34th Annual INCOSE international symposium
hybrid event
Dublin, Ireland
July 2 - 6, 2024

Modeling NASA's Procedural Requirement Processes - Implications for Digital Future

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Abstract. The National Aeronautics and Space Administration (NASA) has an ongoing Digital Transformation effort and to leverage and showcase the power of Digital Transformation, an effort is underway to develop an integrated, datacentric, model representing NASA's key process requirements. The task was divided into three phases: As Is modeling, Analysis, and To Be Planning. As part of this effort, a team has

completed the first Phase I of the modeling task and is nearing completion of the second phase. This effort will capture the key elements as requirements, responsibilities, allocations, roles, products, and associated lifecycle elements. The scope of modeling included NASA's NPR 7120.5 (Project and Program Management), NPR 7123.1 (Systems Engineering) and NPRs 8705.2 (Risk classification for Robotic Missions) and 8705.4 (Human-Rating Requirements for Space Missions).

This paper will summarize the approach, scope, parsing patterns applied, metamodel, and associated workflows for the As-Is modeling. It will also summarize the results and insights gleaned during that phase, including the review process. These insights have informed the analysis and will be discussed. The analysis modeling phase will also be summarized including how the stakeholders were engaged, how the common elements were handled and dispositioned, and will also describe some of the plans for the future of NASA NPDs and NPRs.

Keywords. MBSE, SysML, process modeling, data-centricity, NASA, digital engineering

Introduction

The ultimate Digital Engineering Transformation (DET) goals within NASA's Engineering domain center around the more effective datacentric flow and management of information in support of standardized engineering and business/institutional processes and workflows (with the required data/information constructs and meta data needed for maximum benefit). Using integrated toolchains (suite of tools used within an organization that are able to share data and information) and associated digital threads across the system lifecycle, will enable programs and projects to decrease the time required to define mission architectures and designs, reduce design errors and later rework, facilitate change impact analysis, and enable datacentric management of all data and information associated with engineering products, services, design, and associated artifacts.

NASA, like most government organizations and industry partners, in today's economy have restricted budgets yet strong driving forces to enact digital transformation in multiple domains. To provide a systematic approach to determining the prime locations for digital transformation investment to gain maximum return, NASA DE leadership team applied systems engineering principals to help guide organizations through the different layers of their business model (referred to within DE as the 'four-layer cake') and help resist the natural tendency to jump directly into picking new software tools.

- The 'top layer' defined at the Domain represents why a program, project, organization, or domain exists; to produce some explicit product or service. This layer also captures the customer, roles and responsibilities, business value chain, and any overarching standards.
- The second layer is the Process Framework and is defined by the processes which have been implemented to ensure predictability of product/service outcomes, quality, safety, security, efficiency – generally the desired 'ilities' of the value chain.
- The third layer is the Data Architecture/Construct where the information and data which are required to execute the domain processes, and to measure the efficacy of said processes, resides. This will be the program/project's databases, data repositories and aggregators, models, and project lifecycle management environments.
- The fourth layer, Infrastructure, encompasses the implemented enterprise architecture, infrastructure, governance, and tools to enable the prior three layers.

It is critical to understand these layers and how they interact with the others before performing the analysis to identify areas of investment with the goal of digital transformation of the domain. Looking back at the four layers through the data-centricity lens, the nature of the domain products and services will not likely change that much. However, the supporting processes layer is the important area to focus on for DET, especially for organizations which have been around for more than a decade.

In the case of the NASA Engineering domain, many of the processes in place have been honed over decades of programs' successes, failures, and lessons learned. The information required to execute the processes and associated performance metrics has historically been managed on paper in documents, with the last decade or so resulting in the digitization of the paper to electronic versions but with the information still largely being managed within the digital document and not in a structured data construct. Understanding a process's data and information sources, format, consumers and corresponding required format of ingestion of information, mechanism of the transference from one party to the next (manual vs. automate vs. on demand), and the associated transactional time cost and opportunities for injection of errors with every transaction requiring translation or reformatting of the data, will provide the basis for identifying high-value investment targets for engineering digital transformation. Translation of between paper, digital, and data will allow access to the information needed to streamline the processes.

At the process level, the subsequent analysis will inform high-value organizational or enterprise changes in terms of process automation and movement of information, interoperability requirements between systems and tools can be identified. In cases where the same information is needed by multiple consumers opportunities for the creation of authoritative sources of truth (ASoT) or federation of ASoTs can be identified and investments made. The identification of one or more ASoT will then drive the requirements to the Data Architecture/Construct layer along with any additional meta data needed (currently or in the future when AI/ML search capabilities are brought in by the organization) to provide greater leverage of corporate knowledge which then manifests in changes to the process data constructs. The data interoperability and automation requirements from the process analysis inform the enterprise/infrastructure layer and only then should new tools be selected and implemented. This approach ensures the required capital investment will be rightsized and directly support the desired DET outcomes; no more, no less.

While this approach may appear to be very prescriptive and overly methodical, in environments like NASA where decision making and implementation approaches are largely decentralized to individual field Centers and steeped in culture with their own investment history, priorities, different programs supported (e.g., funding sources), and culture, this approach will allow targeting of high-payoff opportunities of DET in the absence of top-down Agency direction and funding.

In this vein of reviewing the processes associated with engineering within NASA, some of which some have been around for multiple decades, it was important to start with the main Agency-level process documents (NPRs/NPDs) which bound how engineering is performed: NPR 7123.1 - NASA Systems Engineering Processes and Requirements, NPR 7120.5 - NASA Space Flight Program and Project Management Requirements, NPR 7120.8 - NASA Research and Technology Program and Project Management Requirements, NPR 8705.2 - Human-Rating Requirements for Space Systems, and NPR 8705.4 - Risk Classification for NASA Payloads.

Each field Center has derivative versions of the NPRs/NPDs which have been tailored to reflect their areas of expertise, but to affect how work is performed at the field centers regarding integrated digital engineering, first the Agency-level NPRs/NPDs would have to be analyzed from a datacentric position to determine if changes needed to be made and then flowed to Center versions. This paper will provide an accounting of NPR modeling approach, lessons learned, and path forward.

NASA Procedural Requirement (NPR) Overview

NASA has a lot of documentation, and guidance for documentation, most of which has evolved from managing very large, complex systems in a risk-adverse environment. This led to large number of documents providing guidance for how to generate the various sub-products, and what to include.

