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NASA SPACE MISSION ARCHITECTURE FRAMEWORK (SMAF) HANDBOOK FOR UNCREWED SPACE MISSIONS

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FOREWORD

This NASA Technical Handbook is published by the National Aeronautics and Space Administration (NASA) as a guidance document to provide engineering information; lessons learned; possible options to address technical issues; classification of similar items, materials, or processes; interpretative direction and techniques; and any other type of guidance information that may help the Government or its contractors in the design, construction, selection, management, support, or operation of systems, products, processes, or services.

This NASA Technical Handbook is approved for use by NASA Headquarters and NASA Centers and Facilities. It may also apply to the Jet Propulsion Laboratory (a Federally Funded Research and Development Center [FFRDC]), other contractors, recipients of grants and cooperative agreements, and parties to other agreements only to the extent specified or referenced in applicable contracts, grants, or agreements.

This NASA Technical Handbook establishes an Uncrewed Mission Architecture Framework intended to increase the value of the scientific investigations; improve effectiveness of end-to-end mission development, including leveraging digital engineering techniques; enhance institutional capability management; and improve collaborative application of digital models and products across NASA's science portfolio.

Requests for information should be submitted via "Feedback" at https://standards.nasa.gov. Requests for changes to this NASA Technical Handbook should be submitted via MSFC Form 4657, Change Request for a NASA Engineering Standard.

Original Signed By Adam West for	3/11/2021
Ralph R. Roe, Jr. NASA Chief Engineer	Approval Date

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1. SCOPE

1.1 Purpose

This NASA Technical Handbook provides guidance for establishing a mission architecture as part of an acquisition framework for a NASA uncrewed space mission. Note that in this context, acquisition refers to a larger context than the procurement; rather, it refers to the acquisition of a capability. Acquisition of such a capability encapsulates the conception of an idea, the development of a Mission to realize that idea, and the management of the design, build, integration, test, and operation of that Mission. The framework is applied to a specific project using an appropriate methodology. This NASA Technical Handbook is focused on project formulation and execution in the context of NASA's operating model, as defined in NASA Policy Directive (NPD) 1000.3, The NASA Organization. In the context of this NASA Technical Handbook, a project is typically sponsored by a NASA program within the NASA Headquarters Science, Space Technology, or Human Exploration and Operations Mission Directorates (SMD, STMD, or HEOMD) and represents a specific investment having defined goals, objectives, requirements, and life-cycle cost, as well as a timeframe with a beginning, and an end. This NASA Technical Handbook implements relevant NASA policies, processes, and standards as defined in NASA Procedural Requirements (NPR) 7120.5, NASA Space Flight Program and Project Management Requirements; NPR 7123.1, NASA Systems Engineering Processes and Requirements; NASA/SP-6105, Revision 2, NASA Systems Engineering Handbook; and other governing documents. Specifically, Systems Engineering (SE) activities are guided by the SE Engine in NASA/SP-6105, Revision 2, Section 2.1.

It is also noted that a key objective of this version of the NASA Technical Handbook is to create an initial starting point for a continuing and evolving discussion across NASA for embracing System Architecture Development in a consistent manner. This dialogue will help NASA evolve to more interoperable digital work processes. It is expected that this NASA Technical Handbook represents a starting point that will help bring various Center cultures to the discussion of Architecture, and it is expected to evolve, consistent with the dialogue.

1.2 Applicability

This NASA Technical Handbook is applicable to uncrewed space missions concerned with scientific discovery, including, but not limited to, an entire spacecraft or one or more scientific instruments. It provides guidance and support from which a project can draw to efficiently develop a mission architecture for a project and for the system described by that architecture that will successfully perform the mission. These projects formulate and implement uncrewed science missions that are planned, realized, and ultimately operated through the science, project management (PM), and engineering efforts of the responsible NASA Center for use primarily by system engineers and architects, scientific investigators, program managers, and support staff, who should be familiar with the NASA project life cycle, requirements, and model-based approaches for applying the SE process defined in NPR 7120.5, NPR 7123.1, NASA-STD-7009, Standard for Models and Simulations, and NASA-STD-1006, Space System Protection Standard.

Depending on mission objectives, the guidance in this NASA Technical Handbook can be applied with customization to replace the science content with equivalent technology-related goals, objectives, mission and system designs, and operations.

This NASA Technical Handbook is approved for use by NASA Headquarters and NASA Centers and Facilities. It may also apply to the Jet Propulsion Laboratory (a Federally Funded Research and Development Center [FFRDC]), other contractors, recipients of grants and cooperative agreements, and parties to other agreements only to the extent specified or referenced in their applicable contracts, grants, or agreements.

This NASA Technical Handbook, or portions thereof, may be referenced in contract, program, and other Agency documents for guidance.

2. APPLICABLE DOCUMENTS

2.1 General

References are provided in Appendix F.

2.2 Government Documents

None.

2.3 Non-Government Documents

None.

2.4 Order of Precedence

2.4.1 The guidance established in this NASA Technical Handbook does not supersede or waive existing guidance found in other Agency documentation.

2.4.2 Conflicts between this NASA Technical Handbook and other documents are to be resolved by the delegated Technical Authority.

3. ACRONYMS, ABBREVIATIONS, AND DEFINITIONS

See Appendix G.

4. DIGITAL ENGINEERING ENVIRONMENT ENABLING AN ARCHITECTURE FRAMEWORK FOR UNCREWED SPACE MISSIONS

4.1 General Principles of Architecture Framework Application

As uncrewed space missions get more complex and involve more partners, a greater need exists for working collaboratively. It is essential that information be expressed in a formal manner that supports more rigorous integration and analysis, and then to capture and manage the information in a form consistent with automation in all aspects of its use. This approach is widely referred to as digital engineering and implemented in a controlled environment that provides the necessary tools and methods. A complete SE environment defines both an architecture framework and a methodology through which the framework is realized in a system. One barrier to working in this manner is the consistency with which systems are described internally and externally to an organization. This NASA Technical Handbook describes a broad application of the principles and methods of digital engineering, specifically Model-Based Engineering (MBE) as a way to manage complexity, enhance information management and communication, and make the many processes involved in a mission more efficient, repeatable, and rigorous. A central tenet of MBE is that a project should start with models and end with documents, rather than the reverse, to realize the payoffs in efficiency, quality, reduced rework, and cost and schedule savings that motivate the model-based approach.

The International Organization for Standardization (ISO) defines an Architecture as the fundamental concepts or properties of a complex entity in its environment embodied in its elements and relationships and in the principles of its design and evolution. When properly implemented, an SE process establishes a system architecture. (Refer to ISO/International Electrotechnical Commission [IEC]/Institute of Electrical and Electronics Engineers [IEEE] 42010, Systems and Software Engineering – Architecture Description.) Similarly, ISO defines an Architecture Framework as a common practice for creating, interpreting, analyzing, and using architecture descriptions within a particular domain of application or stakeholder community. This NASA Technical Handbook defines an architecture framework specifically for the domain of uncrewed space missions within the context of the NASA stakeholder community that will help NASA to move toward digital engineering tools and methods. Appendix A provides a fuller explanation of the goals addressed by SMAF, especially in terms of improving quality and productivity in SE processes and of more consistently meeting stakeholder expectations and concerns. Architecture frameworks can be of value whether applied in the context of digital engineering or not.

This architecture framework employs a set of foundational concepts and terms that are widely accepted in the Systems Architecture community including:

a. Stakeholder: In general usage, a Stakeholder is an individual, group, or organization having a significant and recognized interest in a system or project. This NASA Technical Handbook defines two roles that parties to a project can exercise: Stakeholder and Participant. Stakeholders are parties who are external to a project organization and who have concerns for budget and other resources, policies and approved practices, science data and other mission outcomes, safety and environmental matters, and other aspects; they are also referred to as External Stakeholders. Participants are individuals or organizations that belong to a Project Team and are responsible for satisfying stakeholder concerns; they may be considered to be Internal Stakeholders. Some parties have responsibilities that cross project boundaries and therefore have elements of both Stakeholder and Participant roles, and some parties may change roles over the course of a project life cycle. This is further discussed in Appendix A.

b. Architecture: The fundamental concepts or properties of a system or other complex entity in its environment embodied in its elements, relationships, and principles of design and evolution (ISO/IEC/IEEE 42010); an architecture is expressed in an Architecture Description, which is commonly organized into Viewpoints and Views that capture structural, functional, and other aspects of the system or entity as well as the constraints that apply to its development and operation.

c. Viewpoint: A set of related concerns identified by one or more stakeholders. A Viewpoint translates these concerns into the specification of one or more Views and thereby defines part of the content of an architecture description. A Viewpoint typically addresses stakeholder concerns that are common to multiple systems or projects and is therefore reusable whenever those concerns arise.

d. View: A View is composed of a set of products that may be models or other artifacts whose structure and content depend on the methodology employed in conjunction with the architecture framework. A View focuses on a particular area of an architecture and establishes truth for that area. A View also includes source materials relevant to the area with which it is concerned and may be created from a repository of source materials. The creation and maintenance of a View are the responsibility of one or more Participants.

e. View Product (or simply Product): An individual product within a View embodies specified content of an architecture description. The concepts, structure, format, content, analysis techniques, and other aspects of a product are defined by the architecture framework. Like Viewpoints and Views, products are often reusable from project to project with tailoring to the specifics of a given project. In a model-based environment, many Products can be automatically generated, in whole or in part, from models.

