Hubble Space Telescope Planning and Scheduling Problems

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Abstract

The Hubble Space Telescope (HST) is a highly complex, Low Earth Orbiter (LEO) spacecraft. Extensive and time consuming processes are required to schedule and execute scientific observations due to occultations, passage through the South Atlantic Anomaly, viewing restrictions in terms of the sun and moon, and availability of guide stars. Because of the hardware design, momentum management and slewing are constrained and have to be carefully managed; the scientific instruments provide limited flexibility in terms of operations; and the on-board data recording and playback systems limitations prevent full utilization of space to ground communications, decreasing observational efficiency. These and other constraints have forced the HST operation of HST to be mostly pre-planned, with limited real-time commanding. Attempts to provide "branching" - originally a Level I requirement - in which one of several pre-planned observations would be selected in real-time, proved impossible to implement.

Although significant progress has been made since launch, some planning and scheduling processes are difficult to optimize or even improve. The HST Project is addressing some of these problems as part of VISION 2000, a program to reengineer the HST ground system and flight computer. Changes to both the planning and scheduling system and the command and control center are being made in order to simplify the operations of HST and reduce operational costs.

Aside from the technical problems presented, some planning and scheduling complexities trace back to decisions made well before the launch of HST. At Goddard Space Flight Center (GSFC), planning and scheduling system development and operations for spacecraft (including command load generation) are typically performed by a single organization. This provides a single user interface. But for programmatic reasons, it was decided that for HST the "science" aspects of planning and scheduling would be performed by the Space Telescope Science Institute (ST ScI) and the "mission" aspects, along with command load generation, would be performed at GSFC. The mission scheduling process is driven by the science planning inputs. As a result of this split responsibility, two major problems occurred. First, there is a duplication of functionality with the same functions being implemented differently. For example, since occultation computations for the Fine Guidance Sensors were computed differently, the mission planning system would sometimes reject science schedule inputs and the science schedule would require regeneration. Second, outputs from mission scheduling were required as inputs for the science scheduling. For example, the science scheduling system needs knowledge of the space to ground communications resources and relies on the mission scheduling system to secure these resources. However, the resources can't be requested until the science schedule is generated. Multiple iterations between science scheduling and mission scheduling are required to resolve this type of problem.

Major improvements are underway. The mission scheduling function has been moved to the ST ScI and put under the control of a single organization. It will eventually be integrated with the science scheduling system which will result in major improvements: elimination of redundant modeling; earlier constraint checking and speedier replanning in response to missed observations or spacecraft anomalies. Due in part to the integration of the two systems as well as to changes in the science planning and scheduling process, observing efficiency has more than doubled since launch.

The HST command and control center plays an integral role in the planning and scheduling process since it makes any necessary changes to space to ground communications schedules during the execution of the observing program. Although the Tracking and Data Relay Satellite System (TDRSS) resources are scheduled at least one week in advance, numerous changes are required due to such factors as: shuttle launches, equipment outages, and unexpected new communication needs (e.g. support other spacecraft emergencies). The goal is to automate this process in VISION 2000. Specific TDRSS resource schedule requests are made 14 days in advance for a one week period. Because the user of TDRSS doesn't have *a priori* knowledge of TDRSS availability, scheduling is done “in the blind”. It isn’t until the rejected schedules are returned and services negotiated that a final schedule can be constructed. To expedite this process, “generic” scheduling or developing a highly reliable real-time scheduler are under study with the GSFC’s Network Control Center (NCC).

Another complexity is integrating new HST Scientific Instruments (SIs) requirements into the planning and scheduling system. System upgrades to accommodate their enhanced performance has been an expensive and extensive process which needs to be simplified. The solution of retrofitting a new SI to the existing system is unacceptable since much of that SI’s scientific capability would be unrealized.