Methodologies for Improving Flight Project Information Capture, Storage, and Dissemination

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Abstract—As the complexity of Flight Projects continues to grow, the management of information has become the underpinning of effective organizational communication. Documentation is the preferred method for capturing and disseminating information in organizations and at the Jet Propulsion Laboratory (JPL), there are a series of documents called Gate Products that each Flight Project is required to generate. The goal of these documents is to capture the requirements, concepts, design, and testing plan for a given project such that it is reviewable and can easily be shared across the project. The process for generating these documents on Flight Projects, however, is typically done through a series of informal inquires for older versions of a needed document which is then updated with project specific information. This can present a number of problems which can increase overall cost and risk to the project.

At JPL, the Project Support Office (PSO) developed a common-sense approach for improving the way in which project information in gate products is generated, communicated, and stored. This task, called Document QuickStart, consists of 3 phases:

- Fifty-eight projects from Earth, Mars, Astrophysics, and Outer Planets missions were data-mined for existing examples of Gate Products. These examples were then posted in an easily accessible area for scientists, engineers, and managers looking for examples of a particular gate product.
- From these examples, templates of key Gate Products were system engineered and peer-reviewed in an intuitive multi-mission format with both narrative description of content as well as boiler plate formatting.
- Finally, in conjunction with the Office of the Chief Information Officer (OCIO), a tool, called DocAssist, was developed for the storage of project specific information that then could be used to pre-populate the existing templates providing a user with a more mature entry point into document development.

This paper will discuss the drawbacks and risks of the current documentation paradigm, how Document QuickStart improves on that process and ultimately how this stream-lined approach will reduce risk and costs to the next generation of Flight Projects at JPL.

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1. INTRODUCTION

Since the launch of Explorer 1 in 1958, the Jet Propulsion Laboratory (JPL) has been directly involved in the Design, Development, Integration, Testing and Operations of nearly 100 spacecraft and instruments. And today, JPL has 35 active Flight Projects and 22 instruments[1] that are in various phases of their respective project life-cycles. Each instrument and spacecraft is being or will be used in a wide variety of environments including orbital and surface operations on the Moon and Mars, Astrophysics, Outer Planets, the Sun, comets, asteroids, and of course the Earth. These fundamentally different missions, however, all require an effective method of information capture, storage, and dissemination.

The way in which a project manages its body of knowledge has a profound effect on the efficiency and efficacy of knowledge transfer within that project. A poorly maintained body of knowledge can result it unnecessary impacts to budget and schedule, the loss of tacit knowledge, miscommunication, and even project failure.

In order to standardize the process of knowledge management, NASA has implemented a set of required documents, called Gate Products, on new Flight Projects which is captured in 7120.5D, "NASA Space Flight Program and Project Management Requirements". This

[1] 978-1-4244-7351-9/11/$26.00 ©2011 IEEE
[2] IEEEAC paper #1831, Version 2, Updated Jan 5, 2011

document specifies the methods for compliance with this knowledge capture requirement which is then "verified by submission to responsible NASA officials, at key decision points, of the gate products identified in this document and by internal and external controls"[2].

In addition to this list of required documents, JPL also requires a set of one-hundred and forty-four project life cycle gate products which Flight Projects must develop as part of each life cycle gate transition. This list of gate products is consistent with JPL's Flight Project Practices.

2. DOCUMENT QUICKSTART

In 2008, the Document QuickStart Program (DocQS) was formed and tasked with evaluating and improving the methods for knowledge capture, storage, and dissemination specifically concerning the gate products required by 7120.5D and by JPL.

The issues that DocQS were to address: Establish improved processes to:

- Obtain existing documentation
- Think about design issues earlier in the process
- Streamline the documentation process
- Assist in the preparation of documentation for reviews
- Standardize review products
- More easily create documentation that is also more robust

This Program was divided into 3 phases; Data Call, Template Development, and DocAssist Development.