4.2 Applying an Architecture Framework in a Project

The architecture framework should be instantiated in a specific project in accordance with the following general principles:

a. The foundation of the project should be a high-quality mission architecture that addresses the concerns of all stakeholders as defined in Appendix A. Following the structure and methods of this NASA Technical Handbook to create a full set of architecture viewpoints (Viewpoints) helps ensure this is achieved for any given mission architecture. Furthermore, application of this NASA Technical Handbook across the NASA portfolio helps normalize mission architectures and facilitates compliance with applicable policies, directives, and standards.

b. Modern Program Management and Systems Engineering are model-based, in that models such as requirements tables, product breakdown structures, bills of materials, GANTT[1] charts, performance models, and many others are used extensively to convey information. Modeling approaches and supporting tools vary significantly across various stakeholder groups, both within and external to a program or project. While uses of modeling may vary, the information conveyed by models has to be consistent when shared across the boundaries of stakeholder groups. The various content areas shown in Figure 1, Content Areas, employ a corresponding variety of models, described in Appendix D, tailored to the specific needs of a project and designed to facilitate model interoperability and information exchanges internally and externally.

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1 A Gantt chart is a type of bar chart that illustrates a project schedule, named after its inventor, Henry Gantt, who designed such a chart around the years 1910–1915.

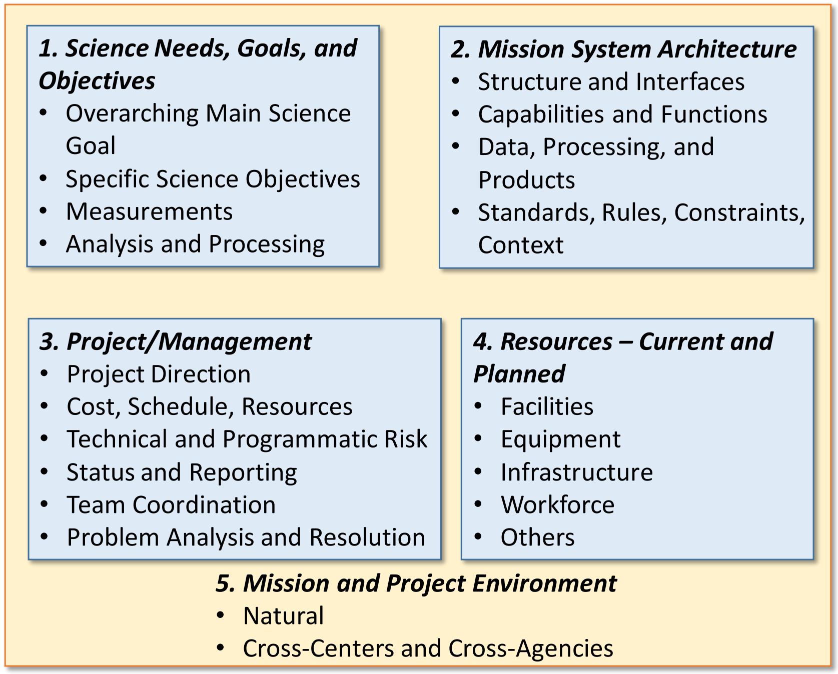


Figure 1—Content Areas

c. The architecture framework enables state-of-the-practice modeling approaches that support quality, productivity, communication, and overall cost effectiveness in NASA's missions. Wherever feasible, model-produced artifacts can be used to create, or in some cases replace, traditional document-centric products and materials.

d. Within a model-based framework, a degree of flexibility in the selection of methodologies and tool environments will facilitate application of the architecture framework with the skills and resources available to a project. A modeling environment provides the tools and procedures that implement a particular modeling strategy as defined by a program/project. Models themselves, and artifacts generated from models, create the content of a Mission Architecture. Appendix B discusses the ways in which modeling supports the creation of various categories of architecture content summarized in Figure 1.

e. Program reviews across the NASA project life cycle are major factors in mission success and major consumers of project resources, especially labor. Architecture framework Viewpoints can be used to set expectations for content and format and to promote efficient information exchanges that minimize the time required to prepare for, participate in, and close out reviews. Progress toward realizing such efficiencies can be achieved through automated generation of review materials from architecture framework models, and further enhanced by increased reliance on model-based reviews over traditional document- and slide-based reviews.

4.3 The Role of Mission Architecture in a Project Life Cycle

A project instantiates the principles of this NASA Technical Handbook to create a project-specific mission architecture. SE process activities change over the course of the project life cycle and focus primarily on architecture design during mission formulation. The architecture provides valuable support during implementation and operations, e.g., as a tool for planning system integration, analyzing test data, and diagnosing on-orbit anomalies. Detailed activities are tailored to the specific circumstances of each project.

SMAF content is created and used in the context of other project elements, as summarized in Figure 2, SMAF Content in thei Context of a Project. This NASA Technical Handbook addresses the structure of the framework in terms of Viewpoint, Views, and Products that address individual NASA functional roles and categories of stakeholder concerns. The SMAF is aligned with NASA Project Management processes as defined in NPR 7120.5 and with NASA Systems Engineering Processes as defined in NPR 7123.1, while facilitating a transition from legacy document-centric approaches to the model-based paradigm. A mission architecture developed in accordance with the SMAF will deliver quality and efficiency improvements in SE processes. For example, SMAF Views and Products are explicitly linked to entry and success criteria for reviews across the project life cycle as spelled out in NPR 7123.1, Appendix G. The architecture model can be used to generate many of the recommended key documents listed in Appendix C, using the reporting utility of a modeling tool with suitable document templates. Figure 2 also shows correlation to the project work breakdown structure (WBS) since, in general, SMAF Products relate to PM work packages in an integrated schedule, executed throughout the project life cycle.

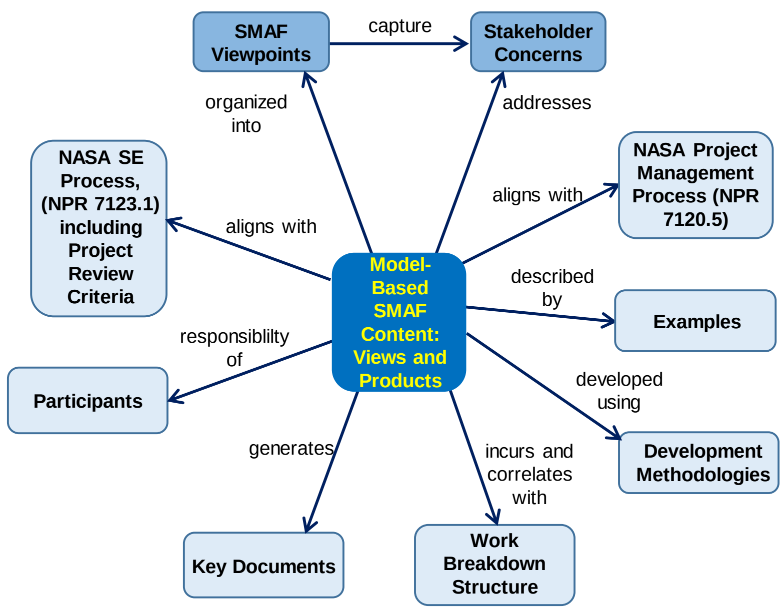


Figure 2—SMAF Content in the Context of a Project

Appendix B of this NASA Technical Handbook defines Viewpoints, Views, and Products and discusses methodologies for their creation. The SMAF serves as a unifying structure that helps tie together the elements of a project and promotes consistency and shared understanding across a project team and with other stakeholders.

Products are created at various points in the project life cycle and evolve across its phases. Most are created in basic form in early phases, then refined and fleshed out in detail as the project progresses, often including an approval and baselining process. Appendix B describes products in terms of their evolution to a mature form, with successive versions generally associated with various life-cycle phases and project reviews.

4.4 Overview of the Space Mission Architecture Framework (SMAF)

As described in section 4.1, this NASA Technical Handbook describes an architecture framework that aligns with standards and practices of the global SE community, especially ISO/IEC/IEEE 42010, Systems and software engineering – Architecture description. Following these standards, a framework is organized into Viewpoints, Views, and Products that describe a complex entity such as a system in terms of the interests and concerns of various Stakeholders and Participants. Table 1 summarizes the SMAF structure, and the following sections summarize the Viewpoints and Views. Each product has a short identifier for easy reference. Appendix B gives details of the products that make up each View.