NASA's NPRs/NPDs establish authorities for establishing other more detailed specifications or requirements as shown in Figure 1. Overview of the NASA top-level document tree. In short, NPDs provide guidance internally whereas the NPRs contain requirements for how people are expected to perform in their role. The NPRs cover a wide range of areas including the ones selected for modeling: NPR 7123.x (Requirements for Systems Engineering), 7120.x (Requirements for Program Life Cycles) and 8705.x (Requirements for Risk Classification). These three document sets cover a large portion of the overall NASA Lifecycle requirements, technical authority requirements, and roles that tend to be matrixed to a project/program. These documents also see a high level of overlap due to requirements set based on the lifecycle phase and interfaces between organization/roles.

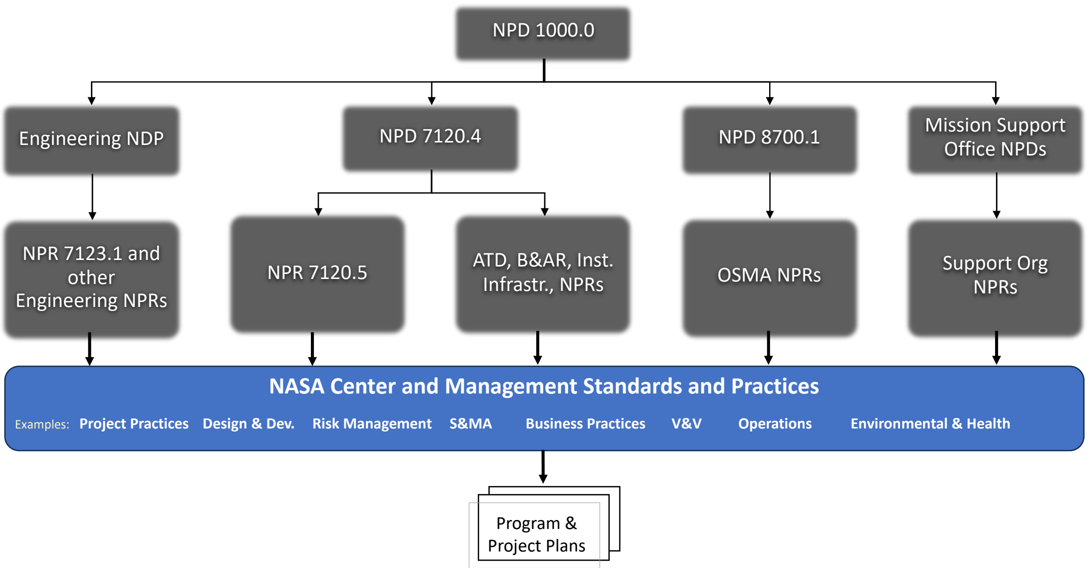

Figure 1. Overview of the NASA top-level document tree

NPR 7120.5 Program and Project Management [2]: is a comprehensive framework outlining processes, procedures, and requirements guiding NASA's approach to effectively manage programs and projects while emphasizing safety, risk management, technical excellence, and accountability.

NPR 7123.1 NASA Systems Engineering Processes and Requirements [1]**:** contains the procedural requirements and guidelines for conducting Systems Engineering activities within a program or project. It would serve as a reference and guide for engineers, project managers, and other stakeholders involved in the development and management of complex systems. The purpose of this NPR is to define and implement processes, procedures, and requirements necessary to produce human-rated space systems that protect the safety of crew members and passengers on NASA space missions.

NPR 8705.2 Human Rating Requirements for Space Systems [3]: is a critical aspect of space exploration and is central to ensuring the safety of astronauts who venture into the challenging and often unforgiving environment of space. This rigorous certification process is a testament to the dedication to safety and the commitment to the well-being of those who participate in human spaceflight missions. In the context of human space exploration and spaceflight, 8705.2 refers to the process of certifying and ensuring the safety of spacecraft and launch vehicles for carrying crew into space. The goal of human rating is to minimize the risks to astronauts and ensure their well-being during all phases of a mission, including launch, in-space operations, and return to Earth.

NPR 8705.4 Risk Classification for NASA Payloads [4]: This directive defines the criteria for Mission Directorates (the major Agency execution organizations) within NASA to define the risk tolerance classes for NASA missions and instruments, and the corresponding Agency-level assurance expectations that drive design and analysis, test philosophy, and common assurance practices. NASA classifies risks associated with its missions and projects into different categories to assess and manage them effectively. In addition, 8705.4 utilizes an Objectives-based approach and defines an Assurance Implementation Matrix, with a corresponding workflow, to facilitate and clarify the tailoring process.

Approach

The plan was established to create an integrated process model of the identified NPRs with three phases: As-Is, Analyze, and Transform, as seen in Figure 2. Overview of NPR Modeling Plan. DET and the Model Based Mission Assurance (MBMA) Team worked together to propose, and co-fund a task to model these critical NASA documents to establish the foundation for future NASA digital transformation per aforementioned importance of addressing first the Process Framework to help identify important targets of investment as part of the overall transformation plan.

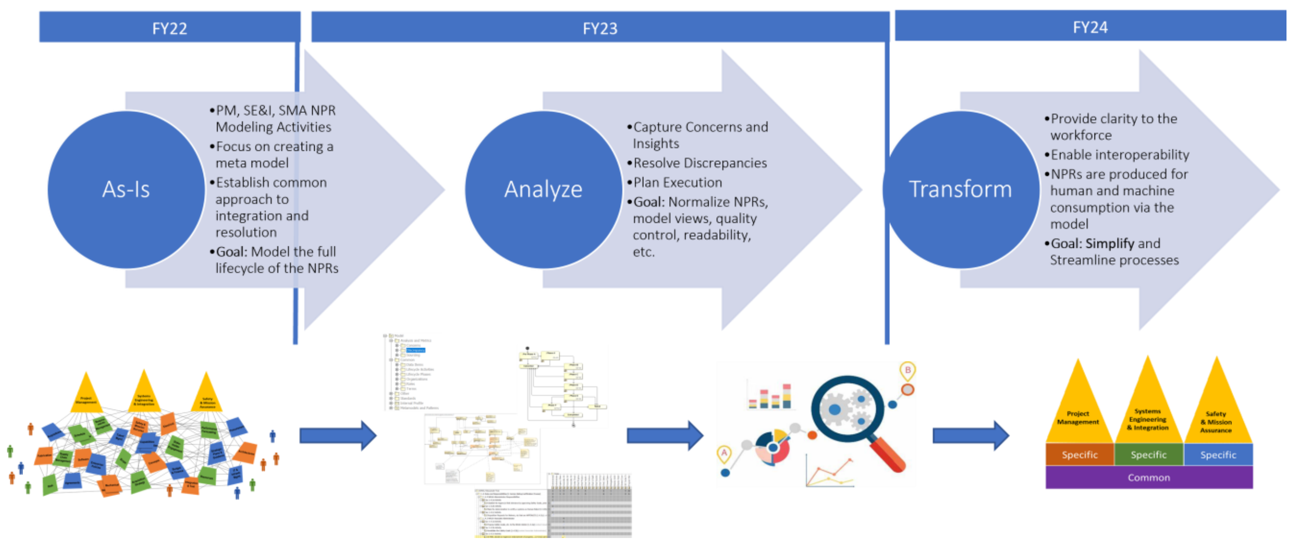

Figure 2. Overview of NPR Modeling Plan

Capturing the 'As Is'