2.1 Data Call- Document Collection

For the initial of the data call, twelve projects were selected which represented a cross-section of projects at JPL in various stages of the project life cycle; from design to operations. The projects contacted were Cassini, CloudSat, Kepler, WISE, Aquarius, OCO, MRO, Pheonix, MSL, Dawn, Juno, GRAIL. Table 1 below lists the projects, the primary mission target for each project, the launch year, and approximate budget.

Project	Primary Target	Launch	Budget
Cassini	Saturn	1997	$3.2B
MRO	Mars	2005	$720M
CloudSat	Earth clouds	2006	$200M
Phoenix	Mars	2007	$325M
Dawn	Asteroid Belt	2007	$450M
Kepler	Extra-Solar Planets	2009	$600M
WISE	Astrophysics	2009	$320M
OCO	Earth atmosphere	2009	$170M
AQUARIUS	Earth oceans	2011	TBR
MSL	Mars	2011	$2.3B
Juno	Jupiter	2011	$700M
GRAIL	Moon	2011	$375M

Table 1 – List of projects contacted for DocQS Data Call

This was expanded to 58 projects a year later. System Engineers from each project were interviewed to both obtain the existing gate product documentation and to learn of the methods used to document gate product information.

From these interviews, several observations were made. First, the current process for documentation was informal for 10 of the projects polled. From the responses received regarding project documentation processes, System Engineers would track down and then update an old example of the required document. The old example would effectively act as a template. This process however, has several inherit weaknesses.

- Deficiencies in the old document are carried forward.
- Potential issues/trades are not considered early in process.
- Inconsistent formats for reviews and knowledge transfer.
- Time consuming process to track down the "example", latest version, access to server, etc.

The second conclusion was that only a subset of the required gate product documents was being generated. Of the 144 gate products required by JPL, there were zero examples provided by any of the twelve projects for 28 gate products.

The reasons for non-compliance varied:

- Information was captured in another document
- Information was captured as part of review packages
- Information was not applicable to our project
- Information was not formally documented
- Unable to locate the document
- Document is incomplete
- Information was contractor-specific so will not provide

The third conclusion was that gaining access to these project gate products was time consuming and often involved contacting numerous people to gain access to individual document collections or contacting individual authors for the most recent version of a given document. And once documents were gathered, a review process was needed to determine the nature of each document. Inconsistencies in document formatting revealed gaps and overlaps in project documentation. Projects opted to merge some gate products and split others making the information validation that much more time consuming.

In all, more than 500 examples of gate products were collected from the 12 projects and those documents were placed on the Project Support Website. At least one example from 88% of the gate products was obtained and at least 4 examples of 41% of the documents.

2.2 Template Library Development

With the data call complete, examples were reviewed for accuracy, completeness, and compliance with NASA and JPL requirements. Each of the examples were unique, however, it was noted that there were similarities and trends of information capture in the examples. Sensitive and contractor-specific information was redacted. Evaluating the examples to identify those of higher quality was considered but rejected because of the lack of an objective evaluation method.

From these examples, multi-mission gate product document templates were system engineered for 20 of the most often generated gate products. The templates were generated in Word format and included two types instructions for the user. Where appropriate, the user is provided with boiler plate place-holder text where keywords (e.g. *name of project, name of instrument, launch date,* etc.) would be replaced with the appropriate value (e.g. GRAIL, Ka-band Lunar Gravity Ranging System September 8, 2011, etc.) The boiler plate approach was typically employed where the infrastructure of the paragraph was highly structured and varied little by project. Some examples would include Mission Operations Concept descriptions, Ground Data System descriptions, and Functional Design descriptions.

For sections that were highly project specific, (e.g. a description of the science, unique operations procedures, etc.), directions were provided as to the required content of each document section. Often a list of the types of information contained in each section is provided based on the examples obtained. Where applicable, these directions would encompass a wide variety of types of missions where directions relevant to the mission type were provided. Prior to release, the templates were evaluated by selected "subject matter experts, cognizant Line Organizations, and institutional reviewers" for feedback and approval. [3]

The strategy for the establishment of templates was not to remove the user, i.e., project personnel, from the documentation process but rather to reduce the monotony of generating the required documentation and provide clear direction with a robust system engineered document that is a superior starting point than an old example. The templates provide a comprehensive list of information that needs to be captured by the user in accordance with JPL and NASA requirements. And in the process of capturing this information, trades that need to be considered early in the process are identified.