Table 1—SMAF Stakeholders, Participants, Viewpoints, Views, and View Products

Primary Stakeholders					
Science and Technology Community	**Center Engineering Directorate(s)**		**Center Mission/Project Management Directorate(s)**		**Agency, Mission Directorate, Center Director & Staff**
Participants					
Principal Investigator & Science Team	**Mission Systems Engineer & Engineering Team**		**Project Manager & Project Management Team**	**Mission Operations Team**	**Same as Stakeholders**
Viewpoints					
Science	**Engineering**		**Project Implementation**	**Mission Operations**	**Enterprise/ Mission Concept**
Views and View Products					
Science	**Technical Solution**	**Product Realization**	**Project Implementation**	**Mission Operations**	**Enterprise**
Sci-1 Science Concept	Soln-1 Systems Engineering Management Plan (SEMP)	Real-1 System & Product Specifications (6)	Proj-1 Stakeholder Expectations Document	Ops-1 Operational/ Mission Plan/Schedule (5)	Ent-1 Project Scope Document (1)
Sci-2 Science Traceability Matrix	Soln-2 Analysis of Alternatives (AoA)	Real-2 Final MEL	Proj-2 Project Plan with Project Control Plans	Ops-2 Observatory Command Sequence	Ent-2 Concept Study Report (2)
Sci-3 Science Datasets/Data Products	Soln-3 System Requirements Document	Real-3 Standards Profile	Proj-3 Project Review Data Package	Ops-3 Conjunction Assessment Risk Analysis	Ent-3 Decision Memorandum
Sci-4 Science Data Management Plan	Soln-4 V&V Plan	Real-4 Integration Plan	Proj-4 Project Status Report	Ops-4 Deep Space Operations Plan	Ent-4 Strategic Plan
	Soln-5 Test Plan (4)	Real-5 Final Interface Control Documents	Proj-5 Compliance Matrix	Ops-5 Range Flight Safety Risk Management Process	Ent-5 Key Decision Point Data Package
	Soln-6 Architecture Model (3)	Real-6 Test Procedure		Ops-6 Expendable Launch Vehicle Payload Safety Process	Ent-6 Center Facilities, Equipment, and Staffing Plan
	Soln-7 Design Specifications	Real-7 Peer Review Data Package			
	Soln-8 Interface Control Documents				
	Soln-9 Document Tree				
	Soln-10 Preliminary Master Equipment List (MEL)				
	Soln-11 Supporting Analysis				
	Soln-12 Review Data Package				
	Soln-13 CONOPS				
	Soln-14 Technology Readiness Assessment				
	Soln-15 Technical Risk Analysis				
	Soln-16 Technology Development Plan				***LEGEND:***
	Soln-17 Software Plans and Documents				Conceptual View Products
	Soln-18 Specific Engineering Plans				Realizational View Products

Notes:
(1) This Product may take the form of an Announcement of Opportunity (AO) or other description of Project/Mission scope.
(2) The Concept Study Report (CSR) is created by the entire Project Team; for a two-step AO, it is the proposal submitted in competition for a mission and documents all aspects of the Mission Concept as assessed against stakeholder concerns and mission success criteria. It is held in the Enterprise View because it is primarily directed to a NASA Headquarters Mission Directorate.
(3) The architecture begins in the Conceptual/Formulation phase of the project life cycle and progressively becomes a Realization/Implementation product as detailed design is completed and physical detail is added to model elements.
(4) The Test Plan begins in the Conceptual/Formulation phase and becomes a Realization/Implementation product as detailed design and accompanying test procedures are defined.
(5) Operational Plans include launch and trajectory/orbit control along with mission activities and other aspects of flight dynamics.
(6) System and Product Specifications include successive system configurations associated with preliminary and final design, integration and test, transport and storage, and the operational system.

Table 1 captures several significant aspects of the architecture framework.

a. The overall structure of the SMAF has three tiers: Stakeholders and Participants as defined in Appendix A, Viewpoints as defined in section 4.1, and Views containing View Products, also defined in section 4.1 of this NASA Technical Standard.

b. Appendix A distinguishes Stakeholders (“External Stakeholders”) and Participants (“Internal Stakeholders”) who have recognized roles and concerns and who are, respectively, external and internal to a project organization. Table 1 identifies the primary organizations and individuals in these categories and maps them to Viewpoints, with each Viewpoint having a Participant that is primarily responsible for creating and maintaining its products.

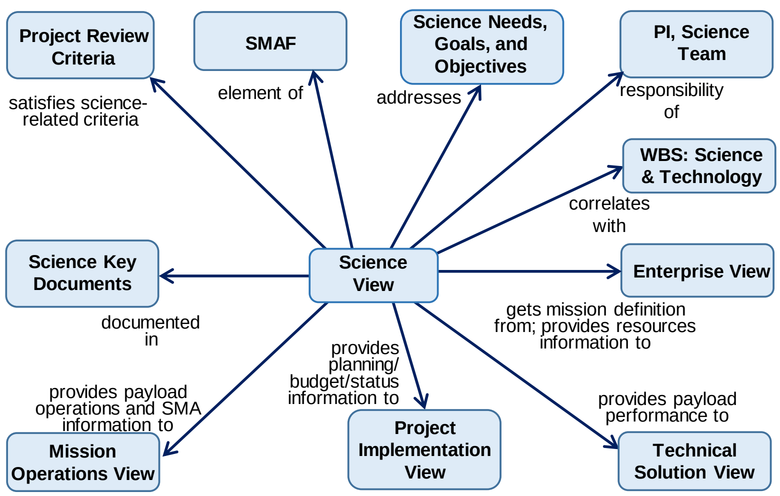
c. Architecture content can be conveniently characterized as chiefly associated with the earlier, Conceptual or Formulation stages of a project or with later, Realization or Implementation stages. In many cases, a particular product is first created during an early stage and then refined with details as technical and programmatic decisions are made across a project’s life cycle. This distinction is indicated in Table 1 with color coding and in some cases further described in the Notes. For example, the Technical Solution and Product Realization Views under the Engineering Viewpoint are both the responsibility of the Engineering Team, with the first of these primarily conceptual in content and the second primarily concerned with system implementation.

d. The majority of the listed products represent well-known information entities from the NASA SE process, and many are also explicitly associated with entry and success criteria of various Life Cycle and Technical Reviews in accordance with NPR 7123.1, Appendix G.

e. Although not explicitly called out as a View in Table 1, requirements are essential and pervasive elements of a valid SE process and span the entire project life cycle from early concept definition through system development and mission operations. In particular, product Soln-3 is a System Requirements Document holding the current requirements baseline; and other products deal with project scope, requirements verification and validation, allocation of requirements to design, and other aspects of requirements engineering.

4.4.1 Science Viewpoint

The Science Viewpoint addresses mission architecture from the perspective of the mission science being conducted, starting with high-level goals and objectives and proceeding to define phenomena to be investigated, measurements and analysis steps, and science datasets and other data products at multiple levels of processing. It specifies the Science View, and these products establish the principal intended outcome of a mission and establish the foundation for system implementation and operations. This Viewpoint also establishes the relationship between mission science and the larger NASA and international science community. This Viewpoint is the responsibility of the Principal Investigator and Science Team and reflects the concerns of the larger scientific community that uses science data products from the mission. Figure 3, Context Diagram of the Science View, Including View Products, shows the context of the Science View with a tabulation of included products.



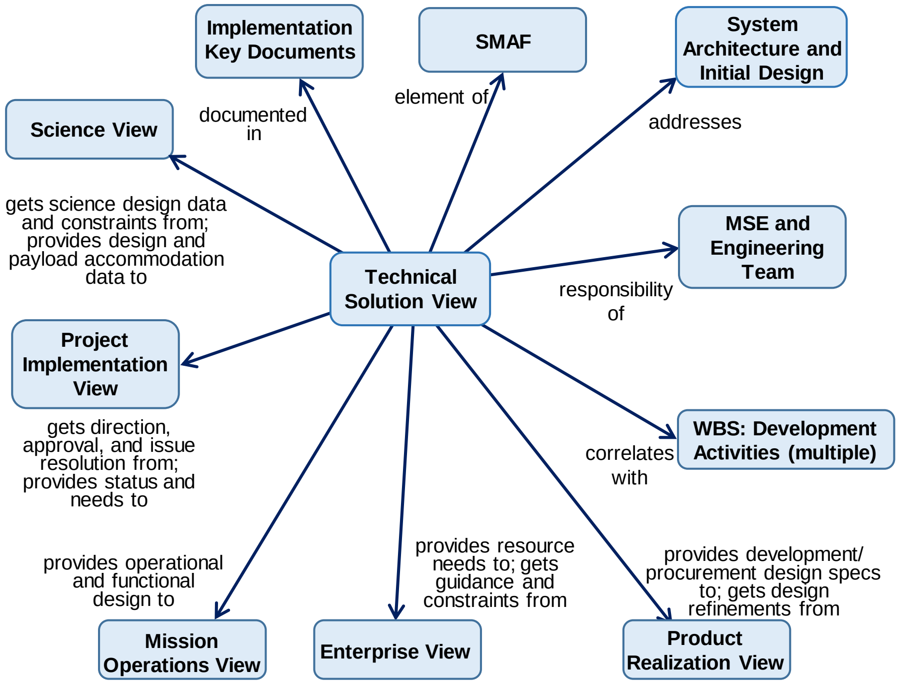
Science View Products
Science Concept
Science Traceability Matrix
Science Datasets and Data Products
Science Data Management Plan

Figure 3—Context Diagram of the Science View, Including View Products

4.4.2 Engineering Viewpoint

The Engineering Viewpoint addresses the technical activities and resulting products involved in formulation and implementation of the mission. It specifies two Views: Technical Solution and Product Realization. This Viewpoint is the responsibility of the Mission Systems Engineer and the Engineering Team.