The initial step in this transformation activity was to define the current state. The initial parsing model that was used was re-used from ongoing exercise in NASA's Office of Safety and Mission Assurance Model-Based Mission Assurance (MBMA) initiative. It had identified that a rather simple model could be used to capture the elements and relationships from NPRs, and to help standardize how current and future NPRs/NPDs were modeled. The team developed and applied a pattern for "parsing" as summarized in Figure 3. Simplified Parsing Example, and generated an integrated model. The primary elements:

Requirements, Roles, Activities and Products are connected by relationships. Activities produce Products or input Products produced by other activities, and subsequently, Activities are allocated to Roles.

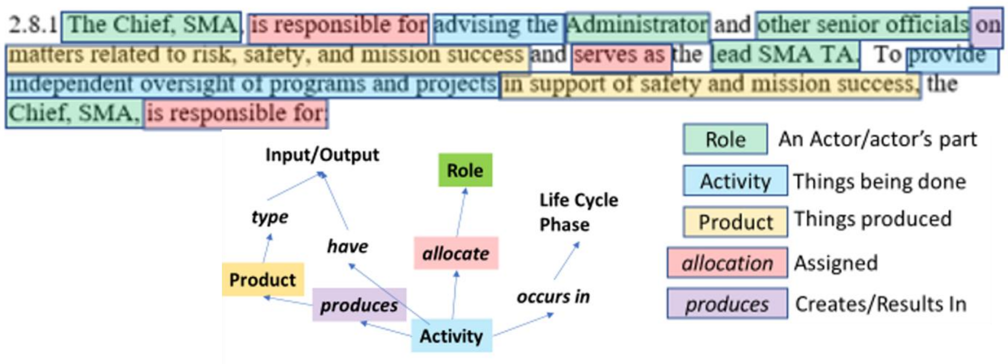

Figure 3. Simplified Parsing Example

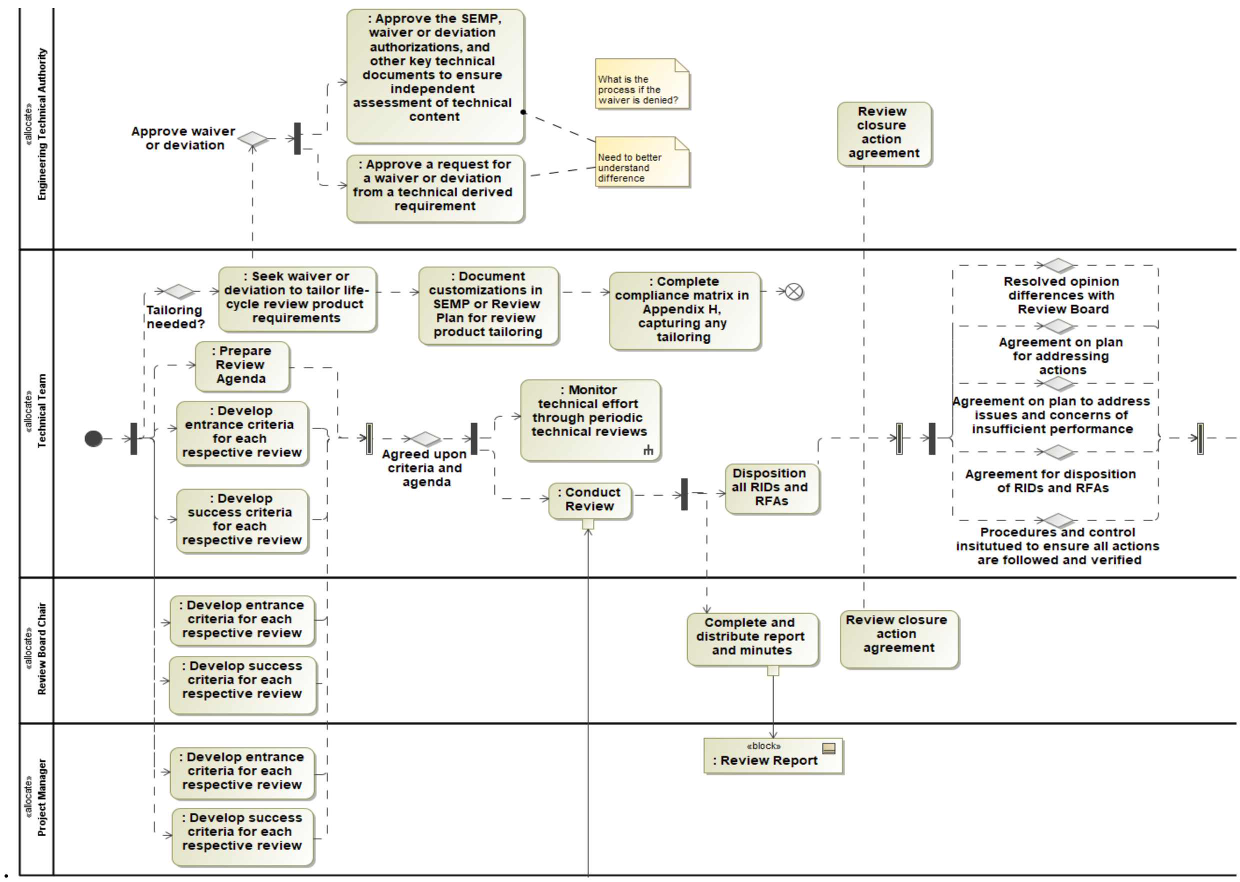

Figure 4: Example of modeling a particular review preparation process.

