Applying Modeling Tools to Ground System Procedures

Final Report for 2012 JPL Summer Space Grant Internship

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Abstract

As part of a long-term effort to revitalize the Ground Systems (GS) Engineering Section practices, Systems Modeling Language (SysML) and Business Process Model and Notation (BPMN) have been used to model existing GS products and the procedures GS engineers use to produce them.

1. Introduction

In the Ground Systems (GS) engineering domain, Mission Operation System Engineers (MOSEs) and Ground Data System Engineers (GDSEs) perform systems engineering functions that are typically learned from years of on-the-job experience. These activities have traditionally been captured in a way that makes it difficult for newer engineers to learn the desired GS engineering procedures.

While GS procedures exist, the current set lacks a desired level of granularity, traceability, clarity, and consistency, and products are not identified with a standard taxonomy. A model-based approach to defining the GS procedures better-describes the roles and responsibilities of MOSEs and GDSEs than traditional training material and product templates.

To create a model that GS engineers can utilize, the MagicDraw Software tool was used to create draft procedures and products models [1]. Using MagicDraw, GS procedures were modeled via Business Process Model and Notation (BPMN), and GS products were modeled via Systems Modeling Language (SysML). Because MagicDraw was used, the models produced can be transformed into human-readable documents using the JPL-developed DocGen (Document Generation) plugin.

Even though the procedures and products are produced in separate modeling languages, they have been linked together through MagicDraw to visualize the relationships between the products and procedures. After the model is refined and expanded, it will become a guiding reference that GS engineers can use to efficiently and consistently generate GS architectures.

Currently, the resulting preliminary model is a comprehensive description of the tasks completed by the MOSE and GDSE throughout the Life Cycle phases of a project, and the products that are produced during those phases.

2. Background

The Ground Systems Engineering Section (318) at NASA's Jet Propulsion Laboratory (JPL) is responsible for the design, implementation, testing, integration, and support of various ground-based operations through the mission’s life cycle [2]. Section 318 manages the ground portion of many projects that utilize the Deep Space Network, which allows for unbroken communication with a variety of spacecraft [3]. As seen in Figure 1. Systems that Section 318 is responsible for are distributed among several different countries.

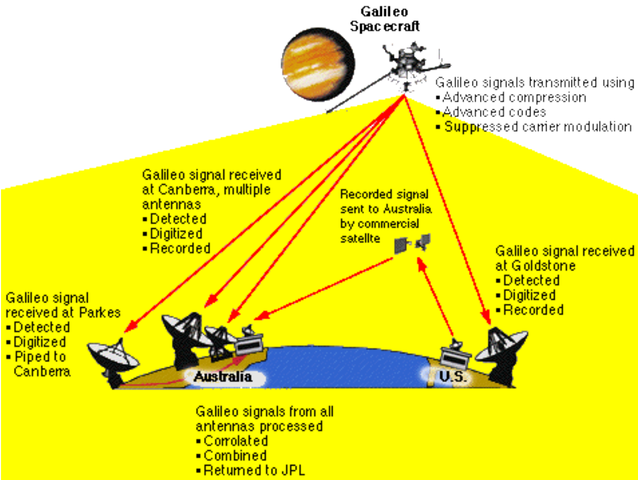
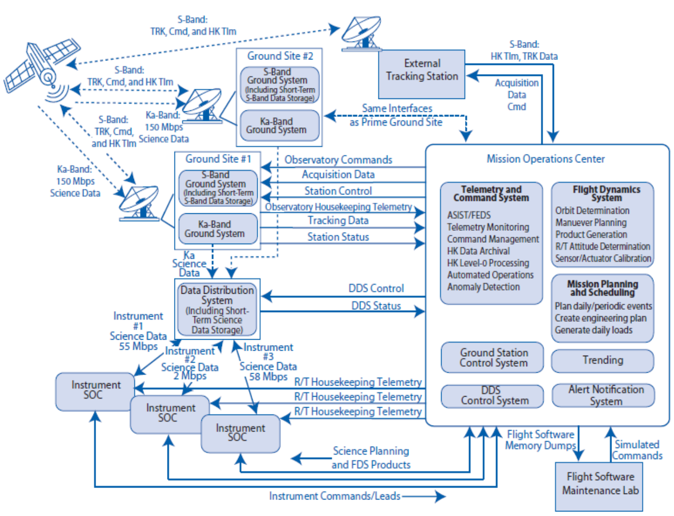


Figure 1. Example ground system [3]

In order to provide the necessary support to each mission, Section 318 must consolidate many different projects, and build on existing ones. This leads to complex networked ground systems that can be challenging to manage effectively. Additionally, as the complexity of the network increases, the chance that there may be “gaps” in the design increases as well [4]. As seen in Figure 2, the topology of interconnections of



a ground system can be fairly complex.