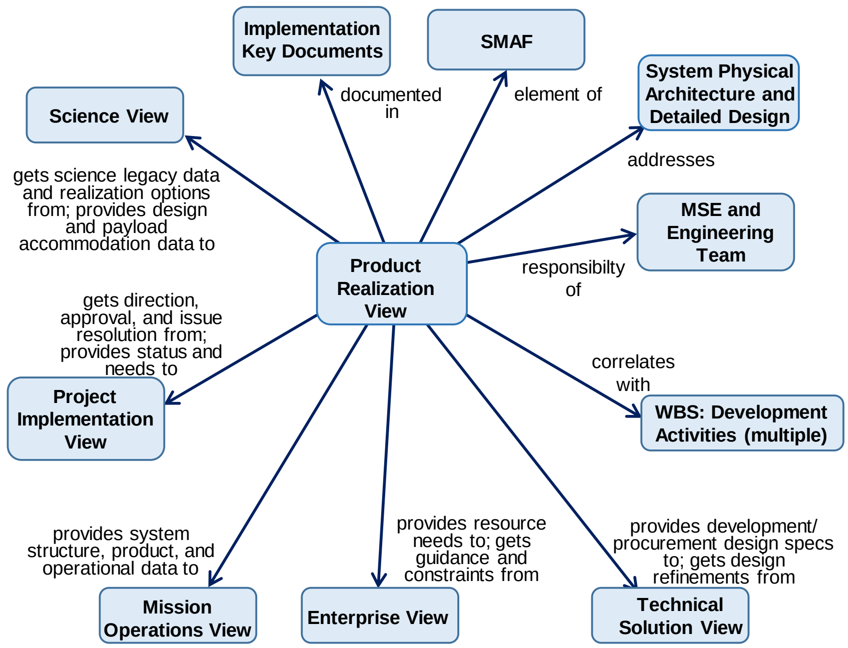
a. *Technical Solution View*. This View deals with mission architecture from the perspective of conceptual and functional architecture, including exploration of alternative concepts and approaches and assessment of these against mission criteria. The included products create functional definitions of the entities making up the system, describe the behaviors of the system and its constituents, define data and data flows, document internal and external interfaces, and identify constraints that impact the design space available to the project. It reflects the concerns of the Principal Investigator, the Engineering Team, and the Project Manager. Figure 4, Context Diagram of the Technical Solution View, Including Products, shows the context of the Technical Solution View with a tabulation of included products.



Technical Solution View Products
Systems Engineering Management Plan
Analysis of Alternatives
System Requirements Document
Verification and Validation Plan
Test Plan
Architecture Model
Design Specifications
Interface Control Documents (Initial)
Document Tree
Preliminary Master Equipment List (MEL)
Supporting Analysis
Review Data Package
Concept of Operations (CONOPS)
Technology Readiness Assessment
Technical Risk Analysis
Technology Development Plan
Software Plans and Documents
Specific Engineering Plan (multiple)

Figure 4—Context Diagram of the Technical Solution View, Including Products

b. *Product Realization View*. This View addresses mission architecture from the perspective of implementing the functional architecture in a physical system. The included products define how mission architecture elements will be procured, developed and built, reused, modified, assembled, integrated, tested, and verified for satisfaction of allocated requirements. This View reflects the concerns of the Principal Investigator, Project Manager, Chief Safety and Mission Assurance Officer, and Mission Systems Engineer (MSE). Figure 5, Context Diagram for the Product Realization View, Including Products, defines the context of the Product Realization View with a tabulation of included products.



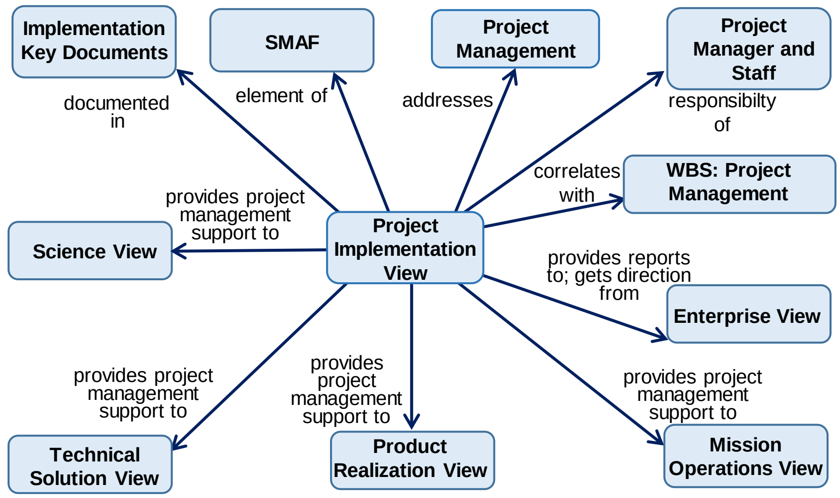
Product Realization View Products
System and Product Specifications
Final Master Equipment List
Standards Profile
Integration Plan
Final Interface Control Documents
Test Procedure
Peer Review Data Package

Figure 5—Context Diagram for the Product Realization View, Including Products

4.4.3 Project Implementation Viewpoint

The Project Implementation Viewpoint addresses mission architecture from the perspective of overall project planning, management, and control. It specifies a Project Implementation View whose included products define how the Project Manager and PM Team, with supporting staff and functional specialists, balance cost, schedule, risk, and performance to deliver and operate a system that satisfies mission goals and objectives. This Viewpoint reflects the concerns of the Project Manager. Figure 6, Context Diagram of the Project Implementation View, Including

Products, defines the context of the Project Implementation View with a tabulation of included Products.

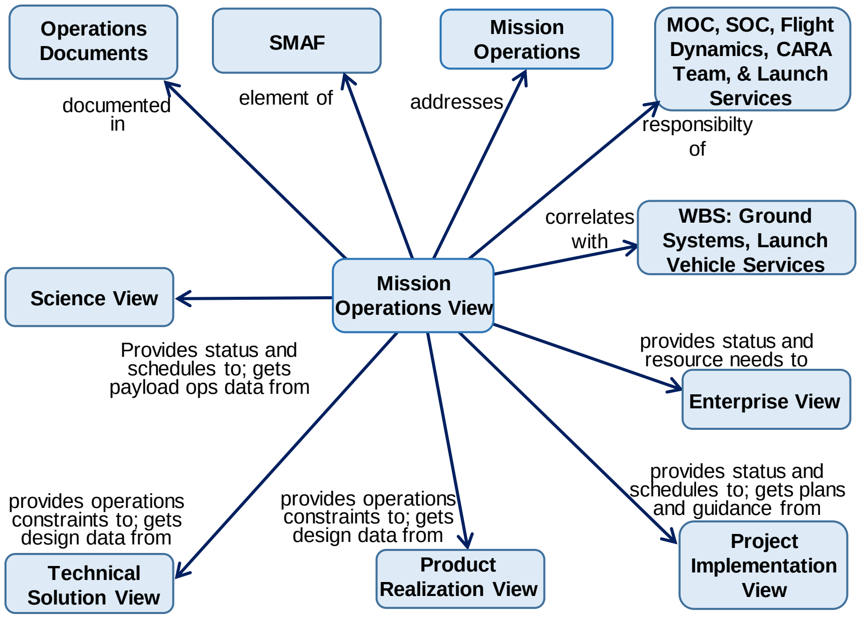


Project Implementation Viewpoint Products
Stakeholder Expectations Document
Project Plan with Project Control Plans
Project Review Data Package
Project Status Report
Compliance Matrix

Figure 6—Context Diagram of the Project Implementation View, Including Products

4.4.4 Mission Operations Viewpoint

The Mission Operations Viewpoint addresses the operations of the flight, ground, and launch segments in performing a mission. It specifies a Mission Operations View whose included products define tasks and activities that span all phases of a mission, including interactions of the system with its operational and support environments, launch and commissioning, flows of information and other resources, planning and system management, management of faults and other anomalies, orbit and attitude control, and end-of-mission decommissioning and disposal. This Viewpoint reflects concerns of the Project Manager and the Mission Operations Team. Figure 7, Context Diagram for the Mission Operations View, Including Products, defines the context for the Mission Operations Viewpoint with a tabulation of included products.