Based on the published promise of the parsing of documents for the purpose of data centricity, it was first was applied to NPR 8705.2, Human Rating Requirements for Space Systems, which provided some valued insight. At that point, the introduction of some additional nuances was necessary: NASA Programs and Projects have lifecycles and the Gate products have specified maturity levels; thus, products can have different maturity levels (e.g. Preliminary, Initial, Baseline, Revised) and different Lifecycle inputs and outputs need to by properly typed. Also, the ability to re-use data in integrated model led to the creation of a common area where elements that were used across multiple documents could reside for modelers to be able to find and access the items.

These NPRs cover the majority of Gate Products, Technical Authorities, Roles and Assigned Responsibilities in NASA's Programs and Projects. The parsing pattern was applied to each to clearly extract the key elements (e.g. Responsibilities) and key relationships (e.g. Allocation between Responsibilities and Roles). To further elaborate on the Purpose and content of each of these to illustrate how 'natural' the application of the basic pattern the following details provide the basic structure of the documents, but of course there were, nuances such as maturity levels and design iteration which provided some parsing and modeling challenges.

The overall model structure is shown in Figure 5. Model Structure. Currently, this is a single model that integrates the multiple documents. The documents are approximately 300 pages of text that were translated into 257 requirements, over 50 roles that map to 506 responsibilities, and over 600 inputs/outputs to activities. The description of the numbered sections in Figure 5. Model Structure are as follows:

1. Contains the views needed for analysis and metrics. This area also includes discrepancies/issues/concerns between documents that have been identified. It also is the area the modelers have used to highlight clarifications that are needed in the metamodel.

2. Contains the common area for the terms common between the documents including Roles, Lifecycle Phases, Life Cycle Reviews, Products, Terms and Definitions. Figure 4: Example of modeling a particular review preparation is one example of a diagrammatic representation of a particular review element.

3. Contains the area where the individual NPRs are located, the specific text that was in the documents. This area also contains the relationships to items that have been defined as common across the NPRs.

4. Contains the other documentation that hasn't been modeled but is referenced from the NPRs modeled.

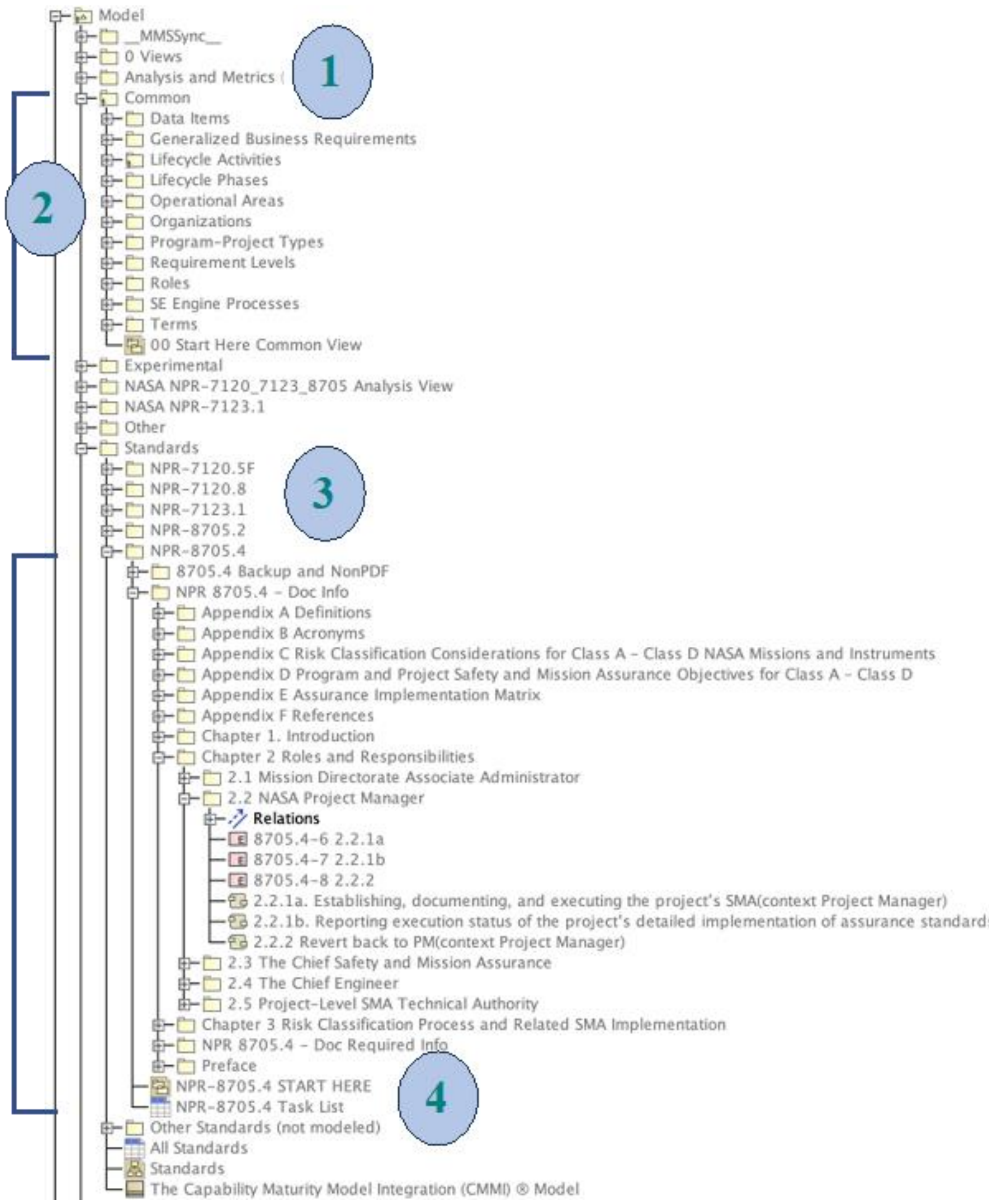

Figure 5. Model Structure

Prepare for Analysis

The initial step in preparing for analysis was verifying the model "correctly" represents the NPRs. The modeling team paid considerable attention to ensuring the accuracy of the model or put simply to verify that the model represented the NPRs as currently documented. Validation or quality assessment was included as part of the following analysis phase.

As part of the modeling process, it was important to show a practical example of putting "machine-assistance" into practice. To that end, scripts were utilized to confirm text matching. Comparison of documents generated from the model and to those available online was performed and modified until correct. However, some discrepancies required human insight and correction.

