“Automating the SMAP Ground Data System to Support Lights-Out Operations”

Antonio Sanders

Jet Propulsion Laboratory, California Institute of Technology

I. Introduction

The Soil Moisture Active Passive (SMAP) Mission is a first tier mission in NASA’s Earth Science Decadal Survey. SMAP will provide a global mapping of soil moisture and its freeze/thaw states. This mapping will be used to enhance the understanding of processes that link the terrestrial water, energy, and carbon cycles, and to enhance weather and forecast capabilities. NASA’s Jet Propulsion Laboratory has been selected as the lead center for the development and operation of SMAP.

The Jet Propulsion Laboratory (JPL) has an extensive history of successful deep space exploration. JPL missions have typically been large scale Class A missions with significant budget and staffing. SMAP represents a new area of JPL focus towards low cost Earth science missions. Success in this new area requires changes to the way that JPL has traditionally provided the Mission Operations System (MOS)/Ground Data System (GDS) functions. The operation of SMAP requires more routine operations activities and support for higher data rates and data volumes than have been achieved in the past. These activities must be addressed by a reduced operations team and support staff. To meet this challenge, the SMAP ground data system provides automation that will perform unattended operations, including automated commanding of the SMAP spacecraft.

II. SMAP GDS Overview

The SMAP Ground Data System (GDS) is the integrated set of ground hardware, software, facilities, and networks required to support mission operations. Key functions performed by the GDS include sequence and command generation and uplink, real-time and playback telemetry processing, navigation, ephemeris generation and distribution, data management and accountability, time correlation, and station scheduling. The use of automation to reliably perform GDS functions is key to achieving lights-out operations for SMAP.

The SMAP GDS is partitioned into nine subsystems that represent the top level system architecture. These subsystems are further decomposed into a set of functional elements to facilitate system development. This system decomposition is consistent with prior JPL missions and allows SMAP to inherit GDS architecture, design, and implementation. Figure 2.1 illustrates the SMAP GDS subsystems and elements.

