ULSGEN (Uplink Summary Generator)

Y.-F. Wang[1], M. Schrock[2], T. Reeve[3], K. Nguyen[4], and B. Smith[5]
Jet Propulsion Laboratory, Pasadena, CA, 91109

Uplink is an important part of spacecraft operations. Ensuring the accuracy of uplink content is essential to mission success. Before commands are radiated to the spacecraft, the command and sequence must be reviewed and verified by various teams. In most cases, this process requires collecting the command data, reviewing the data during a command conference meeting, and providing physical signatures by designated members of various teams to signify approval of the data. If commands or sequences are disapproved for some reason, the whole process must be restarted. Recording data and decision history is important for traceability reasons. Given that many steps and people are involved in this process, an easily accessible software tool for managing the process is vital to reducing human error which could result in uplinking incorrect data to the spacecraft. An uplink summary generator called ULSGEN was developed to assist this uplink content approval process. ULSGEN generates a web-based summary of uplink file content and provides an online review process. Spacecraft operations personnel view this summary as a final check before actual radiation of the uplink data.

I. Introduction

The uplink process plays an important role in spacecraft operations. Errors in the uplink process could result in the loss of a spacecraft. The uplink process starts with uplink products generation, followed by review, test, approval, and radiation. The process of reviewing and approving command products involves many human interactions which are error-prone. In order to reduce human error and improve performance, ULSGEN was developed to assist this process.

A typical uplink approval process using the ULSGEN software begins with the collection of a set of uplink-related file products such as SCMFs (Spacecraft Command Message File) and DKFs (DSN Keyword File). These files are parsed and analyzed to generate an uplink summary. Users such as mission managers, sequence integration engineers, and designated members of the spacecraft team, sequence team, science team, instrument teams, subsystem teams, and mission control team are required to review and approve the uplink summary before the uplink data can be radiated to the spacecraft. If any reviewer disapproves the uplink summary, the spacecraft uplink manager must resolve the issue and restart the process. Once all reviewers approve, the uplink summary is marked approved, and the ACE may radiate the corresponding uplink data. The entire approval process is performed electronically via the ULSGEN web application with email notifications.

This paper describes the uplink summary approval process, the design concept of the ULSGEN software, project adaptation in a multi-mission environment, and how the software is used in operations.

II. Uplink Summary Approval Process

The uplink summary approval process can vary from project to project, but there are several common steps in this process. Basically, all uplink products needs to be generated, reviewed, tested, and approved before they can be radiated to the spacecraft.

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[1] Senior software engineer, Jet Propulsion Laboratory, 4800 Oak Grove Drive, Pasadena, CA 91109.
[2] Software engineer, Jet Propulsion Laboratory, 4800 Oak Grove Drive, Pasadena, CA 91109.
[3] Senior Software Engineer, Jet Propulsion Laboratory, 4800 Oak Grove Drive, Pasadena, CA 91109.
[4] Software engineer, Jet Propulsion Laboratory, 4800 Oak Grove Drive, Pasadena, CA 91109.
[5] Element manager, Jet Propulsion Laboratory, 4800 Oak Grove Drive, Pasadena, CA 91109.

A. Uplink Product Generation

Before using the ULSGEN software, uplink files must be generated. The main files referenced in uplink summaries are SCMFs (Spacecraft Command Message File) and DKFs (DSN Keyword File). These files are generated using certain software and stored in a repository for approval before the SCMFs can be radiated to the spacecraft.

B. Review and Test

After the command products are generated, all groups and individuals involved must review the products. Tests are conducted. Subsystem reviews occur in this stage, and waiver information is provided if it is needed. The Spacecraft Uplink Manager determines the readiness of the uplink products to start the approval process. The uplink summary is then generated for various parties to review and approve.

C. Approval

The approval process requires all of the groups and individuals involved in the process, such as mission managers, sequence integration engineers, designated members of the spacecraft team, sequence team, science team, instrument teams, subsystem teams, and mission control team, to sign the uplink summary which was generated based on the information in the command products. Some missions have command conferences in this phase to get a general agreement. Approval is the last step before command products are radiated to the spacecraft.

III. Purpose of ULSGEN

Figure 1 depicts a high level view of the uplink summary approval process. It is not a complex process in itself. However, due to the number of people involved and the importance of correctness of the uplink products, it is a sophisticated one. With many human interactions on top of that, the process can be error-prone. ULSGEN is designed to simplify the process by introducing command product parsers, versioning, and an electronic signature cycle to streamline the approval process. It is also designed to be easily adaptable by new missions with new file formats and new summary forms in a multi-mission environment. This allows operators to use similar software interfaces with different data formats and functions for different missions. Because ULSGEN is implemented as a web application with a database backend, it supports a large number of users in various operating computing environments without requiring installation of a desktop application on client machines.