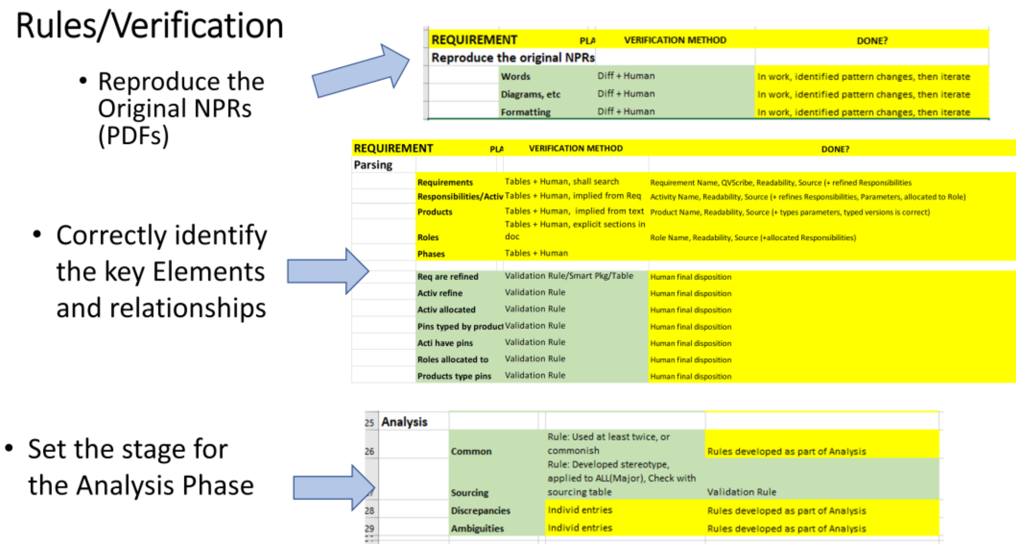

Figure 6. Example of Rules/Verification

Figure 6. Example of Rules/Verification shows the three aspects of Rules and Verification we utilized. The first aspect was to reproduce the original documents from the model. No interpretations, no modifications just the original text and graphics.

The second was to ensure the parsing was done correctly and consistently. For the latter, we applied validity checking rules available in the tool. Examples include: every requirement must be refined into some activity; every activity must refine some requirement or have another activity as its parent and every Responsibility (Activity) must be allocated to at least one Role. The tool also had the ability to group data making it easier to assess.

Finally, to support the human validation aspect of the parsing review, the team fully utilized the web output feature of the product suite. This enabled browser-based views like those shown in Figure 7. Web Output View Generated from the Model and Figure 8. Web Review Comments Incorporated.

These views, customized for reviewers, were critical to the validation aspect of the document parsing to address if the statements were correctly interpreted as requirements, if the associated responsibility was allocated to the correct role, etc. These and many other questions were best checked by subject matter experts and of which the specific model views facilitated that effort.