Additionally, templates provide an effective vehicle for capturing lessons learned. In future versions of the templates, knowledge gained through current flight project experience can be captured in the form of notes, directions, or considerations for the next generation of flight projects.

2.3 DocAssist

One of the conclusions that we made from the template generation process was the clear repetition of specific pieces of information in each of the examples and across different gate products. For example, the *name of the project* was captured in nearly every document collected. Likewise, the launch date, date of arrival, primary target, as well as the

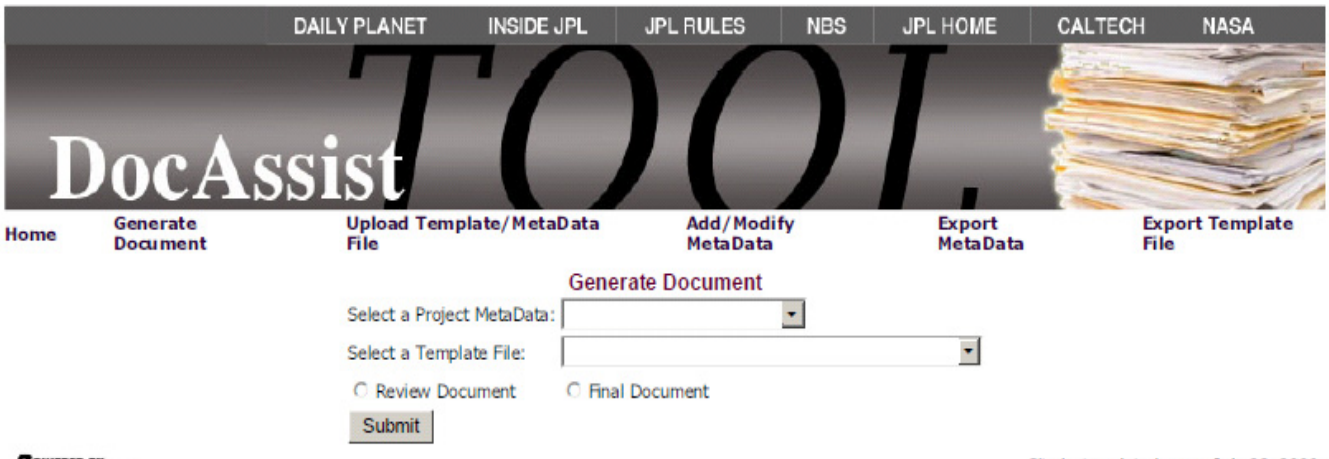

Figure 1 - Screenshot of DocAssist GUI

names, acronyms, developers for each of the instruments, were all repeated in many locations across various gate product examples.

In conjunction with the Office of the Chief Information Officer (OCIO), we developed a web-based documentation tool called DocAssist. The purpose of this tool was straight-forward; to store project specific information that could then be autonomously merged with an existing set of gate product templates.

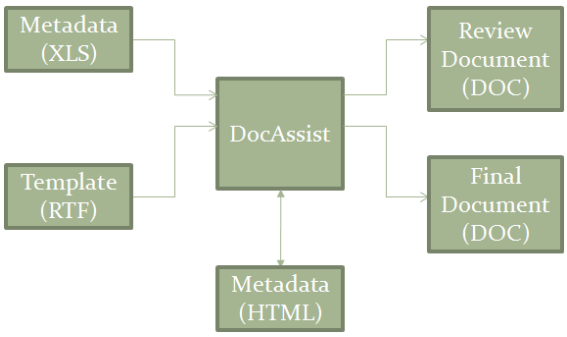

Figure 2 – Basic DocAssist Tool Architecture

With this tool, the user has the capability to create and maintain a database of project specific information either via the web-based Graphical User Interface (GUI) which is shown in Figure 1 or an Excel file that is uploaded and processed by the server. This database of project metadata is stored in the form of a keyword and value pairing and can be exported for review and modification. An existing library of gate product templates is provided to the user in Rich Text Format (RTF) format.