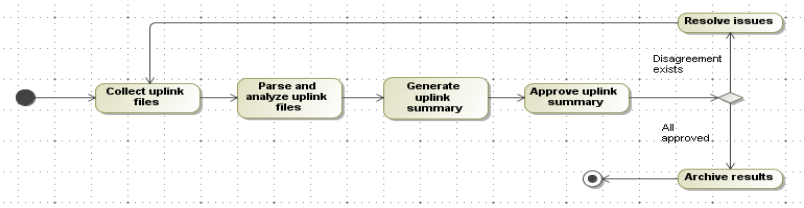

Figure 1. High level process of the uplink approval process.

IV. Software Design Concept and Implementation

Detailed below are the major design concepts which influenced the architecture and implementation of the ULSGEN software.

A. Code Reuse

Before ULSGEN, tools existed which could adequately perform certain aspects of the uplink summary approval process, such parsing SCMFs. Instead of rewriting everything from scratch, ULSGEN's software philosophy was to take reusable pieces from existing software, refactor them as necessary, and add ways to adapt the software for use in a multi-mission environment.

B. Multi-tier Design

Like many modern information systems, ULSGEN is a multi-tiered loosely coupled system. This allows considerable flexibility for future evolution of the software and integration with other software systems. The three major tiers in ULSGEN are data, computation, and user interface. In order to make the system accessible to users in various computing environments without requiring installation of client desktop software, ULSGEN was developed as a browser-based web application. The web front end communicates with the middle tier for computation and

analysis, while the middle tier communicates with a back end relational database. In this particular implementation, the web pages are written in PHP, the middle tier code is written in Java, and MySQL is used for the database.

C. Web Services and Automation

Many missions like to automate common tasks in order to save time and money. For the uplink summary approval process, there are times when missions wish to completely automate uplink summary generation and even approval. In order to support this use case, ULSGEN provides a representational state transfer (REST)-based API which acts as a wrapper to middle-tier functionality. While users normally use the ULSGEN browser-based web interface, automated mission scripts can call the REST-based API. Both methods use the same middle-tier functionality and underlying database for their operations.

D. Security

Because the ULSGEN system involves mission-specific uplink data files and is designed to be accessed by multiple missions, it is important to have proper authentication of users as well as authorization controls which prevent one mission's users from accessing other missions' data.

ULSGEN uses a basic authentication scheme using Lightweight Directory Access Protocol (LDAP), while the Hypertext Transfer Protocol Secure (HTTPS) protocol is used to secure communications between the browser and middle-tier web services. For authorization, ULSGEN uses a "workspace" concept. Uplink summaries are contained in a workspace, and permissions can be set on a per-workspace basis. Usually, each mission has a single workspace and sets permissions on that workspace so that only that mission's users can access uplink summaries in that workspace and only a subset of those users can actually create new uplink summaries. This permission scheme provides simple but robust authorization capabilities.

V. Adaptation

Each mission has different requirements for uplink summaries. While all current missions require data in SCMF files, the actual content and layout of the uplink summary can vary from mission to mission. ULSGEN provides four areas of adaptation to address the needs of a multi-mission environment.

A. File Parser Extension

ULSGEN provides some standard file parsers, such as a SCMF parser and a DKF parser, which provide a decent amount of information from the parsed file. However, a project may need additional data from a file or data in a different format. During the adaptation process, the generic parser class can be extended and developed to include additional information in a relatively easy way. For example, Mars Science Laboratory (MSL) has bundled sequences in one SCMF file. The common SCMF parser does not generate that information. Therefore, an MSL-specific SCMF parser was derived from the common SCMF parser to generate data with bundled sequences. Because the derived parser contains the functionality of the base parser, data from the common parser is still available in the derived parsers.

B. Data Template

A data template is used to determine which fields (from either the parsing results or independently entered data) need to be included in the uplink summary. The data template is data driven, which means projects can construct their data templates from within the ULSGEN user interface without programming assistance or software release. Figure 2 depicts the concept of the data template. After the file parsers generate a complete set of data, the data template determines which of those fields should be included in the uplink summary, as well as which fields are editable by the user. ULSGEN only stores the data specified by the data template in the database for each uplink summary.