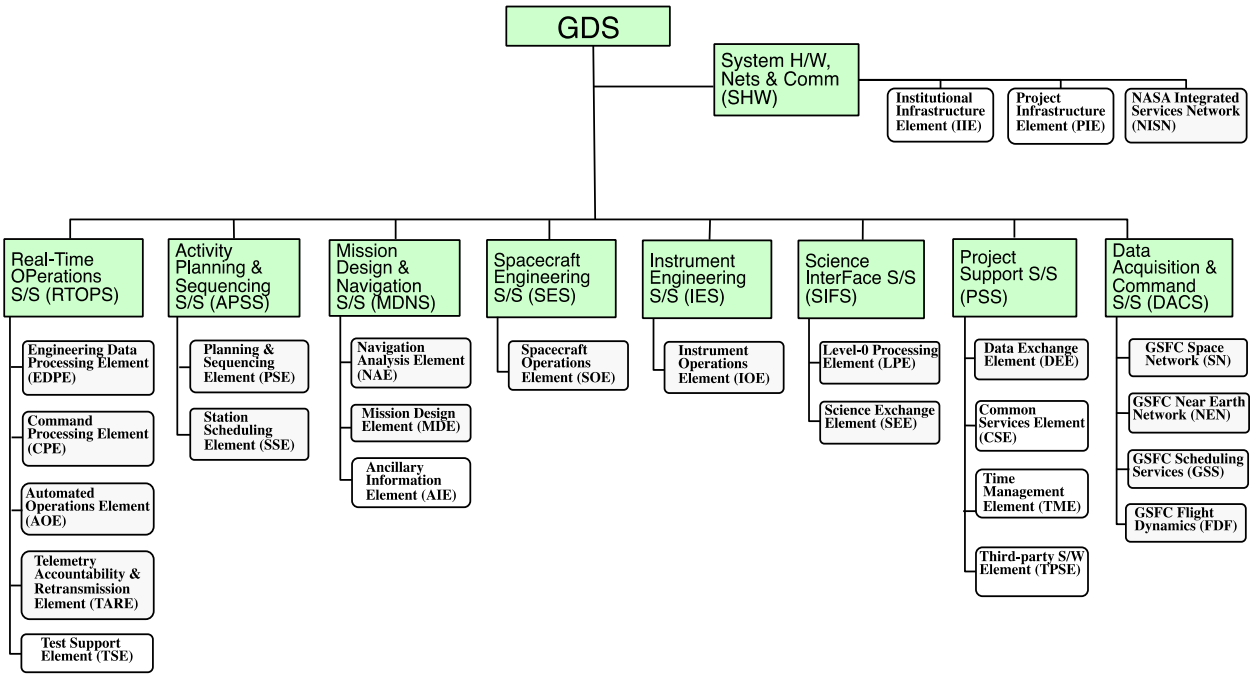

Figure 2.1 SMAP GDS Subsystems and Elements

III. SMAP GDS Automation Patterns

Ground Data System automation is not new for JPL missions. The use of automation to support ground data system functions has been successfully demonstrated for over ten years by the Jason-1 and WISE missions that were operated by the JPL Earth Science Mission Center (ESMC). Within the ESMC, a lights-out approach to ground data system processing was successfully demonstrated for Jason-1. Despite this accomplishment, both Jason-1 and WISE were staffed by 24/7 on-console operations personnel. Therefore, lights-out automation was never fully achieved for routine operations of these missions.

Analysis of the automation approach used by Jason-1 and WISE has led to the discovery of common automation patterns. An analysis of the Jason-1, WISE, and SMAP operational uses cases has revealed that the automation required for operations can be achieved through the use of file-based, pass-based, and time-based automation. File-based automation involves data processing, transfer, and notification activities that are triggered by file system events. Pass-based automation involves the orchestration of all activities necessary to perform unattended tracking passes including post-pass activities. Time-based automation involves the ability to schedule and execute routinely occurring tasks at arbitrary times or intervals.

IV. SMAP GDS Automation Software

File-based automation is at the core of the SMAP GDS automation design. File-based automation is used to perform data exchanges among GDS elements as well as data exchanges with external systems. In addition to performing data exchanges, the file-based automation provides workflow automation by invoking software processes that can operate on the data that is being exchanged. Notification and logging of file exchanges and the processing status of invoked processes are also provided by the file-based automation.

In order to achieve file-based automation, SMAP employs the use of an NFS-based file system called the Operations Storage Server (OSS). The OSS implements a hierarchical directory structure that provides storage for the data that will be exchanged among the various SMAP teams. Within the OSS, POSIX groups are used to restrict access to team data. The SMAP Operations Storage Server directory structure is shown as Figure 3.1.