When the user selects a specific project and template, the project metadata is then merged with the chosen template and a new document is generated where keywords within the template are replaced with corresponding values as defined in the project metadata file. The user has the option to create a review document where all replacements are highlighted in blue or black. The basic structure of DocAssist is captured in Figure 2.

DocAssist is not a document *automation* tool nor is it designed to take the document owner out of the loop. Rather, it is a series logical and efficient steps which assist the customer in creating a document that is more robust and more mature than simply starting with a random potentially incompatible example. We believed that the customer should always be in the documentation loop, reviewing and modifying a document generated with DocAssist.

Further, DocAssist provides a common location for project metadata which any document template would be able to harvest for the latest information. Aside from the benefits of assisting in the documentation process, having a "gold standard" database for project specific information creates consistency across all project documentation. DocAssist effectively becomes a configuration management tool for common high frequency information on a project.

3. Return on Investment

The DocQS task was a JPL institutional investment and a positive Return-on-Investment (ROI) was expected. The total time complete the DocQS task to date was 2 work-years and subsequently the goal of DocQS is to provide resources to a user to make the documentation and knowledge management process more efficient which should result in time savings for the user and the project and ultimately a positive ROI. Due to the nature of the savings realized by projects using DocQS, a true ROI is difficult to establish and estimates must be made.

