft, and the ground system are often possible in the early development stages.

An experiment is considered to be feasible if a spacecraft operation can be created and scheduled that responds to the objectives of the experiment and where spacecraft resource usage for that operation is within allowable limits. The tools needed by the Operations Coordinators to evaluate experiment feasibility are the same tools as are needed by the Operations Planning team on-orbit to configure and schedule the spacecraft and manage spacecraft and ground resources. These tools include orbit propagators, spacecraft dynamics models, tools to analyze satellite-to-target geometry, spacecraft configuration tools, and spacecraft resource usage models. Therefore, a second role of the Operations Coordinator during system development is to support the ground systems engineer in specifying user requirements for system capability. As early users of the ground system elements that support analysis, the Operations Coordinators also serve as members of the system test team.

5. THE OPERATIONS COORDINATOR ROLE ON-ORBIT

For the current mission, it is anticipated that the majority of experiment design will be completed prior to launch. Although some level of experiment design and feasibility analysis will continue after launch, the primary role of the Operations Coordinators will shift at launch from experiment and ground system design support to on-orbit operations coordination. At launch, the full Mission Operations team is in place. To understand the Operations Coordinators role on-orbit, it is necessary first to understand the baseline process of scheduling and executing satellite operations for the current mission (Figure 3).

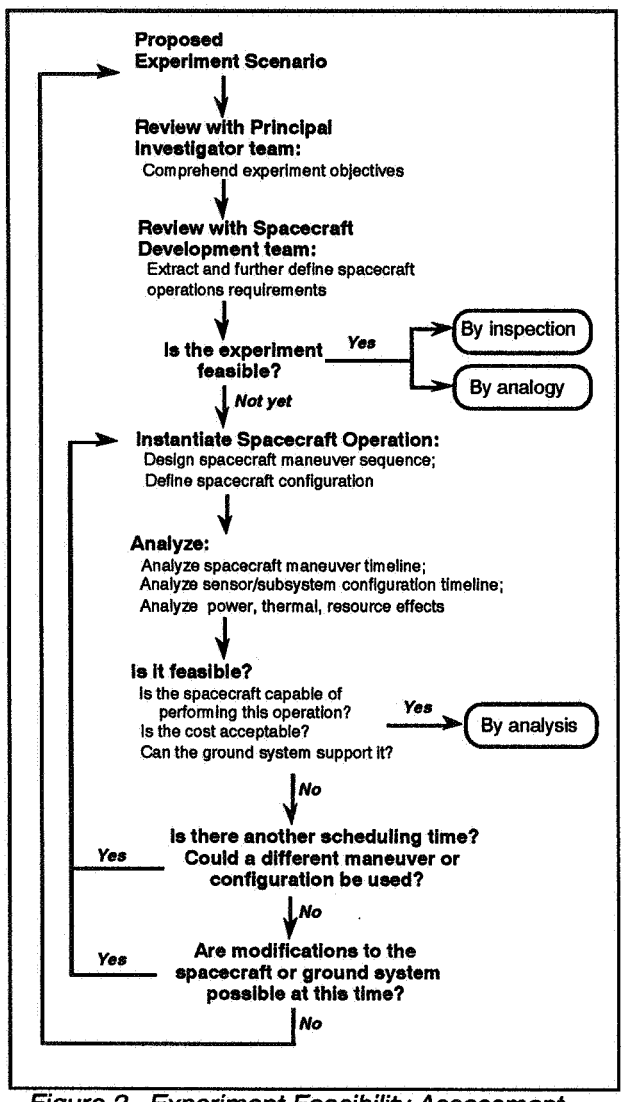

Figure 2. Experiment Feasibility Assessment

On a monthly basis, a set of experiments are selected by the Mission Director (representing the sponsoring agency) and provided to the Mission Operations team as "monthly objectives". This occurs approximately six weeks prior to the beginning of the month of interest. The Operations Planning team identifies the scheduling opportunities for the

spacecraft operations associated with each experiment and interleaves the operations into a monthly schedule accounting for experiment priority, spacecraft recovery between operations and data downlink requirements. The ground station contact activities are coordinated on a weekly basis and reported in a weekly schedule. Each day the schedule for the following day is refined; objectives are defined for each contact the ground network makes with the spacecraft, a daily schedule is assembled detailing all contact activity and spacecraft activity, and commands are generated. Contact level procedures, called contact plans, are generated specifying what action is to be taken and what critical spacecraft status is expected on each contact, and then delivered to the control teams for execution.