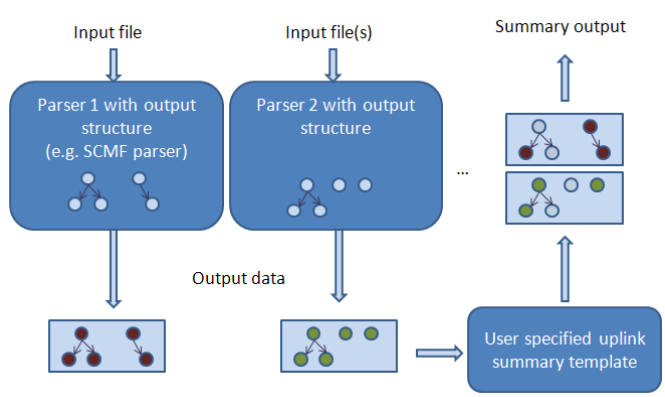

Figure 2. ULSGEN data template concept for adaptation.

C. Dataset Template

The dataset template defines the default grouping and hierarchy of files and required signatures in the uplink summary. Basically, it defines how the data is organized. For example, if a project has a set of "main" SCMF files for normal radiation as well as a set of "contingency" files, the dataset template can organize the summary into a top-level dataset with two subsets of data: one for main SCMFs and one for contingency SCMFs. In addition, a set of required signatures can be specified at any level of the dataset, such as the lower level group of main SCMFs or at a higher level which indicates approval of both main and contingency SCMFs. The dataset template allows projects to define a default structure of file inputs and required signatures which will apply to new uplink summaries. However, users can also change the default structure for individual uplink summaries during the configuration phase.

D. Report Template

Each mission can specify its own uplink summary report format, which defines the look of the uplink summary presented to users in the browser-based web interface. Because different missions desire different ways to present the uplink summary in the web interface, different report templates must be used. In order to provide the highest level of flexibility in this regard, ULSGEN allows each mission to have its own set of PHP files for generating uplink summary report pages while keeping common pages the same for all projects. This is performed by having a separate folder for these report template pages for each mission in the ULSGEN web application. Because no code needs to be recompiled and changes to one mission's set of report template pages will not affect other missions, changes can be made to these pages without requiring a new software delivery.

VI. ULSGEN in Operations

A. Login and Workspace

In order to use ULSGEN, a user must first log into the system using his/her LDAP credentials. Once the user logs in, a list of workspaces that the user has permission to access is shown in the browser (see Figure 3). The hyperlinks in this page can connect to pages that allow the user to modify uplink summary data templates, manage groups, configure workspaces, and set workspace access permissions if the user has the privilege to do so. Each workspace serves as a container for uplink summaries with a specific configuration. Each mission should have its own workspace, but missions may have multiple workspaces for further organization and separation of data. The owner of a workspace can specify the data template, dataset template, and report template used by uplink summaries in that workspace via the workspace configuration page. Owners also have the ability to configure user permissions.

Figure 3. ULSGEN workspace selection with dummy test data

B. Uplink Summary Listing and Search

After selecting a workspace in the workspace listing page, ULSGEN will show a page with a list of all available uplink summaries in that workspace (see Figure 4), along with the status of each uplink summary. Users can also use the search capability on this page to search for specific uplink summaries in this workspace. The search function allows searching on a partial SCMF filename, summary creator, required signer, words in the uplink summary metadata, and/or the summary itself. This page also provides a link to metadata, logs, and user comments about each

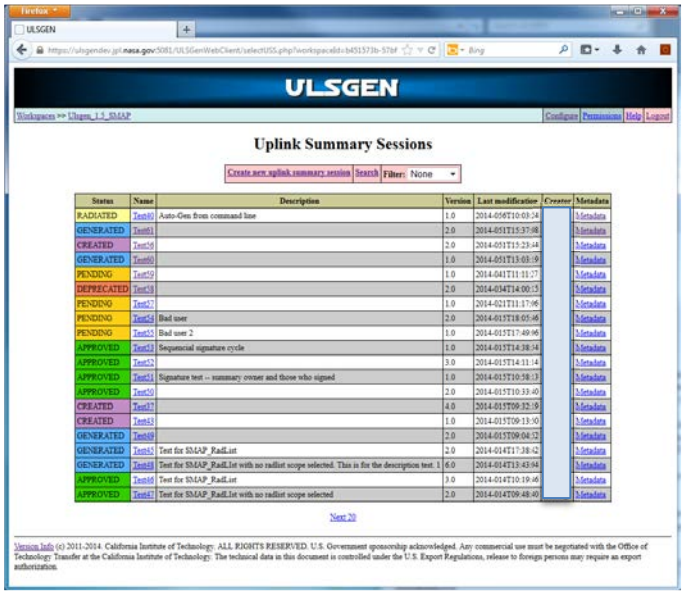

Figure 4. ULSGEN uplink summary list with dummy test data in a workspace.

uplink summary.