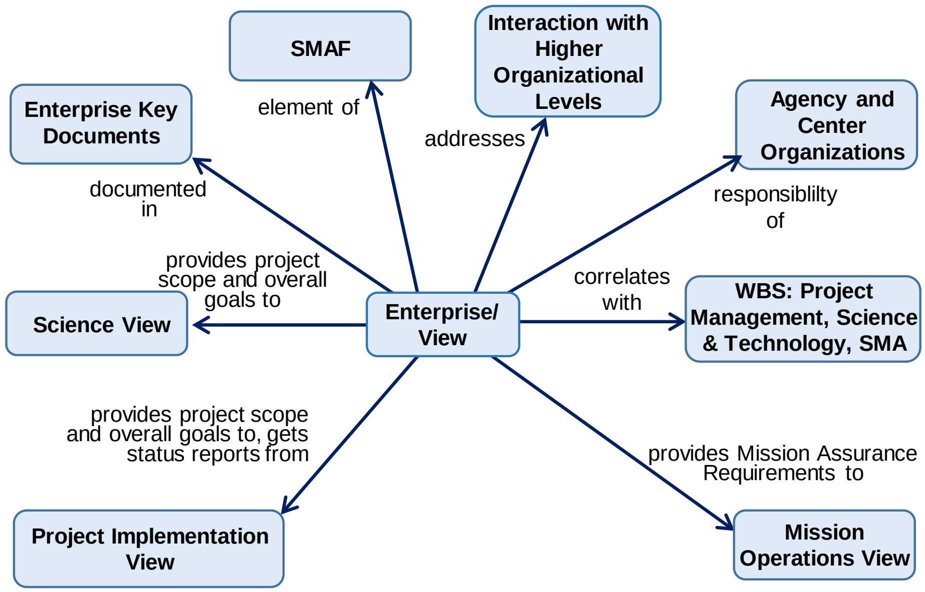


Mission Operations Viewpoint Products
Operational/Mission Plan and Schedule
Observatory Command Sequence
Conjunction Assessment Risk Analysis (CARA)
Deep Space Operations Plan
Range Flight Safety Risk Management Process Documentation
Expendable Launch Vehicle Payload Safety Process

Figure 7—Context Diagram for the Mission Operations View, Including Products

4.4.5 Enterprise/Mission Concept Viewpoint

The Enterprise/Mission Concept Viewpoint addresses mission architecture from the perspective of the Center and Agency stakeholders, especially in capturing all aspects of the mission concept for assessment against higher needs, goals, and objectives. It specifies an Enterprise View whose products link the project to strategic and program plans, as well as to overarching drivers of NASA science efforts such as decadal surveys. They also supply guidance and direction that apply across the Center portfolio and provide linkage between project concerns in areas such as safety and mission assurance (SMA), resources, and higher level plans and priorities for facilities, equipment, workforce development, and other Center and Agency responsibilities. This Viewpoint reflects concerns of NASA Headquarters Institutional Authorities, the Mission Directorate, the division and sponsoring program, and the Center Director and staff. Figure 8, Context Diagram for the Enterprise View, Including WPs, defines the context of the Enterprise Viewpoint with a tabulation of included products.



Enterprise Viewpoint Products
Project Scope Document
Concept Study Report
Decision Memorandum
Strategic Plan
Key Decision Point Data Package
Facilities, Equipment, and Staffing Plans

Figure 8—Context Diagram for the Enterprise View, Including WPs

Appendix C lists the key documents that are created or supported by SMAF WPs. Because of the importance of mission architecture in successful project reviews, Appendix D lists the categories of models used in creating SMAF WPs.

Appendix E maps the SMAF Viewpoints and WPs to the entrance and success criteria of the primary reviews in the project life cycle. Using SMAF WPs in this way yields a number of benefits:

a. A project applying the SMAF will be able to readily apply WPs to prepare for and conduct project reviews and will be able to reduce the work and enhance communication with the reviewers.

b. The mappings in Appendix E highlight the fact that many WPs are created and baselined at early reviews, then updated through the remainder of the life cycle. WPs are easily updated as mission formulation and implementation proceed, again reducing the effort associated with preparing for reviews.

c. Viewpoints. Views and Products promote consistency and reusability in project reviews and in science, engineering, and PM activities across the project life cycle and potentially among successive projects.

Appendix F lists references, and Appendix G defines terms and acronyms used in this NASA Technical Handbook.

APPENDIX A

INTRODUCTION AND RATIONALE FOR THE ARCHITECTURE FRAMEWORK FOR UNCREWED SPACE MISSIONS

A.1 PURPOSE

This Appendix provides the goals, motivation, and rationale for a Space Mission Architecture Framework (SMAF) targeted to NASA uncrewed space missions.

A.2 GENERAL

This Architecture Framework is intended to:

a. Increase the value of the scientific investigations through:

(1) Tighter coupling between science objectives and mission architecture based on enhanced insight into traceability of goals and objectives to requirements, design, and implementation.
(2) Improved understanding of the mission architecture as it evolves throughout the life cycle to enhance collaboration between the Science, Engineering, and PM teams involved in a project.
(3) Increased support for technical and programmatic decisions such as mission de-scope, extended mission options, and other operational trade-offs.

b. Improve effectiveness of end-to-end mission development, including leveraging model-based engineering techniques, specifically by:

(1) Providing more explicit guidance on content of the products used in Project Life Cycle review product, described in NPR 7120.5, NPR 7123.1, NASA-STD-7009, NASA-STD-1006, and other directives, including materials such as front-end definition of expected functional behavior, simulation, and interfaces to improve mission software design, development, integration, verification and validation (V&V), and maintenance, with special emphasis on the inclusion of relevant industry standards.
(2) Better aligning expectations between the Project Team (Science, Engineering, and PM) and external reviewers, through clearer definition of the products used to communicate entrance and success criteria for project reviews.
(3) Enabling easier and more effective management of hardware and software reuse per the requirements of NPR 7150.2, NASA Software Engineering Requirements, through greater standardization of SE and PM products, processes, design patterns, test cases, documentation, and modeling; specifically:

A. Managing system integration (interfaces).
B. Managing integration of other models.
C. Facilitating capture and dissemination of lessons learned.
D. Improving management of technical readiness level (TRL) maturation and its impact on mission cost, schedule, performance, and risk.

c. Enhance institutional capability management by:

(1) Providing insight into the short-term, project-level needs for and utilization of the technical workforce, assets, tools, standards, and methods.
(2) Providing insight into the long-term, Center-level needs for and utilization of workforce, assets, tools, standards, and methods.

d. Improve collaborative application of digital models and products across the science portfolio by:

(1) Specifying standardized ways to define, request, offer, and exchange information between stakeholders across the full systems life cycle.
(2) Applying a standardized taxonomy for WPs and other artifacts.

By aligning with this structure, a project will realize the maximum benefits derived from proven methodologies, standardized materials and presentations, and increased confidence in the completeness and correctness of system formulation and implementation. Specifically, the SMAF will:

a. Provide a vehicle for ensuring the completeness of a mission architecture;

b. Provide guidance on creating and documenting mission architecture content; and

c. Promote a standard approach for developing, presenting, and reviewing mission architectures.

A.3 INTRODUCTION

This NASA Technical Handbook and an accompanying repository of reference materials providing background information, procedures, and examples, along with technical and programmatic guidance for applying the SMAF to uncrewed space missions. Additional handbooks complete the description of the model-based SE approach with tailoring for various mission system categories and modeling methodologies. The SMAF identifies Stakeholder and Participant concerns and correlates them across interdisciplinary perspectives (Viewpoints). The SMAF is structured to align with NASA's operating model and to identify and satisfy the expectations and concerns of mission stakeholders. Viewpoints represent the primary concerns and interests of the various organizations and stakeholders involved in a project. Viewpoints specify Views that contain products that capture the detailed information needed to define a mission architecture and to satisfy Stakeholder needs.

In the SMAF construct, a Space Mission Architecture is composed of:

a. Mission Science Goals and Objectives,
b. Mission System Architecture,
c. Project/Organizational Architecture,
d. An Enterprise Architecture (Resources Model), and
e. Natural and Organizational Environment of a Mission and Project.

The SMAF bridges existing gaps among the Science, Management, and Engineering communities involved in a mission, as well as those among Agency, Center, and project organizations. The SMAF also establishes a common and repeatable structure for project proposals to enhance their overall quality and simplify the task of evaluating competed proposals.

A.4 MEETING STAKEHOLDER NEEDS

The SMAF enables a uniform, consistent, and effective approach to creating, documenting, and presenting information about an uncrewed space mission architecture. It is predicated on a model-based approach. However, to facilitate its adoption and use in projects, the framework references existing documents, referred to as key documents and tabulated in Appendix C, as well as other artifacts that are familiar to NASA personnel. In the near term, these will continue to furnish the primary content of many project reviews and are used across the project life cycle to enable concept definition, technology development, design, fabrication, integration and test, launch, operations, and disposal of a mission system.