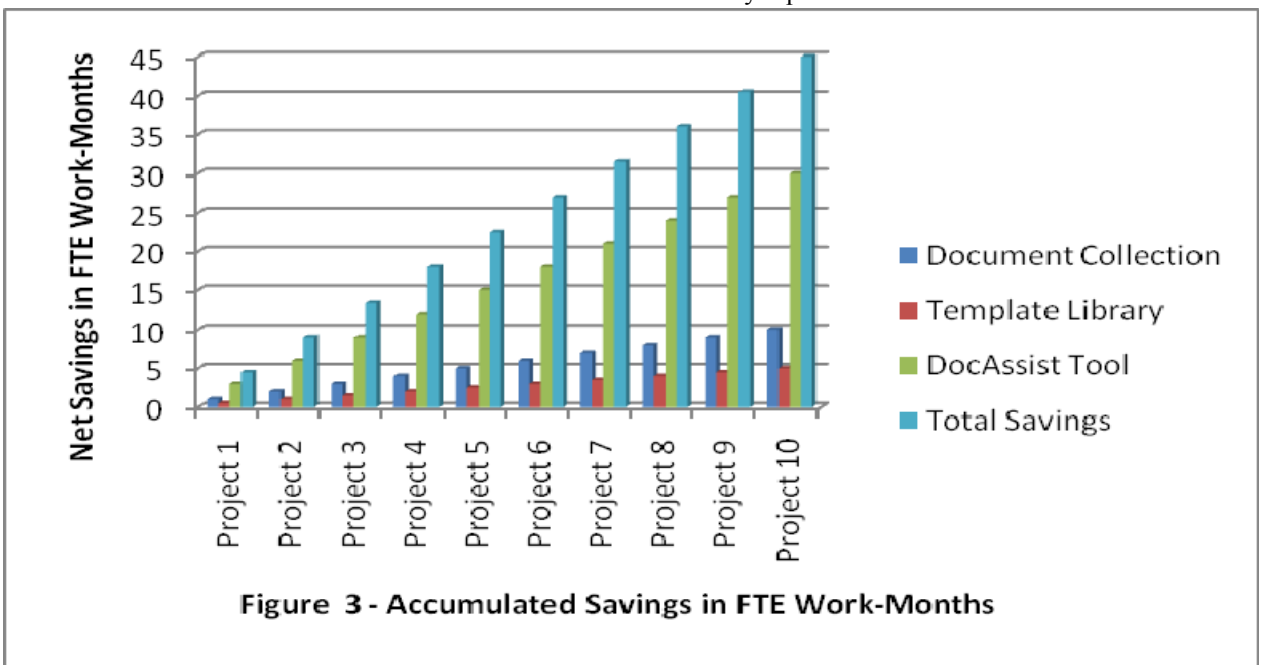

Figure 3 - Accumulated Savings in FTE Work-Months

To predict the savings that future projects will obtain by using the DocQS resources as compared to the current documentation paradigm, estimates were made on the savings realized in specific elements of the work breakdown structure (WBS). To establish this, the owners of the Team X (the JPL organization responsible for costing future missions) cost model and cost element leads were asked to estimate the savings in work-months in each of their areas. Savings realized for various projects will of course be different based on the complexity of that mission. Larger more complex missions will receive greater benefit in dollars from DocQS. For the purpose of this ROI calculation, it was assumed that a series of New Frontiers Missions (with a cost cap of $700 million) would use the DocQS. Savings in work-months for each phase of the DocQS task were computed.

Here we will discuss the process for estimating the savings realized by each of the DocQS resources provided to the user.

3.1 Project Savings for Document Collection

Having a centralized database of historical project documentation cuts down on the time required to locate a particular document. In addition, it also provides the user with a greater pool of examples to more precisely match the current project. Without this database, the process for tracking down and gaining access to a particular document, could take between 0.5 hours (you have the document on your hard drive) to 2 days (i.e. in order to track down the document, one would need to go through several people, phone calls, emails, access to various servers, iterations on versions, etc.) before successfully retrieving the needed document.

The projected value of such a centralized data base for 144 gate products would range from 2 work-weeks to 2 work-months of saved time depending on the complexity and uniqueness of the Flight Project. For the ROI calculation, one work-month saved per project is assumed.

3.2 Project Savings for Template Library

The use of a template library eliminates the need to become educated about required gate product structure and it streamlines the documentation process by providing specific directions on how to complete the document.

The projected value of using a Template Library as compared to the current methods of documentation, would be small. Both the template and an example generated by a previous project would both need to be updated. The process for documenting the project information would be more clearly defined which would translate into some saving. For the ROI calculation, two work-weeks saved per project is assumed.

However, having well designed templates will make the gate product production process more robust.

More robust documentation implies a more robust design which reduces risk and could potentially lead to time savings later in the process. A template would identify more engineering trades to be considered earlier in the process. This savings, while real is nearly impossible to objectively quantify and therefore is not included in the ROI calculation.

3.3 Project Savings for DocAssist

With the use of DocAssist to pre-populate existing templates, the customer would see negligible time savings for the first document. The time spent entering information into a database is roughly equivalent to time spent replacing fields in a template. However, all subsequent documents that reference the project database will see between moderate and significant time savings. The amount of time savings depends on the use of preexisting information captured in the project metadata.

The assumption was made that each gate product requires ¼ to 1 work-month to complete, a 25% reduction in the time required to complete the document would save one work-day to one work-week of documentation effort.

Applying DocAssist to the 20 gate product templates would equate to roughly 5 work-weeks to 19 work-weeks of effort saved per project. For this calculation, it is assumed that a project will save 3 work-months in their documentation effort.

However, it is important to note that this is a subset (20 of 144) of the total number of gate product templates possible. As the number of templates increases, the realized savings for DocAssist will also increase. This is scalable and can be extended to all project documentation. As the number of templates increases, and hence the information contained in the project metadata database, so too does the efficiency of this process.

3.4 ROI calculation

Based on the assumptions and calculations outlined in sections 3.1, 3.2, and 3.3 (and captured in Figure 3), the projected ROI after 10 projects is:

(1) Cost of DocQS 24 work-months
(2) Savings from Doc Collection 10 work-month
(3) Savings from Template Library 5 work-months
(4) Savings from Doc Assist 30 work-months
(5) Projected Return-On-Investment
(45 - 24) / 24 = 87.5%

3.5 Project ROI from future Missions

The calculation in section 3.4 however, is based on 10 hypothetical missions with budgets of $700M. In reality, the size and the specifics of each project will drive the complexity of each of these documents, the scope and time required to capture the information in document form, and subsequently the impact of the savings from the DocQS initiatives.