C. Create Uplink Summary

If a user has the proper permissions, he/she can create a new uplink summary from the uplink summary listing page by simply providing a name for the new uplink summary. Additional metadata is encouraged for clarity and search capabilities, but it is not required. After this action, users can then configure how the uplink summary should be generated. This includes selecting the report template, dataset structure, SCMF files, uplink window files, and required signatures.

Figure 5 shows an example of the uplink summary configuration page. The default configuration is inherited from the workspace settings. However, users can modify the settings for a specific uplink summary, including the organization of the uplink files and required signatures.

Once the configuration is finished, the summary creator can click the "Generate summary data" button to generate the uplink summary. During this process, data is generated by parsing the SCMFs and uplink window files. Afterwards, users can modify this data if needed. For example, the creator of an uplink summary may want to add comments regarding flight rule violations or testing. Some users may even want to change the uplink rates of certain SCMFs and have the uplink durations be recalculated. ULSGEN supports these kinds of editing and calculation capability. ULSGEN administrators can define which data fields in the uplink summary are editable in the data template.

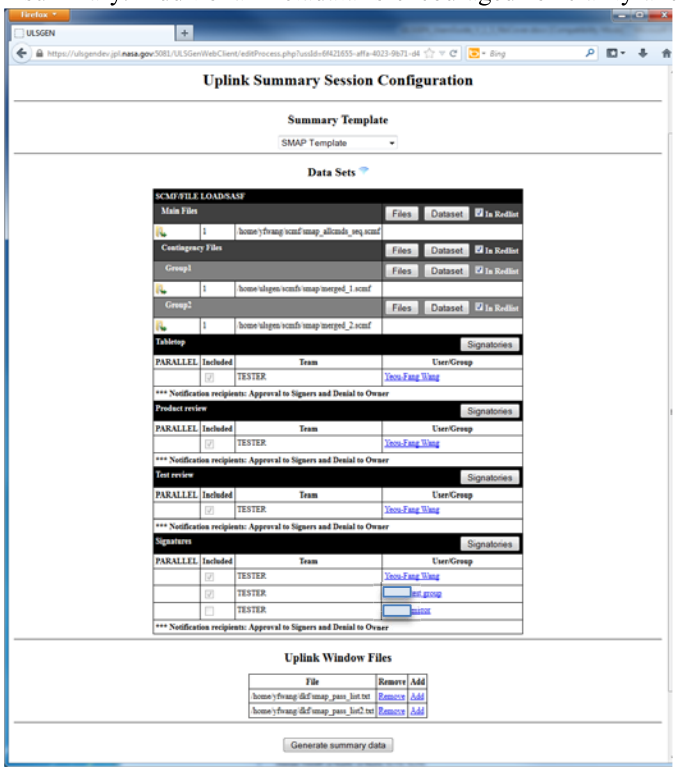

Figure 5. ULSGEN uplink summary configuration page

In order to more easily track changes, each uplink summary has a version number *M.m*, where *M* is the major version number and *m* is the minor version number. When an uplink summary is generated, the major version number is incremented. When a user modifies the uplink summary, the minor version number is incremented. Figure 6 depicts an uplink summary generated with test data.

D. Signature Cycle

Once the uplink summary is generated and ready to be signed, the owner of the uplink summary (usually the Spacecraft Uplink Manager) can start the approval process. ULSGEN provides a simple interface for starting signature cycles and displaying signature cycle information (see Figure 7). When a signature cycle is started, email notifications are sent to various parties according to the uplink summary's configuration. Signatures can be configured to be parallel (everyone is notified simultaneously) or sequential (the next signer is not notified until the previous signer in the list has approved the uplink summary). Notification emails contain a link to the uplink summary in question and direct the user to review the data in the uplink summary and either approve or deny the summary using the signature cycle page.

E. Report Generation

While uplink summary reports can normally be viewed via ULSGEN's web interface, ULSGEN also provides the ability to generate a PDF file. This allows the uplink summary report to be archived in a file system or content management system so that ULSGEN is not required for accessing historical data. Special reports can also be generated upon based on mission requirements. For example, ULSGEN generates a radiation information file specifically for the Soil Moisture Active Passive (SMAP) mission.