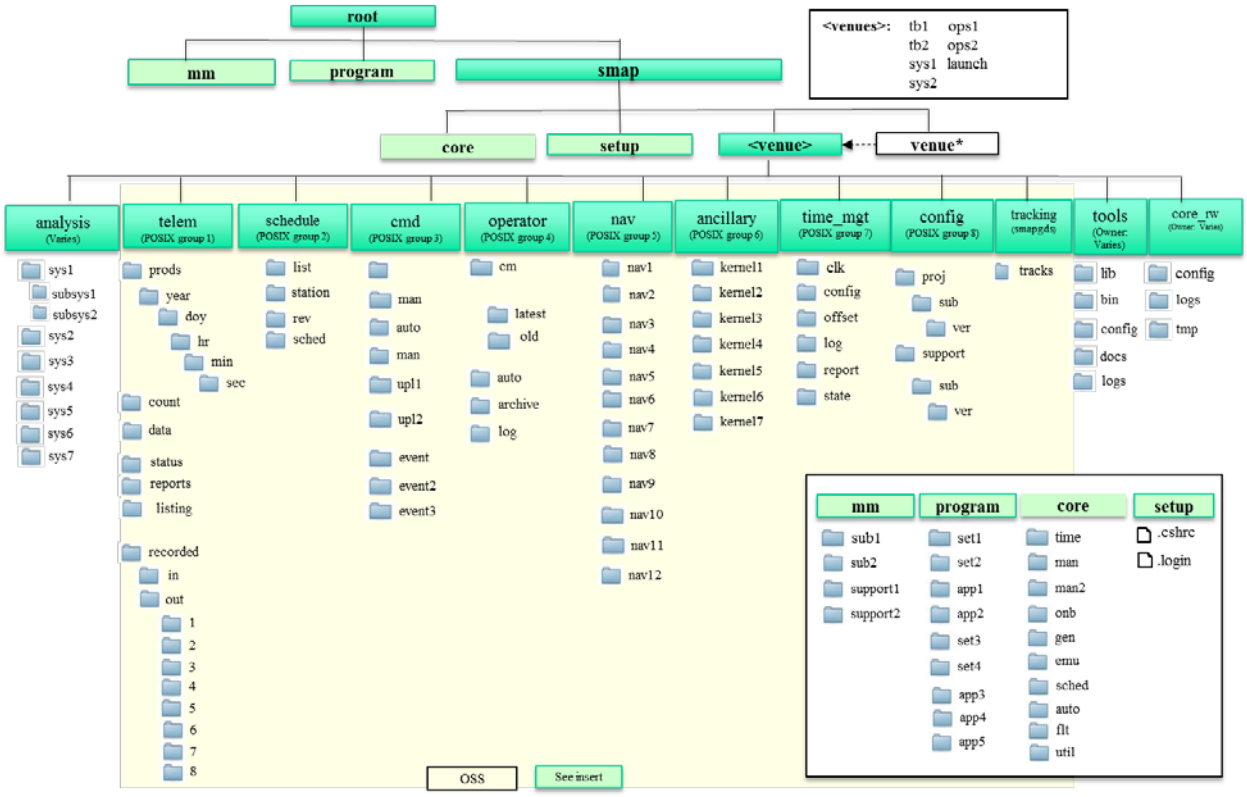

Figure 3.1 The SMAP Operations Storage Server Directory Structure - Sample

File-based automation within the OSS is performed by the SMAP File Notification Service (FNS) software. FNS can be configured to monitor any number of directories within the OSS. Upon detection of a file event within a monitored directory, FNS can invoke user specified processing on the detected file. This processing can be as simple as sending user notification of file availability within the OSS, or as complex

as invoking a GDS application to process the detected file. This processing could result in new data stored to the OSS, which in turn could result in new file detections and application invocations. This detect/process/notify construct provides the capability to implement workflow automation within the OSS.

Pass-based automation is also essential to the SMAP GDS automation design. Pass-based automation is used to orchestrate all activities associated with unattended tracking passes. Pass-based automation is performed by the Pass Automation Daemon (PAD) software. PAD is driven by a pass list which is a schedule derived from the tracking pass schedule output of the NASA Near Earth Network (NEN) / Space Network (SN) scheduling process. Each entry in the pass list represents a scheduled contact period with a NASA NEN/SN station resource. For each pass, PAD allows the automation of pre-pass, in-pass, and post-pass activities. Such activities include station connection management, automated uplink, telemetry processing, invocation of custom flight operations scripts, data management, and time correlation functions. A sample interaction of PAD, OSS, and FNS with custom Flight Operations Team (FOT) scripts to automate the ephemeris generation and uplink process is shown as Figure 3.2.