In order to establish more accurate ROI projections for future missions, the cost element leads were consulted and algorithms for the DocQS savings were developed and integrated into the Ground Systems Cost Model for Team X, which is the concept costing organization at JPL. Based on a survey of pre-Phase A projects that have used the new Ground System Cost Model with the integrated DocQS modifications, the projected savings from DocQS ranges from $500k to $1.5M over the project lifecycle.

3.6 Additional Benefits

It was realized early in this process that the savings in terms of dollars and time for projects was only part of the benefit of DocQS. There are intangible and perhaps greater benefits that were not used as part of the Return-on-Investment calculation:

- Robust Documentation
- Well-defined "gold standards" of information
- Risk Reduction
- Quality Control
- Flexibility to adapt to changes at JPL
- Ability to capture Lessons Learned

Having documentation that is more robust can reduce cost, schedule, and performance risk for a mission. And having a methodology which enables documentation and information capture more efficiently is critical for adoption of this system. Templates provide a detailed mental framework for exploring various trade spaces across all areas of a project. And with this, projects will be more prepared to handle or avoid schedule slips, cost overruns and even project failure if key trades are explored and captured early in the process. The fiscal significance of this impact should not be overlooked. Even a modest one-percent reduction in project failure rates would be equivalent to a $7M savings for a New Frontiers-class mission. This is seven times the projected savings of DocQS alone.

4. MODEL-BASED SYSTEM ENGINEERING

Model-Based System Engineering (MBSE) is "the formalized application of modeling to support system *requirements, design, analysis, and verification and validation activities* beginning in the conceptual design phase and continuing throughout development and later life cycle phases." [4]

Although there might appear to be an overlap, DocQS and MBSE are not mutually exclusive. Phase 1 and phase 2 of DocQS works in conjunction with MBSE. A model contains information and informational relationships. And while models can be used to create documentation, models need the framework for how information is captured in a user readable format. The system-engineered templates developed by DocQS, provide that direction for MBSE.

5. CONCLUSIONS

In conclusion, DocQS sought to improve the current methods of documentation and to help meet the needs of future projects who must meet the institutional requirements placed on them by NASA and JPL. The goals were:

- Get the right people thinking about trades earlier in the process
- Reduce the tedium of documentation
- Make documentation more robust
- Standardize the Gate Products making reviews more streamlined.

Through the application of common sense initiatives, such as centralized documentation repository, system engineered document templates, and an intuitive document pre-population tool, DocQS implemented process improvements which will help future projects to achieve these goals. The projected savings to future projects as discussed in section 3 is only a subset of the benefits of using the DocQS methodologies. The implementation of an efficient documentation process in which information is managed, templates are system engineered, and documents are more robust is critical for an efficiently run project. Conversely, the current process of starting with an incomplete example from a previous project, with no specific direction on the types and methods of information capture can result in deficient documentation, unexplored trade space, and knowledge loss, which could lead to project schedule and costs overruns and even project failure. Document QuickStart provides an alternative methodology for improving Flight Project Information Capture, Storage, and Dissemination over current methods.

References

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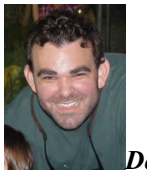
BIOGRAPHY



Douglas Equils *joined JPL in 1997 as a software engineer on the Shuttle Radar Topography Mission where he wrote the payload control software for STS-99. Since then, he has worked as a Systems Engineer on a number of projects including Odyssey, Deep Impact, MGS, and Cassini as a Science Planner. Most recently, he was the Mission Operations lead on two Discovery proposals and is the lead for the Document QuickStart task discussed here. Outside of JPL, Douglas is also an Adjunct Professor of Astronomy at Santa Monica College.*

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Douglas lives in Lake Balboa with his two children, Alex and Anna and his interests include cooking, writing, photography, and playing guitar.