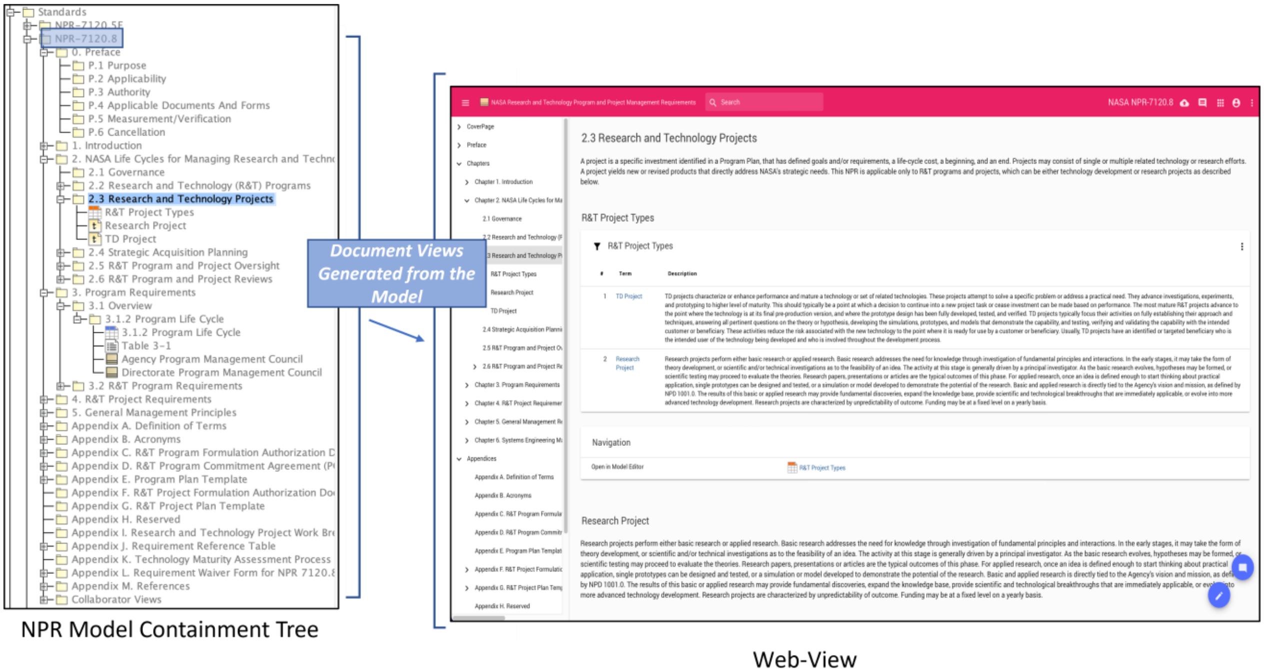

Figure 7. Web Output View Generated from the Model

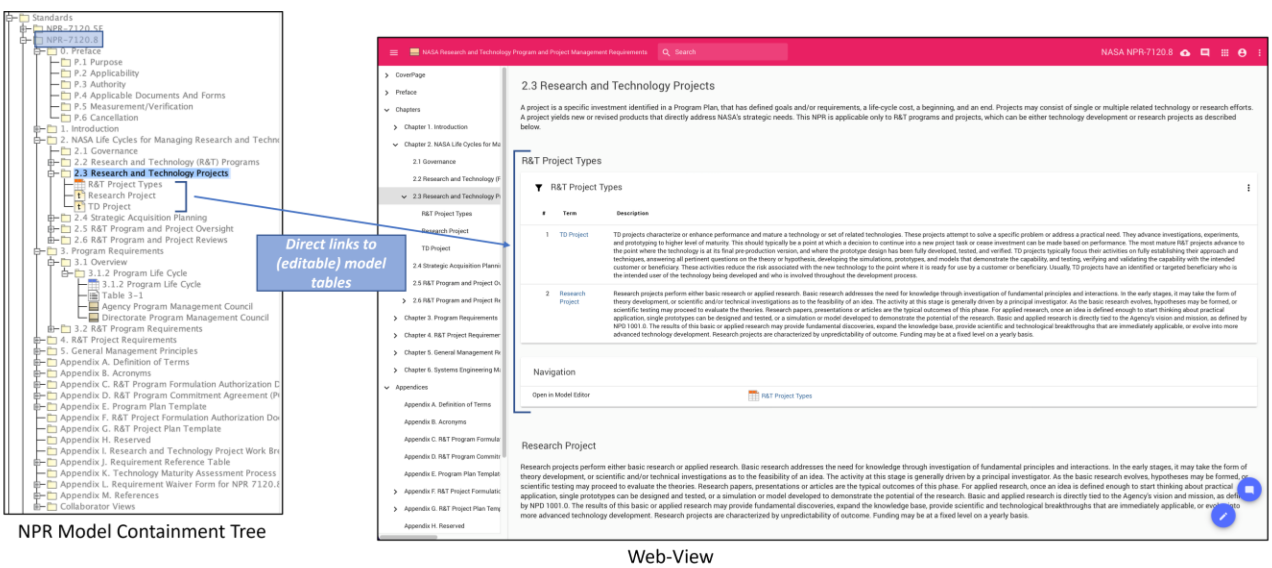

Figure 8. Web Review Comments Incorporated

Perform Analysis/ Prepare for To Be Planning

The datacentric analysis of the modeled documents is still in progress, but early engagement with the Office of Primary Responsibility for each of these is underway to ensure the creation of needed views to provide needed insight for the next generation of policies so that they will be better integrated, less obtuse, and efficient.

As the documents and associated content were modeled and integrated, cross-cutting views emerged which have never been generated in the past. As an example, the sum-total of all "cost" elements was somewhat incomplete and inconsistent in terms of levels of abstraction. The data contains specific methodologies, specific tools to use for execution, others that are product-oriented with details on what is expected, and very generic terms. One reviewer remarked they hadn't been able to see ALL the elements in their domain, sorted by role, across these documents.

The team started creating domain tags to better explore the model process patterns. Initially, the tags were implemented to cross check the model for errors but quickly became an analysis aid. Currently, there are approximately 20 tags which cover 90% of the elements and have generated thousands of relationships. Figure 9. Summary View of the Tags Used illustrates for tags of Cost, Schedule, Authority, etc., it is possible to explore the various elements from the modeled documents to get all the references to Roles, Products, Terms, etc. for any given domain and explore them as one collection.

	Analysis Tags																								
	Acquisition/Contracts	Assurance	Authorities	Decision Authority	ConOps / Concept	Cost	Design	Human Rating	Implementation	Integration and Produc	Logistics	No Grouping	Operations	Performance	Planning	Process	Quality	Requirements	Reviews	Risk	Safety	Schedule	Technology Developme	V&V	Waivers Exceptions an
Common	45		56	2	34	71	60	60		29	38	65	66			45	25	54		57	61	39	27	35	
Policies, Directives and Standards	104	105	330	202	36	164	62	159	27		64		152	3	16	11		202	44	50	101	147		51	11

Figure 9. Summary View of the Tags Used

Another view that has been created is the role and activities across the documents. Each NPR puts work requirements on a defined role, but there hasn't been an easy way to view all the requirements and if/how the overlap. The view has made it easy to identify overlapping responsibilities between multiple organizations and to identify expectations of responsibilities from stakeholders on the role.

Initial Insights

Terminology: As part of the process of jointly modeling these processes, discrepancies and inconsistencies between the documents and terminology become readily apparent. In some cases, one of the documents is extending definitions of terms beyond that used in other documents. In other cases, there are terms that conflict or different terms that are used that mean the same thing. The contradictory terms are not clarified or reconciled, so it is unclear if the same expectation of maturity is desired, or if there is a nuance being called in one document versus another. Also, the documents do not define if the deliverables of a requirement should be stand-alone or be part of a higher-level product. Clarity could be improved if those aspects associated with terminology and data hierarchy are reconciled and have been made painfully evident through this modeling initiative.

Roles and Data Hierarchy: When it comes to lifecycle review products, a joint view is helpful to aggregate the expected products required and when. This is another area where the clarification of delivered products and data hierarchy could simplify the overall process, as there have been over 500 data items identified. The modeling also helps highlight where the documents are calling out different maturity levels (example: draft, preliminary, baseline) for products at the same milestone points in the lifecycle, or where the text calls out an updated product, when the purpose of the review in question is to assure that the product is baselined. The joint view of the products also shows overlap in responsibility and content between numerous organizations/roles. It also shows assumed delegation paths. There have been over 50 roles identified in the integrated model. Based on the parsing construct, requirements (or responsibilities) are refined into activities. The team is in the process of using the identified responsibilities derived from the requirements to identify gaps in the information flow for each of the lifecycle reviews. If gaps are identified, these could be added as derivations or explicit requirements.

Out of date or lack of references: Modeling the standards also allows for rapid detection of out-of-date references, like the 2007 versus 2016 Systems Engineering Handbook versions, incorrect table of contents, or obsoleted NPRs or Standards which had not been removed from the modeled documents. It also helps highlight references to non-data-managed material like white papers, reports and memorandums, which if they are truly to be guiding recommended processes, should have some control of their content, and be managed for relevance to current practices.

Integrated views: There is interest in having an integrated model of the primary processes which drive the milestone review products to simplify the tailoring the review criteria for the program or project. As discussed previously, the use of tags is enabling the team to engage a variety of disparate stakeholders to both review the existing, and plan for the future of NASA's Policies and Requirements.