Figure 2. Typical operational architecture [2]

Given the complexity and scope of Section 318’s operations, different space mission projects may have different taxonomies that make collaboration and reuse among projects more challenging. Additionally, that project taxonomies can be dissimilar makes it more difficult for engineers outside the project to give constructive feedback about the the project during design reviews. Additionally, without a standardized products model, there is a significant chance that projects with similar goals may not be able to collaborate, thus wasting limited resources and time achieving the same task twice.

By developing a consistent approach to ground systems representation and Systems Engineering (SE) procedures definition, the overall effectiveness of Section 318 can be increased. With a consistent approach, any engineer familiar with the use of model-based systems engineering practices would be able to understand the basic structure of any other project, which would increase the effectiveness of feedback and the chance of collaboration, via more effective communication, between projects.

3. Objectives

As part of the long-term “effort at JPL to revitalize GS engineering processes and products using model-based engineering techniques” the procedures used by JPL GS engineers throughout the project lifecycle are to be modeled [4]. While an initial procedures model previously existed, it was created using SysML, not BPMN. The new model will update and expand the previous model using BPMN because this notational language has a richer ontology for describing business procedures than SysML.

4. Approach

The project consisted of a team of two engineering students, Peter Di Pasquale of the Space Grant program and Samuel Szuflita of the Summer Undergraduate Research Fellowship (SURF) program. To ensure satisfactory project completion, Subject Matter Experts (SMEs), mentors, and group supervisors were consulted on a weekly basis.

To create the combined model of 318's existing procedures and products, Object Management Group's (OMG) SysML and BPMN were used. SysML is a systems modeling language based on the Unified Modeling Language (UML). It is designed to represent complex systems in a conceptually simple manner, so it is ideal for the project. BPMN is a graphical representation of a business process that is designed to coordinate the "sequences of processes and the messages" that are exchanged by collaborators in related activities [5]. BPMN is ideal for modeling GS procedures, since it has many different ways of passing and receiving messages, a vital part of the GS procedures.

In order to implement the SysML and BPMN model, MagicDraw was used. Magicdraw is a commercial modeling tool designed to assist engineers with Object Oriented Design and Analysis methods. MagicDraw is already used by GS engineers at JPL, and has JPL-developed document-generating plugins that allow models to easily be transformed into human-readable documents. Since MagicDraw was used to create the model, any GS engineer at JPL will be capable of navigating and updating the model without special training, which will make the model simple to update in the future.

Since the project is expected to be refined and expanded in the future, documentation was created throughout the project that showed the logic and design steps taken. All documentation for the project can be found on *Section 318's System Engineering Processes for Realizing Mission System Architectures*[1] internal wiki website. The documentation includes references, the current version of the human-readable model, and comments about the model. It will allow an engineer previously unfamiliar with the project to update and expand it in the future with minimal research.

5. Results

Over the course of the summer, the GS procedures have been modeled in equal or greater detail than current documentation provides. As can be seen in Figure 3, the sentence "Perform a trade study to explore whether existing in-house Ground Data System or an external commercial GDS will satisfy mission requirements. Using the results of this trade study, generate a trade study report" does not show the input and output products as clearly as a BPMN Process Diagram accomplishing the same task.