A.4.1 Primary Stakeholders

This section addresses the concerns of stakeholders who are directly and continually involved in a project. The primary parties to a project are of two kinds: External Stakeholders (“Stakeholders”) who are outside the project organization and Internal Stakeholders (“Participants”) who make up a project team. Additional stakeholders whose concerns occur at a higher level and whose involvement is less frequent include Congress, various Federal agencies, the academic community, the aerospace industry, and potential international and academic partners, as well as the general public through education and outreach. At some point in a project’s life cycle, any of these parties is likely to be concerned with any given area of architecture content. However, to achieve a logical and consistent SMAF structure, this NASA Technical Handbook focuses on the primary concerns of specific stakeholders. Stakeholder concerns commonly involve mission/project scope, technical issues, safety and mission assurance, project management, and resources, as well as other concerns peculiar to an individual Stakeholder. In some cases, these concerns can be seen as risks and addressed through the project risk management process. Figure 9, Overall Crosscutting Categories of Stakeholder Concerns, summarizes this overall view of External and Internal Stakeholders and their concerns.

Major areas of concern can be conveniently grouped into Scope, Technical, Safety and Mission Assurance, Project Management, Resources, and a catchall Other category. The figure indicates that, at some level and at various points in time, any Stakeholder may be interested in any area of concern. However, individual stakeholders will place their main emphasis on concerns directly related to their roles and responsibilities; for example, the Science and Technology Community and the Center Engineering Community will place the greatest emphasis on Technical concerns. The following subsections summarize the concerns of individual Stakeholders.

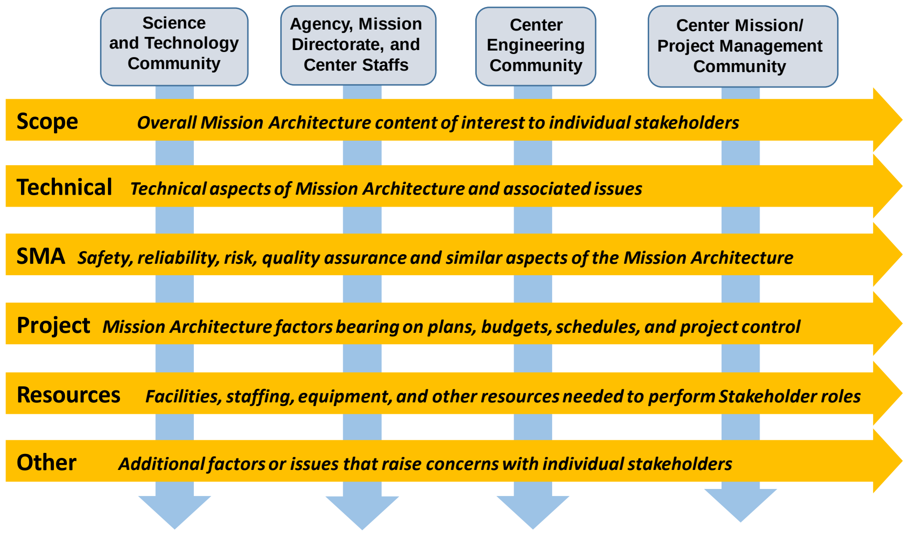


Figure 9—Overall Crosscutting Categories of Stakeholder Concerns

A.4.1.1 Science and Technology Community

Since the ultimate purpose of a science mission is to gather, analyze, disseminate, and archive scientific data, the primary customers of such a mission are the scientists who define the content of a mission and use the results to further human knowledge and address humanity's needs and aspirations. In the early stages of concept development for a mission, the PI represents this community, which includes both scientists directly involved in a mission and the larger, often global, body of interests in the researchers, teachers, and others with interests in a particular investigation. Once the science needs, goals, and objectives of the mission are established, the PI and Science Team transition to Participants who collaborate within a Project Team to develop, fly, and operate a mission system.

The Science Viewpoint deals with the following concerns:

a. Ensuring that mission science goals and outputs are traceable to approved overall NASA scientific goals and strategies, including those derived from Decadal Surveys and other sources of national science priorities;

b. Ensuring that science needs, goals, and objectives of the mission are properly identified, analyzed, documented, and translated into the system design;

c. Ensuring that the instrument payload of each Observatory is functionally defined, technically mature, and capable of collecting the required data;

d. Ensuring that the spacecraft bus is defined, characterized, and technically mature to perform the mission and to accommodate and support the instrument payload;

e. Ensuring that all required onboard and ground science data processing, telemetry, archiving, and dissemination are defined and that required resources will be available when needed; and

f. Ensuring that appropriate plans and processes are defined so that the interested science community has timely access to data products, algorithms, archived data, and other content and that there is efficient interaction between the project science team and the larger science community so that the latter can input relevant information and request data to optimize the overall science return.

A.4.1.2 NASA Headquarters, Mission Directorate, and Center Director and Staff

Every NASA mission contributes to the agency mission "To reach for new heights and reveal the unknown so that what we do and learn will benefit all humankind." Accordingly, leadership at the Agency and Center levels has a vital interest. Depending on the Class and other characteristics of a mission, approval authority for project initiation and continuation at Key Decision Points will be established at an appropriate level.

The Enterprise/Mission Concept Viewpoint deals with the following concerns:

a. Ensuring that projects are selected, approved, planned, funded, and implemented to effectively support a Mission Directorate program and the overall Center and Agency mission and science portfolio;

b. Ensuring that the maximum science return is obtained from a mission and disseminated to the appropriate scientific community;

c. Ensuring that an appropriate Safety and Mission Assurance program is implemented and documented for a mission;

d. Ensuring that current and planned Center resources (facilities, equipment, workforce, infrastructure, etc.) and technology development efforts can support the project over its life cycle and can use project outcomes to sustain resources for future projects;

e. Ensuring that all applicable Agency and Center policies, procedures, guidelines, standards, and other documentation are appropriately applied in a project; and

f. Ensuring that a project positively reflects credit on the Agency and Center from the perspective of other external stakeholders (e.g., Congress and the general public).

A.4.1.3 Center Engineering Community

Depending on the organization of the Center implementing a project and mission, one or more engineering and technology directorates have oversight of the technical aspects.

The Engineering Viewpoint deals with the following concerns:

a. Ensuring that required engineering standards and processes are in place, appropriately tailored and balanced against currently available technology and techniques to enable formulation and implementation of a successful mission;

b. Ensuring that Measures of Effectiveness (MoEs), Measures of Performance (MoPs), Technical Performance Measures (TPMs), and other metrics are identified and tracked;

c. Ensuring that necessary technical baselines are defined and managed for each project milestone;

d. Ensuring that a project has the necessary engineering resources to implement its mission;

e. Ensuring that the design for an uncrewed mission provides the necessary resources (hardware and software) to perform the mission with the required level of autonomy;

f. Ensuring that the technical content of each project review satisfies review objectives and provides a sound basis for decisions about project continuation and required corrective actions; and

g. Ensuring that technical status and concerns are provided to the Center and Agency leadership and to other participating organizations.

A.4.1.4 Center Mission/Project Management Community

One or more Mission/Project Management directorates have oversight of the planning, project control, resource management, project life-cycle reviews, and other aspects of project implementation. The SMAF identifies two Viewpoints that capture the concerns of this Stakeholder group.

The Project Implementation Viewpoint deals with the following concerns:

a. Ensuring that all applicable policies and processes are implemented, especially in accordance with NPR 7120.5 and Center supplementary requirements, and that they support successful mission/project formulation and implementation;

b. Ensuring that a project identifies issues, concerns, adverse events, and other matters of interest to Center and Agency leadership in a timely fashion and receives support for issue resolution;

c. Ensuring a project maintains a robust and continuing dialog with Stakeholders to ensure their expectations are understood and properly addressed;

d. Ensuring that a project involving collaboration across NASA Centers, other Government agencies, international partners, and other external entities has in place adequate mechanisms for coordination of activities, issue resolution, organizational roles and responsibilities, and other aspects of effective partnership; and

e. Ensuring that a project identifies required facilities, equipment, staffing, and other resources in a timely fashion and that these are provided when needed.

The Mission Operations Viewpoint deals with the following concerns:

a. Ensuring that a project accomplishes all required planning, coordination, and preparation for launch, flight operations, and disposal of the mission system; and

b. Ensuring that a project has adequately defined a Mission Operations Center, Science Operations Center, access to telemetry and communications networks, and other mission support facilities and services.

A.4.1.5 Chief Safety and Mission Assurance Officer (CSO)

The CSO is a special Stakeholder who exercises both External and Internal Stakeholder roles as the representative to a project of Center and Agency SMA organizations and as a member of the project team ensuring an adequate and effective SMA activity is performed. The SMAF does not define a separate Viewpoint for the specialized and project-specific concerns of the CSO, and these are accounted for under the Project Implementation Viewpoint.

CSO concerns include ensuring that:

a. The project implements an appropriate quality assurance program;

b. The project thoroughly identifies and implements a Risk Management Plan to identify, assess, mitigate, and track all major technical and programmatic risks commensurate with the project class (e.g., acceptable risk level in Class A vs. Class D);

c. The project thoroughly identifies hazards to personnel and equipment and implements a hazard management plan to assess, control, and track hazards;

d. The project applies consistent definitions and a safety and mission success taxonomy.

A.4.2 Participants

This section addresses the concerns of the "Internal Stakeholders" who constitute a Project Team and are responsible for implementing a mission and project that satisfy the needs and expectations of the Primary Stakeholders.