Requirements: Currently the NPRs are predominately text-based requirements without visual context. The selected NPRs contain various requirements for processes to manage and oversee space flight programs and projects within NASA. In that vein, the requirements within the NPRs were assessed using commercial-off-the-shelf software that applied the Easy Approach to Requirements Syntax (EARS) [5][6][7]. The assessment resulted in over 50% of the requirements receiving a low score. Some of the issues identified:

- Non-conformance -EARS provides five sentence types for requirements to follow: ubiquitous, event-driven, state-driven, unwanted behavior, and optional. In general, NPR requirements do not conform to the syntax. Many of the NPRs were in existence prior to the establishment of EARS, but not prior to the concept of good requirements writing.
- Excessive continuances & immeasurable qualifiers – The number of continuances (the use of and-or as seen in the below example) or vague language (ex: better, user-friendly) introduces ambiguity, creates complexity, and leads to inconsistent interpretations.
- Optional Escape Clauses – Words like "may", "to the extent", "appropriate" can lead to a lack of accountability, quality concerns, disputes/conflicts, and unclear decision making all which leads to increased risk.
- Number of terms – The number of terms identified in a requirement increases complexity, indicates ineffective communication, and is prone to scope creep.

Another area of concern in the procedural requirements is implied requirements. Requirements that reference figures or tables which need interpretation. Requirements that reference the use of a template or other standards/specifications which indicate the need for additional analysis and/or work to be performed. Requirements so long, that the "lack of a transitive property across commas in English" becomes a problem. These types and others can be explored with modern requirements analysis tools. An example is shown in Figure 10. Requirements Analysis Tool, Example

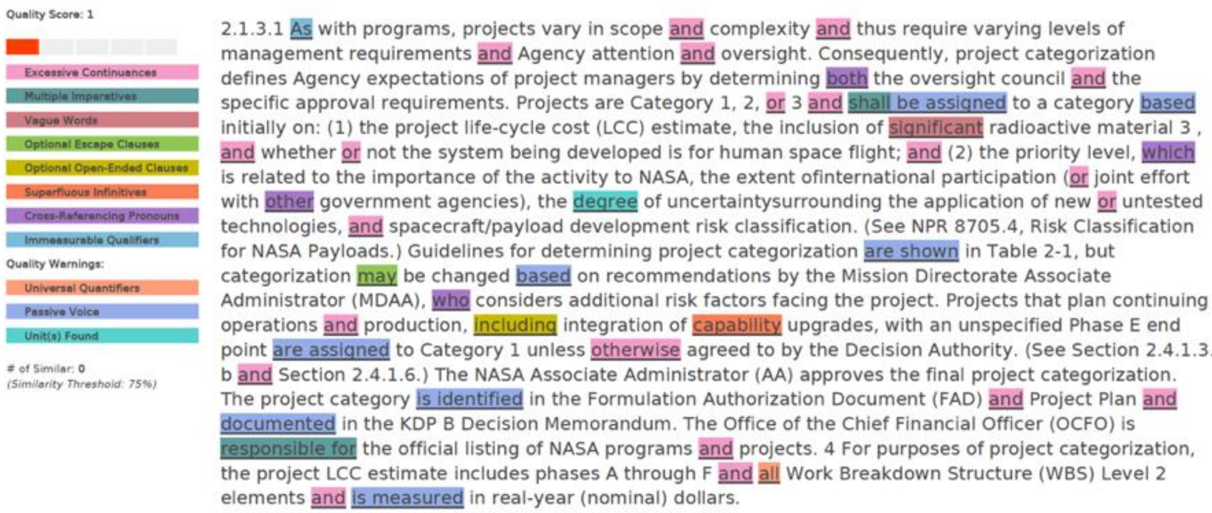

Figure 10. Requirements Analysis Tool, Example

Implications

The language within the NPRs is complex and duplicative which makes the processes arduous and confusing. The process modeling effort of the current state has identified areas of improvement that will improve efficiency, gain transparency, ensure execution of best practices, and support orchestration of large and complex programs/projects.

Process Efficiency: Text based requirements for processes is inefficient without being partnered with a visual process. It allows for interpretation which results in variation and lack of consistency during execution. From the analysis, it was determined that the quality of the process requirements as written today is poor. Modeling ensures that there is a role associated with performing the process steps and clearly defines inputs/output. Modeling allows re-use of common elements or inputs/outputs across multiple organizations/disciplines. The discussion around requirements and their quality usually centers around the end-product to be delivered. Although, requirements nominally document what needs to be built, how it should function, and how to test it, the set under review for this modeling effort is associated with necessary processes for an organization to succeed. The process requirements are centered around:

- Roles, responsibilities, process requirements, and the work that needs to be performed over the lifecycle of the program/project when developing a product for NASA.
- Ensuring that team members know the aspects of what, how, and when for the items they are responsible.
- Training materials and communication/collaboration tools between team members.

Standardization of processes reduces variability in the outputs which leads to increased productivity, quality, efficiency, reliability, and leads to higher customer satisfaction. The process requirements need to be reviewed and conform to nominal requirements writing formats that are clear and concise. There are areas of text that should be converted to rationale versus impacting the clarity of the requirement. There are areas of text that need to be deleted and/or converted to a visual process flow. Modifications to these NPRs will enable them to be useful and easy to follow. Once that happens, it will be easier to monitor performance and identify areas of continuous improvement or innovation, including automation.

Gain Transparency: The analysis shows that the number of data items is excessive and duplicative and that many roles are responsible for the same items. Some of the reasons for the excessive number of data items are due to different disciplines and/or areas of the lifecycle have different terminology for similar data items. Some data items are part of a higher-level deliverable which isn't necessary clear in the NPRs. Another reason is that some of the deliverables have qualifiers dependent on the maturity or level that the data item exists. An example is the use of the terms Architecture Description Document and Mission Architecture. The NPRs are not clear if they are the same thing or if one is a deliverable that should define the other. A clear data and deliverable hierarchy/structure that is associated to the expected lifecycle maturity will ensure that the necessary work is accomplished at the expected time. The data structure will inform the primary use for the data and deliverables which will make it easier to identify the actual role that is responsible and which terminology should be predominant. Clear data and deliverable structures will also support ease of analysis and reporting to programs and projects.

Ensure Best Practices: NPRs were developed based on best practices and lessons learned. These are difficult to implement and understand due to the complex language. Migration to visual processes makes it easier to follow the flow of information, audit of the work that has been completed, easier to ensure compliance, and apply metrics on significant process steps.

Orchestration of Large and Complex Processes: The creation of the common area of the model demonstrated the significant amount of overlap between multiple NPRs. The common area enabled re-use of the data items, roles, lifecycle reviews, etc. The re-use ensures that the relationships on those items are maintained and can include multiple attributes and/or tags such as source document, discipline, etc. The re-use made it easier to identify gaps in data and information flows. Future work is to continue to add NPRs beyond those initially selected which will further add to the complexity and associations. Logical segregation will be addressed at that time.