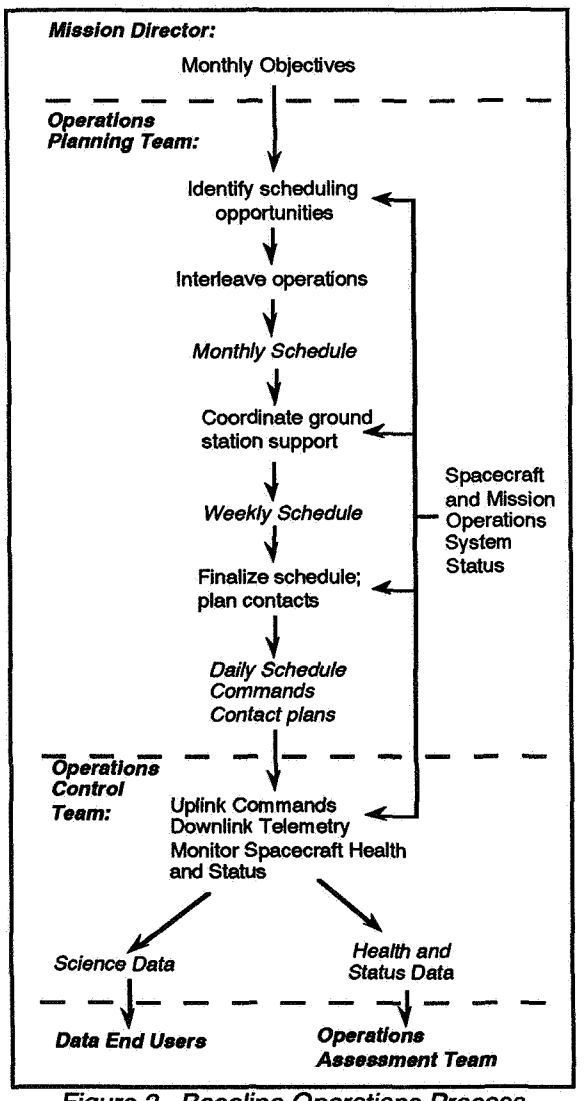

Figure 3. Baseline Operations Process

The Operations Control team responds to the contact plans provided by the operations planners. The contact plans provide details on the link configuration, tracking and downlink activity, uplink requirements a nd spacecraft status. For each contact, the controllers configure the data links, establish communication with the spacecraft, uplink commands as required and manage telemetry downlink and tracking data acquisition, monitor routine spacecraft health and status, and document the actual contact. For those contacts where science data is downlinked, the Operations Control team is responsible for data dissemination to the end users.

The Operations Assessment team analyzes and reports on the execution of each spacecraft operation based on the planned operations specifications and downlinked telemetry data.

The Operations Coordinators are responsible for implementation of specific science experiments from analysis through scheduling, generation of spacecraft command sequences, delivery of science data to the end user and operations assessment. In particular, they direct all operations analysis done at the monthly and weekly scheduling stages. They are supported in this work by the Operations Analysts. Each Operations Coordinator represents the interests of his/her Principal Investigator teams during scheduling exercises. The Operations Coordinator can make changes to experiment operations within guidelines provided by the Principal Investigators if this can improve on the quality or volume of data collected. If an experiment requires coordination with other ground or airborne sensors, the Operations Coordinator provides scheduling information as needed. For each operation, the Operations Coordinator monitors all daily scheduling, command generation and operations control activities performed in support of that operation, provides status to the Principal Investigator as needed, and signs off on the report made by the Operations Assessment team about that operation. Finally, the Operations Coordinator provides the single point-of-contact in Mission Operations for the Principal Investigator concerning his/her experiment operations on-orbit.

6. STAFFING CONCERNS

The broad nature of the Operations Coordinator job requires a broad skill base. The Operations Coordinator must develop an in-depth

knowledge of both the spacecraft and the Mission Operations system, as well as a clear understanding of the objectives of the experiment plans. Although analysis support may be provided by the Operations Analysts, the Operations Coordinator must be able to direct the analysis and interpret results in order to assess whether or not an experiment is feasible, what the resource impact on the spacecraft is, and to select which scheduling opportunities for an experiment may be most productive. Excellent communication skills are essential. Operations Coordinators brought in as part of the core Mission Operations Team during mission and system design have the advantage of learning the systems as they are developed; for all Operations Coordinators the ability to take a system perspective is mandatory.

7. IN PRACTICE

Design of the Mission Operations system for the current mission was initiated three and a half years ago and the system is expected to be operational late next year. Early identification of Operations Coordinators has provided significant gains in the quality of the Mission Operations system being developed:

- the Operations Coordinators have provided continuous input into the experiment design process concerning the capability and limitations of the spacecraft and the ground system;
- the Operations Coordinators have provided continuous input into the spacecraft development process concerning the experiment requirements and the proposed spacecraft operational scenarios;
- the concept of operations addresses the fundamental purpose of the Mission Operations system to collect science data;
- the ground system element that is being developed to support operations analysis is tailored to the types of experiments that will require analysis;
- an effective, productive working relationship exists between the Mission Science and Mission Operations teams; and
- Mission Operations is viewed as being a responsive, responsible organization.