A.4.2.1 Principal Investigator (PI) and Science Team

As noted earlier, once the science content of a mission is defined and documented in a Science Concept, the PI and team transition to a Participant role and work within the Project Team to complete the formulation and implementation of the mission. To satisfy the concerns of the Science Community Stakeholder, the Science Team develops a Science View aimed at ensuring that:

a. Science needs, goals, and objectives of the mission are properly identified, analyzed, and documented in collaboration with the Systems Engineering Team, and captured in the requirements baseline for the mission;

b. The instrument payload of each Observatory is technically mature, fully characterized, calibrated, and capable of collecting the required data;

c. The spacecraft bus provides all required instrument accommodation;

d. All required onboard and ground science data processing telemetry, archiving, and dissemination are fully defined and supported by required resources;

e. Science data products are fully defined, adequate to meet the science goals of the mission, and governed by an appropriate Science Data Management Plan; and

f. Ground data systems are defined, developed, delivered, and verified to process mission science data prior to launch and operations.

A.4.2.2 Mission Systems Engineer (MSE), with Instrument Systems Engineer(s) (ISE), Discipline Engineering Team Leads, and Other Engineering Staff

The Engineering Team transforms the science needs, goals, and objectives of a mission into a mission system that can satisfy them within constraints of schedule and resources and with acceptable risk. Depending on the organizational structure of the Center implementing the mission, there may be an identified Assembly, Integration, and Test (AIT) Team which is responsible for these activities. The Engineering Team develops two Views that are specified by the Engineering Viewpoint.

The Technical Solution View is primarily focused on Mission Formulation during Phases A and B of the NASA Project Life Cycle. Specific concerns addressed by this View include:

a. A high-quality SE process to translate the project's science needs, goals, and objectives into a robust, reliable, affordable, supportable, and fully documented mission system design; the process is documented in a SEMP;

b. An assessment of mission architectural constraints and application of design patterns and other tools to identify and analyze design trade-offs and other detailed analysis to develop mission system architectures that will meet the technical requirements with acceptable cost, schedule, and risk;

c. A complete, consistent, balanced, verifiable, and feasible requirements baseline that accurately reflects mission goals and objectives while balancing cost, schedule, performance, and risk, including supporting plans for V&V;

d. Definition and management of the technical baselines for each project milestone;

e. Identification and tracking of TPMs and other metrics to assess design maturity and provide early warning of technical issues;

f. Application with appropriate tailoring of applicable standards and processes that are balanced against currently available technology and techniques;

g. Technical content of each project review that accurately reflects the current technical baseline and is prepared and presented to satisfy stakeholder expectations for entrance and success criteria, pass the review, and disposition resulting actions;

h. Integration of the activities of engineering discipline teams; and

i. Timely notification of technical status, concerns, actual or potential problems, and risk actions to the Project Management and Science Teams with recommended corrective actions to minimize their impacts.

The Product Realization View is focused primarily on Mission Implementation during Phases C and D of the NASA Project Life Cycle. Specific concerns addressed by this View include:

a. Design, fabrication, assembly, integration, and test of the mission system to satisfy mission requirements;

b. Continued integration of the activities of engineering discipline teams;

c. Analysis and management of mass, power, thermal, and other physical budgets to ensure adequate margins and maintain a balanced mission system design;

d. Integration of the mission system with its launch vehicle; and

e. Integration of the Flight Segment with the Ground Segment for the mission.

A.4.2.3 Project Manager (PM), with the Ground Segment Manager, Launch Manager, Observatory Manager, and PM Staff

The Project Management Team, which includes the overall Project Manager, managers for the Ground and Launch Segments, and their staffs, is responsible for programmatic actions in accordance with NPR 7210.5 and NPR 7120.8 across the project life cycle. The Project Implementation View is aimed at ensuring that:

a. Project planning, budget, schedule, and resources are current and accurate and that they support successful project execution;

b. All applicable Baselines and Project Control Plans of the Project Plan are similarly correct, current, and adequate;

c. The project appropriately tailors and implements all applicable policies, procedures, standards, and other documentation;

d. The Project Team properly prepares for program reviews, satisfies all entrance and success criteria, passes each review, and dispositions actions arising from each review;

e. All aspects of the project (science, engineering, launch services, ground support, logistics, etc.) are properly defined, planned, coordinated, and adequately resourced; and

f. Status and concerns are provided to higher organizational levels, including timely notification of required resources, actual or potential problems, and recommended corrective actions to minimize their impact.

A.4.2.4 Mission Operations Team

This specialized team is responsible for safe and effective operations from launch through orbital flight and ultimately disposal. The Mission Operations View is focused on Phases E and F of the project life cycle and is aimed at ensuring that:

a. The proposed mission concept of operations (CONOPS) identifies existing and future operational elements; defines operational interfaces; and envisions people, processes, and procedures that are compatible with existing infrastructure, practices, and operational doctrine;

b. All necessary operational plans, procedures, requirements, and budget projections are fully defined, validated, and understood prior to Pre-Launch Acceptance Review (PLAR), including all launch and post launch mission phases and associated activities;

c. The facilities, equipment, software, staffing, training, and other aspects of the Mission Operations Center (MOC) are established and verified ready for launch and operations; and

d. Networking and telemetry for launch and on-orbit operations are available and verified to have the required operability for the mission, including connectivity among Flight Dynamics, the Science Operations Center (SOC), and the MOC.

A.4.2.5 Chief Safety and Mission Assurance Officer (CSO)

As noted earlier, the CSO is both a Stakeholder who provides liaison between a project and the Center and Agency SMA organizations and as a Participant who works within a Project Team to ensure SMA is properly defined and implemented. The Project Implementation View includes a Safety and Mission Assurance Plan under the Project Plan, and the associated project management processes include Quality Assurance and other activities associated with SMA. The concerns of the CSO are identified in section A.4.1.5 of this NASA Technical Handbook.

A.4.2.6 Enterprise View

Although Agency and Center leadership are not part of a Project Team, this View contains the Products that are required for effective interaction between a project and higher echelons of the Center and Agency. The concerns of the Enterprise Stakeholder are identified in section A.4.1.2 of this NASA Technical Standard.

A.4.3 Requirements Flowdown and Traceability

An essential aspect of meeting Stakeholder needs involves ensuring that needs, goals, and objectives are rigorously and traceably flowed down from national and Agency levels to programs and then to the missions sponsored by a program, its associated projects, and systems. A mission, project, and system are intimately related but distinct in their natures and purposes. SMAF Viewpoints are impacted in important ways by the need to support this flowdown and traceability. The key terms are defined in Appendix G in this NASA Technical Handbook; and

Figure 10, Flowdown and Traceability of Needs, Goals, and Objectives, summarizes the relationships involved.

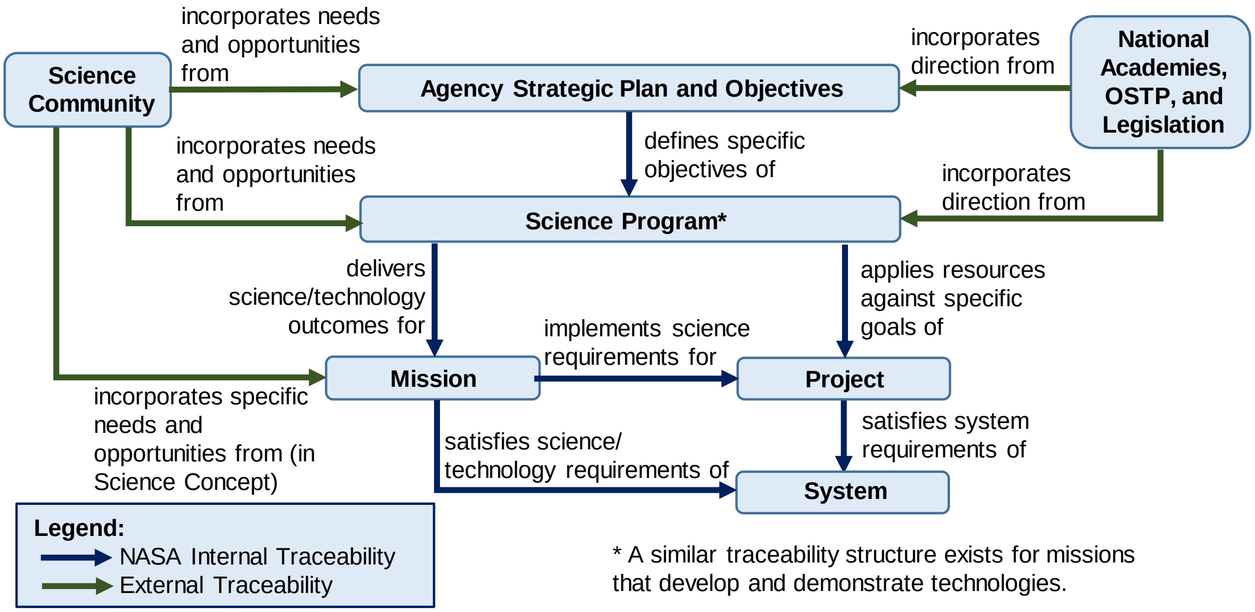


Figure 10—Flowdown and Traceability of Needs, Goals, and Objectives

A.5 SMAF STRUCTURE

A.5.1 Viewpoints, Views, and Products

Figure 11, SMAF Scope Diagram, shows the basic mission architecture content that is included in the SMAF scope, linked to the primary Stakeholders. As discussed in section 4 of this NASA Technical Handbook, Viewpoints specify Views whose products create and hold the information required to address the concerns while employing consistent formats and methodologies to promote high quality and facilitate communication among the many parties to a project. Views may include models, documents, and other products, as described in detail in Appendix B; and the SMAF assumes a model-based approach to content creation. This Appendix gives additional detail about SMAF structure, especially interactions among stakeholders and information exchanges across the boundaries of Viewpoints.