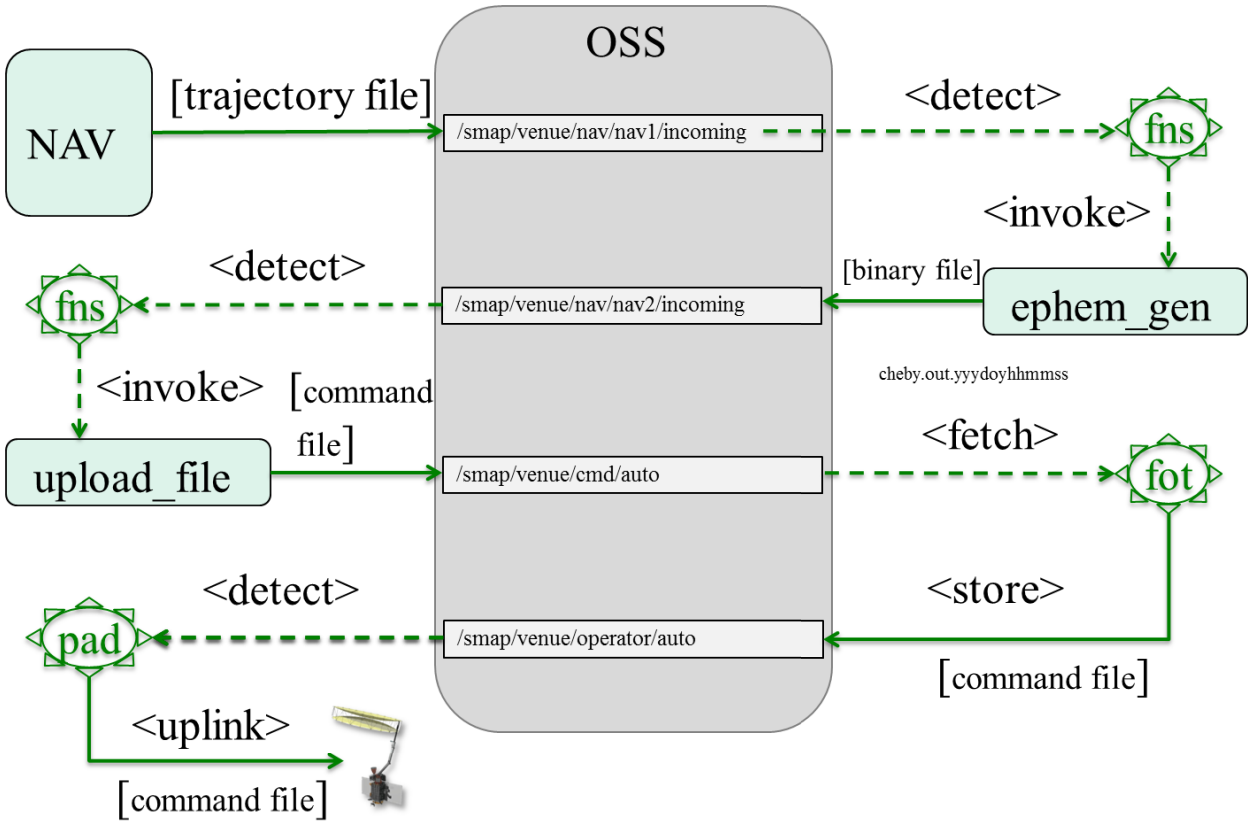

Figure 3.2 Ephemeris Generation and Uplink Automation

Time-based automation is the third component of the SMAP GDS automation design. The Time-based Automation Scheduler (TAS) software provides the time-based automation capabilities for SMAP. TAS provides a flexible means to construct and manage sets of automation activities. The task scheduling algorithms in TAS are aware of SMAP ground station tracking passes. Because tracking passes are critical to SMAP operations, it is often necessary to avoid scheduling arbitrary tasks during these times. Alternatively, it may be desirable to schedule certain tasks to occur during particular passes, such as during the first pass of the week. TAS provides a means to schedule routine activities around and relative to ground station tracking passes. Automation activities supported by TAS include data management, report generation, and data archival.

V. Developing Low-Cost, Reliable Automation

Development of automation for the SMAP Ground Data System involves the integration of SMAP project-specific software with core multi-mission software, which both build upon open-source software. Data processing for SMAP is performed by the SMAP project software, the multi-mission software, and by software systems external to the GDS. The GDS automation software provides a thin software layer that performs orchestration of the underlying software components and data exchanges. This layering approach improves the reliability of the GDS automation by leveraging the maturity of existing software and services which results in a significant reduction in code size and complexity at the automation layer. The SMAP GDS automation software layering is shown as Figure 5.1.

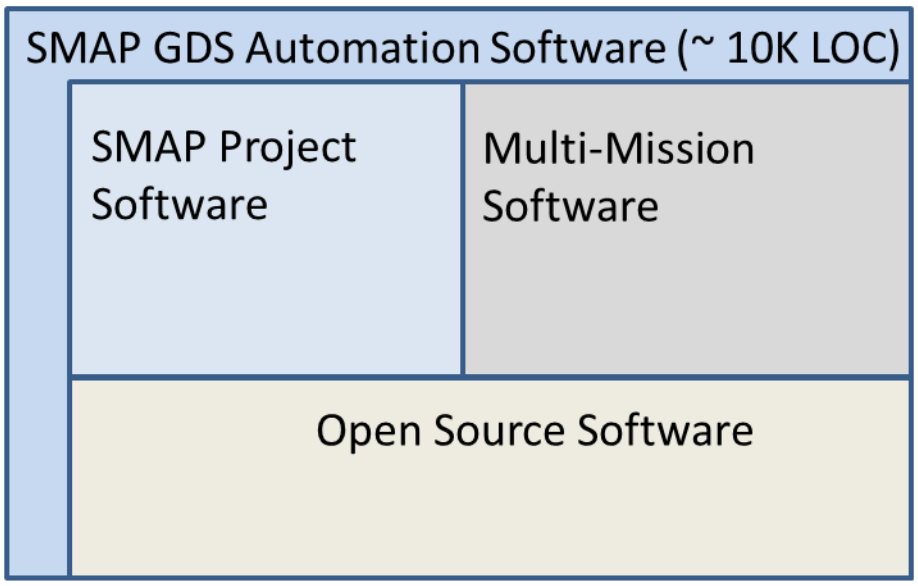

Figure 5.1 SMAP GDS Automation Software Layering

The development of reliable automation that facilitates flight operations with a small ops team has been a key design goal for the SMAP GDS from the beginning. This goal has impacted the GDS development approach in several ways. Automation software development was initiated early in the GDS development lifecycle. This software development has been performed iteratively along with the project software and multi-mission software adaptation, with increasing capabilities realized with each software release. The SMAP project software and multi-mission software development were guided by automation requirements, including updates to the multi-mission software to implement an automation interface. Automation use cases were identified through weekly automation working group meetings with the development and operations stakeholders. Automation interfaces are formally documented in operational interface agreements and interface control documents. Automation validation has been included in the project verification and validation plan and will be exercised during formal functional scenario tests and operations readiness tests.