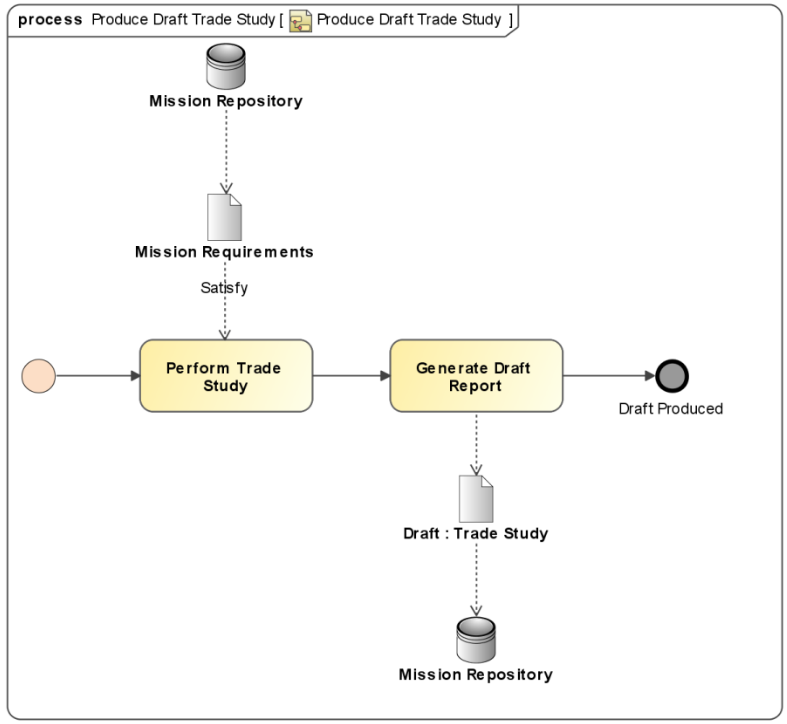


Figure 3. Example BPMN Process Diagram

Using a model-based approach has allowed the procedures to be refined by creating levels in the model that each are further developed through sub-processes. Although there was insufficient information to populate all of the lower-level sub-processes this summer, in the future the added detail will be helpful to GS engineers who are not familiar with the details of a particular step in the procedure.

In order to have as complete and accurate a model as possible, where applicable, MOS and GDS phases that were not specifically documented in JPL Rules documentation have been modeled to provide MOS and GDS engineers with logic to follow where standard procedures have not been defined. An example of such a situation is evident during the closeout of a project; GDS engineers have no specific process to close projects, but are responsible for ensuring mission data remains accessible to science teams or backed up as applicable. By modeling a generalized process, GDS engineers will have a useful reference to consult near the completion of missions.

[1] https://jplwiki.jpl.nasa.gov:8443/display/318SE/Home

The GS products model has also been started, and has been based off of existing templates found in JPLRules documentation. While not every product has been modeled, eventually the model will include all the gate products produced by the GS domain, as well as show the relationships between gate products and the components that they consist of.

As each product was modeled, it was linked to the BPMN model to show the relationships between the processes and the various document maturity states. By linking the document states to the processes that produce them, the model can take the place of both the GDS and MOS processes documents and the GDS and MOS Products list. A model showing both its components and the process that produces it can be seen in Figure 4.

elements that are necessary for particular products have also been modeled, to provide context to viewpoints in a product.

Additionally, the products have been modeled from a development perspective. This perspective takes the product and its development states, and shows its relationship to the procedures that produce and refine each version of the document. While this information could be found in the procedures model, it is more descriptive from the product perspective to show all the procedures that have an effect on a given product on one diagram.

While the draft of the procedures and products model has been completed, it is not currently fully consistent. In some cases, the processes to model are unclear and