F. Automation

Many missions use a series of scripts to automate their processes. This practice saves the mission valuable time and money and allows operators and analysts to focus on other tasks. In order to allow missions to integrate ULSGEN in an automated fashion, REST-based web services are provided for performing basic tasks such as generating uplink summaries. In addition, several Python scripts are delivered as examples to show how to interface with these REST web services. Missions may use these Python scripts as delivered or use them as a basis for developing their own set of automation scripts.

VII. Conclusion

ULSGEN improves the efficiency of the uplink review process and reduces the risk of human error. It combines uplink summary generation and signature collection into a single tool and allows missions to customize their reports with user-defined templates. Browser-based applications, such as ULSGEN, provide easy access to all users without hardware or operating system restrictions. The current version of ULSGEN provides the ability to generate a Radlist file, which aids in uplink file radiation. In the future, ULSGEN may be enhanced to record the radiation status of uplink files in order to "close the loop" in the overall uplink process.

Acknowledgments

This work was supported in part by NASA and JPL/CalTech. Authors work at the Jet Propulsion Laboratory of California Institute of Technology. ULSGEN was developed by NASA's Multi-mission Ground Systems and Services Office (MGSS). ULSGEN is currently used by MSL (Mars Science Laboratory), will be used by SMAP (Soil Moisture Active Passive), and is available for use by future NASA missions.

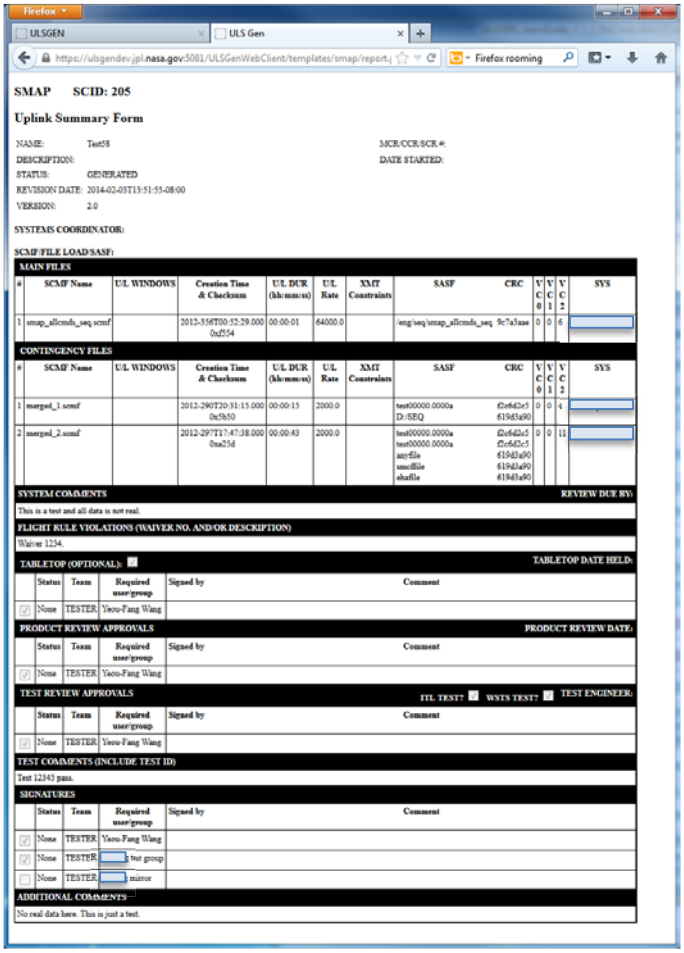

Figure. 6. ULSGEN uplink summary sample with dummy data

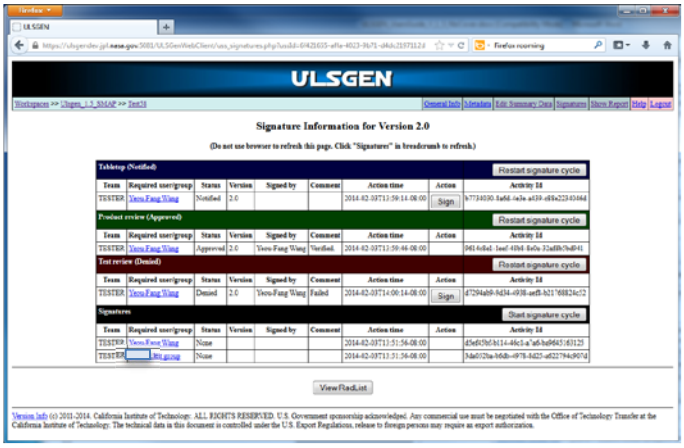

Figure 7. ULSGEN signature page.