Efforts to improve the reliability of the automation have also been applied to the GDS architecture and hardware platform. The same GDS architecture and hardware platform that will be used in SMAP operations was deployed into the early testbeds and used throughout flight system integration and testing. The GDS architecture for the real-time telemetry downlink scenario is shown as Figure 5.2

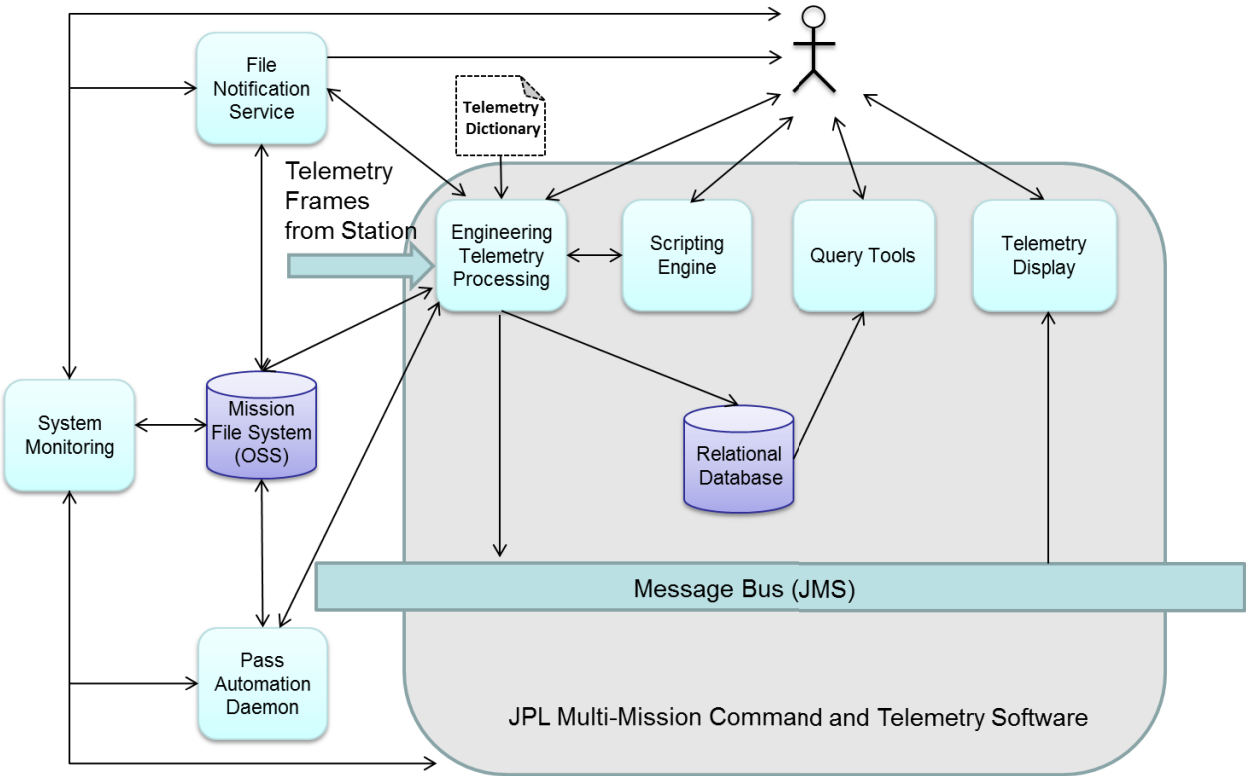

Figure 5.2 GDS Architecture for Real-time Telemetry Downlink

Successful operation of the SMAP mission requires the reliable use of robust GDS automation. The automation software must be highly available, and automated procedures must be performed in a timely manner. Therefore, system monitoring software will be used to detect and respond to anomalous system behavior. A monitoring solution based on the open-source Zabbix and Nagios software will perform the system monitoring function for SMAP GDS. This system will provide a means to monitor GDS automation resources, restart failed processes, and provide closed-loop notification to the GDS support team in the event of automation anomalies.

VI. Conclusion

As GDS development for SMAP continues towards a November 5, 2014 launch date, upcoming system tests will certify the readiness of the GDS automation software and architecture for lights-out operation. Although lights-out operation has been partially demonstrated in the past, SMAP represents the first JPL mission that will utilize a fully lights-out approach for routine operations. The architecture and approaches used by SMAP will set the baseline for future JPL Earth science missions.

VII. Acknowledgement

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