With the data, roles, and activities mapped across the lifecycle it eases the burden of implementing and orchestrating large and complex processes due to the use of views and viewpoints. Views and viewpoints can be used to look at different aspects of the lifecycle and/or discipline with relation to the process and/or system model(s). The process models can be integrated into programs/projects to support status and reporting of work that has been accomplished. Programs and projects can use standard engineering data, technical frameworks and terminology, processes, etc., and still customize and tailor on the data necessary and its presentation.

Another area of improvement is a paradigm shift where we will look at consolidating the multiple lifecycle review processes (currently there are 4 major lifecycle processes) into a single process. Clarifying and simplifying the procedural requirement language aligned with visual processes and relationships that have been created between the elements will allow a series of if/then (or decision block) customizations with input variables that can automatically add or remove parts of the processes, deliverables, and or data required so that one process will satisfy the four different processes.

These activities and others will be looked at in depth during the transform phase to support an agile engineering process which will reduce the time it takes to move through the engineering lifecycle.

Summary

NASA NPRs cover a wide range of topic areas, ranging from Project Management to Systems Engineering to Safety and Mission Assurance practices. They are typically developed incrementally and often independently. There are a lot of pages and Requirements that are not as widely known as desirable. Most NASA employees have read and understood only a subset of these NPRs. As a result, there was a sense that something needed to improve.

The NPR modeling activity started as a way to seek clarity and consistency across the various NPRs. There was no desire to eliminate key elements or “throw the baby out with the bath water”. The NPRs are intended to ensure that the best practices and processes that have been developed and created due to the Agency’s success and failures are not forgotten. There is a history and reasons behind each and every requirement that was added into the NPRs. However, this incremental and evolutionary approach has resulted in a large set of requirements, guidance, and language that is confusing and complex. The modeling effort has highlighted areas for improvement, while identifying and capturing key element that must remain. As we implement the recommendations from the analysis, NASA can move towards datacentric management of the information associated with engineering products, services, design, and their associated artifacts. This translation between paper, digital, and data will allow access to the information needed to streamline, transform, and possibly re-invent the processes for NASA to meet the needs of the current and future missions.

References

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Biography

Terry R. Hill. Serves as the program executive of the NASA Digital Engineering Transformation and responsible for providing an executable strategic and implementation approach for delivering digital engineering and MBSE methodology and interoperable toolchains.

Patricia Nicoli. Received her BS in Electrical Engineering from the University of North Dakota and her MS in Industrial Engineering with a Systems Engineering Focus from the University of Florida. She is currently serving as the Chief for Technical Processes and Tools at Kennedy Space Center. She also serves as the Digital Engineering Systems Engineering Lead. As part of this function, she coordinates across the different NASA Centers with MBSE leaders and practitioners to increase the model-based capabilities of the workforce and migrate to data driven processes using modern applications and tools. The goal is to provide improved processes to enable the workforce to deliver quality products consistently and efficiently.

Dr. Steven Cornford. Is a Principal Engineer in the Strategic Systems Office at NASA/JPL/Caltech. He got a double major in Mathematics and Physics from UC Berkeley, an MS and a PhD in Physics from Texas A&M University. Since coming to JPL in 1992, he has been part of the conception, design, management. building and testing various spacecraft and their components. He has performed a variety of research with the goal of making things better, more practical or more efficient. Lately he is a contributing part of NASA's Digital Transformation efforts. He has authored over 130 papers and been awarded the NASA Exceptional Service Medal among others. He was in a rock band which recorded two albums, and still plays music with his three wonderful boys and his wife.

Robert Morgenstern. Received Electrical Engineering from Virginia Tech. He is currently a senior systems engineer in the Payload and Instrument Systems Branch at NASA's Goddard Space Flight Center. During his 12 years at GSFC, Rob has been a chief architect, mission systems engineer and a division chief engineer overseeing Exploration and Space Communications, supporting National Oceanic and Atmospheric Administration (NOAA) weather programs, space communications and navigation, human spaceflight programs and internal research into on-board autonomy and distributed systems missions. He is the co-lead for GSFC's MBSE Practitioners Forum and is the center representative to the agency MBSE Leadership Team. Before NASA, that he spent 22 years working at the MITRE Corporation supporting air traffic control communications for the Federal Aviation Administration.

David M. Chiras. Is an Enterprise Architect with the Ares Corporation attached to NASA's Enterprise Multimedia and Integrated Technical Services (eMITS) contract. Currently assigned to Langley Research Center (LaRC) assisting in their digital transformation efforts, he has developed process models for LaRC's Program, Risk, and Configuration Management areas and is currently modeling the data architecture for the CERTAIN Smart Center Program. In addition, he is contributing to NASA's overall digital transformation efforts. He received his BS in Management Information Systems from Auburn University, his MS in Space Systems Operations Management (Engineering) from Webster University, and his DoD Certification in Enterprise Architecture from National Defense University. He spent nine years on Active Duty with the U.S. Air Force, and has been developing/modeling enterprise, system, and data architectures for over 15 years.

Patrick D. Barnes. Is a Senior Systems Engineer with Arctic Slope Regional Corporation (ASRC) supporting Goddard Space Flight Center (GSFC) for the past 15 years. Mr. Barnes is an experienced practitioner of model-based systems engineering (MBSE) and has employed that skill set on numerous projects since starting with NASA in 2009, including the Joint Polar Satellite System (JPSS), Advanced Air Mobility (AAM), and the Office of Satellite Ground Systems (OSGS) with the National Oceanic and Atmospheric Administration (NOAA). Currently Mr. Barnes utilizes MBSE methodologies developing architectural and operational models for the Space Communication and Navigation (SCaN) Project, the Lunar Communications Relay and Navigation System (LCRNS), the Delay/Disruption Tolerant Networking (DTN) Project, the Near Space Network (NSN), and the Lunar Navigation System (LNS) in support of the upcoming Artemis missions back to the moon.

Josh L. Bendig. Received his BA in Physics from Occidental College and his MS in Computer Science from University of Southern California. He serves as a Systems Engineer in the Project and System Reliability Engineering Group at the NASA Jet Propulsion Laboratory. Josh is the Model-Based Mission Assurance (MBMA) Lead, responsible for collaborating with both JPL internal and external MBSE/DT stakeholders in shaping and implementing MBMA activities. He has been involved in various efforts to assess and infuse MBSE technologies into JPL's reliability domain, in addition to serving as a lead developer for the Model-Based Probabilistic Risk Assessment (PRA) tool that supported the Europa Clipper mission.