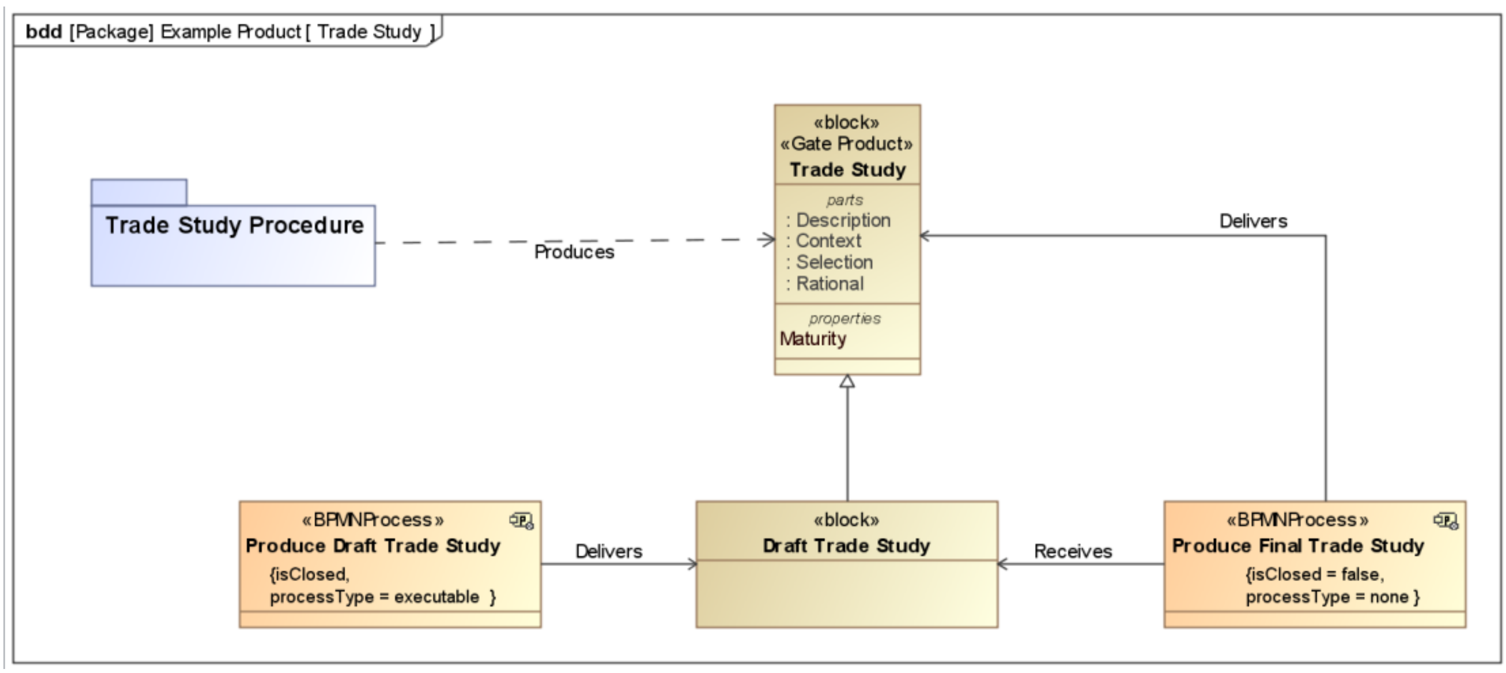


Figure 4. Product Component Model

Where applicable templates were found, the products were modeled. The products model shows the basic relationships between products, and the basic structure of the views that products consist of. To fully capture the products, the products model was split into two perspectives.

First, the products have been modeled from a component perspective. The component perspective of each product shows what that product is expected to include. Each product is composed of sections that are expected to appear in the product, and each section is composed of design elements. Where applicable,

the taxonomy is inconsistent between MOS and GDS; this can lead to separate processes in MOS and GDS that both accomplish the same goal, which is inefficient modeling. Additionally, several BPMN-specific bugs have been found in MagicDraw that have hampered efforts. Each bug has been reported to the software vendor, and several of them are currently being addressed by support staff. It is hoped that before efforts to expand the model are made that all bugs will have been addressed. Currently, identified bugs that affect tree searching using the BPMN plugin are scheduled to be fixed with the release of Magicdraw version 17.02 (Note: the modeling work has been completed in version 17.0).

6. Discussion

The initial draft model of the GS procedures has been created. Where possible, the draft has expanded the current GS procedures. Where applicable, the model shows input and resulting products, allowing engineers who use the model to easily identify expected sources during the engineering procedures.

In order to better create a useable model, when work is resumed on the model, efforts will be made to associate the model with existing the JPL Operations Revitalization (OpsRev) task. The OpsRev team has been working on developing a GS products model, but it is currently incomplete. Once the OpsRev products model is complete, the products drafted in the current model will be replaced with the detailed OpsRev products, increasing consistency in the GS product and their linkages to the descriptions of the procedures that generate them.

To better improve the readability of the model, future work on the model will incorporate the IMCE DocWeb functionality. DocWeb will allow feedback by any DocWeb user that will be used to refine the model, and further its usefulness.

7. Conclusions

In the future, the process models will be refined and expanded, and the taxonomy from the products model will be integrated into the GS Ontology that Sam Szuflita has been creating. To refine the processes, more in-depth information needs to be gathered from GDS and MOS Subject Matter Experts, and modeled in BPMN.

Concurrently with the refinement of the procedures, the existing products model will need to be expanded and merged with the OpsRev products model. The products can each be defined by researching deliveries from previous JPL projects, and identifying the necessary views that the products consist of. By merging the OpsRev products model with the current model, the critical connection between current procedures and the revitalization of SE practices will be made. In the future, the completed model may be a bridge between revitalized operations and traditional practices that shows how both can produce consistent, high quality products.

8. Acknowledgements

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9. References

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