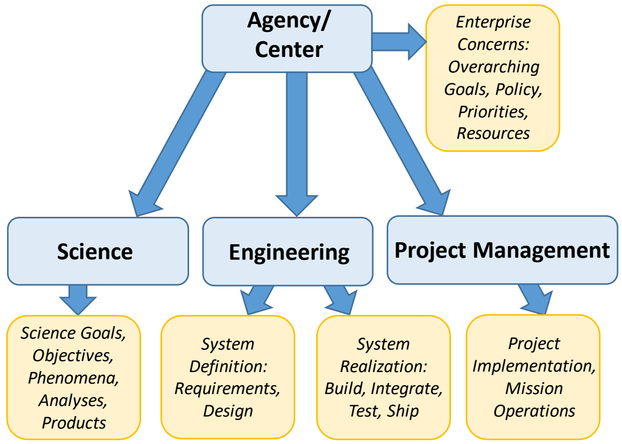


Figure 11—SMAF Scope Diagram

No architecture framework structure can perfectly sort architecture content into isolated Viewpoints. The nature of system development dictates that information developed and documented by any given project organization has to be shared and used by others. For example, the PI and Science Team of a project primarily create the Science Viewpoint. The Engineering, Mission Operations, and other teams use the products of the Science View as the starting point for their own activities. Team members interact extensively throughout the project life cycle to ensure complete, consistent, and valid architecture artifacts are defined, developed, and used in support of achieving mission objectives.

Figure 12, Summary of SMAF View Content, expands on the product listing in Table 1, section 4.4, to identify the most important types of information in each View, including models, key documents, and other content.

View Content					
Science View	**Technical Solution View**	**Product Realization View**	**Project Implementation View**	**Mission Operations View**	**Enterprise View**

• Science Concept
• STM
• Analysis Models
• Science Datasets & Products
• Science Data Mgmt Plan
• Science Operations
  o Planning
  o Observations
  o Processing
  o Dissemination
  o Archiving
• Field Campaign
	• Analysis of Alternatives
	• CONOPS
	• System Rqmts – Base- line, Allocation, V&V
	• SEMP & Process Documentation
	• Architecture Model w/ System Decompo- sition/Structure
	• Functional Specs, Interface Definitions, & Behaviors
	• Engineering Analysis Models & Reports
	• Test Plans & Methods
	• Master Equipment List
	• Technology Maturity & Technical Risk Assessments
	• Hazard Assessment
	• Technology Development Plan
	• Software Plans, Process Documentation
	• Technical Content of Review Data Packages
		• Physical Architecture Model
		• Physical System & Product Specifications
		• MEL/ Product Breakdown Structure (Final)
		• Standards Profile
		• Integration Plan
		• ICDs (Final)
		• CAD/CAM Models
		• Test & V&V Plan(s)/ Procedure(s)
		• Technical Content of Review Data Packages
			• Stakeholder Expectations Document
			• Project Plan with Multiple Project Control Plans
			  o MAIP/SAMP
			  o Risk Management Plan
			  o Configuration Management Plan
			• WBS Baseline
			• Integrated Master Plan & Schedule (IMP/IMS)
			• Cost Methodology Plan
			• Technical and Schedule Reserves Status
			• Unallocated Future Expenses (Budget Reserve) Status
			• SRB Project Review Data Packages
			• Project Reports
			• Compliance Matrix
			• Project Review Data Packages
			• Project Status Reports
				• Operational & Environmental Models
				• Mission Operations Plan(s)
				• Deep Space Operations Plan
				• Operational Schedules
				• Observatory Commands
				• Conjunction Assessment Risk Analysis
				• Range Safety Plan
				• Payload Safety Plan
				• Nuclear Safety Plan
				• Communication Plan
				• Housekeeping/ Fault Data
					• Project Scope Document (from AO, Decision Memo, or other Directive)
					• Concept Study Report
					• Strategic Plans
					• Mission Assurance Requirements
					• Formulation Agreement
					• Decision Memo
					• Key Decision Point Data Packages
					• Center & Agency Standards
					• Center Facilities, Equipment, & Staffing Plan(s)

Figure 12—Summary of SMAF View Content

a. The Science Viewpoint is the anchor of the Mission Architecture and furnishes both information and direction to the others. It is the starting point for the Requirements Baseline; provides results from legacy missions and spacecraft that may inform or constrain the system architecture and implementation; shows traceability to national, Center, and Agency goals and objectives; defines the baseline and objective capabilities of the mission; and establishes capabilities for science measurements, processing, dissemination, and archiving. All other Viewpoints start with the overall Science Concept and develop on the basis of the particular functions, priorities, and constraints established in the Science Viewpoint.

b. The Technical Solution Viewpoint translates the science content of the mission into the Requirements Baseline and functional design of a mission, which may include one or more Observatories in a Flight Segment plus Ground and Launch Segments. This includes assessing alternative mission concepts against the science goals and priorities. The functional design may reveal that adjustments to the mission science are required by risk, cost, operational, or other considerations; these Viewpoints interact in arriving at an optimum mission concept within the constraints. The Technical Solution Viewpoint establishes performance specifications that are satisfied in a system implementation as documented in the Product Realization Viewpoint. This Viewpoint also creates the technical content of a CSR for Center and Agency evaluation; provides the starting point for Mission Operations planning; and furnishes cost, risk, schedule, resource needs, and other data to the Project Implementation Viewpoint.

c. The Product Realization Viewpoint transforms the functional architecture into a point design (physical architecture), accompanied by acquisition, fabrication, integration, test, and other aspects of achieving a system that meets science needs, goals, and objectives. It interacts intimately with the Technical Solution Viewpoint to resolve issues, define interfaces, establish feasible performance parameters, achieve acceptable risk levels, and, in general, optimize system design. It supports detailed Mission Operations planning in areas such as spacecraft commanding and housekeeping, fault management, design for reliability, detailed data and communications definitions, and many other operational specifics. It provides important technical content to a CSR.

d. The Project Implementation Viewpoint is the focus of project execution and interacts closely with all the others. It maintains management plans, schedules, budgets, risk and configuration status, external coordination, and many other factors in planning, managing and controlling the project. Importantly, this Viewpoint provides current and projected resource needs to Center and Agency levels to ensure these will be available when needed by the project.

e. The Mission Operations Viewpoint is the basis for planning and executing the actual space mission, including launch vehicle integration, launch and orbit insertion, checkout and commissioning activities, trajectory/orbit control, conjunction assessment and avoidance, and ultimate disposal/decommissioning. It provides important inputs to requirements and design based on the practical considerations of safety, flight dynamics, environmental factors, and other considerations. It largely establishes the capabilities of the Mission and Science Operations Centers (MOC/SOC).

f. The Enterprise/Mission Concept Viewpoint is concerned with ensuring that the project is properly harmonized with larger Center and Agency goals and strategic plans and that adequate communication and oversight provisions are in place. A mission and project typically begin with an AO that serves as a Scope Definition Document and establishes the policy and guidance for the formulation and implementation of the mission. It therefore interacts with all the other Viewpoints to provide direction and to receive and process status, issues, resource needs, and other information to ensure the mission/project is correctly defined and implemented to meet Center and Agency objectives.

Figure 13, Summary of Mission Architecture Framework Content Exchanged by Viewpoints, is a Viewpoint Interdependency Matrix that summarizes content exchanged among Viewpoints. At the top, Figure 13 also summarizes external inputs to the content of the various Viewpoints. In the matrix in Figure 13, the cell on the diagonal corresponding to the Viewpoint that is providing content traces to the right in the upper part of the matrix or to the left in the lower part to the cell in the column of the receiving Viewpoint. The top row of the matrix summarizes important external information sources, physical constraints, policy and legal requirements, and other influences bearing on a space mission architecture.

External Inputs to SMAF Viewpoints					
- Laws of Physics - Legacy Missions - Partner Capabilities	- Enabling Technologies - Tools & Methods - Community Stds	- Laws/Regulations - Available Products - Environment	- Laws/Regulations - Agency and Program Coordination	- Laws of Flight Dynamics - Conjuncting Objects	- National Policies/ Priorities/ Goals/ Budgets/
Viewpoint Relationships					
Science Viewpoint	- Science Validation of Technical Solution - System Science Constraints - Legacy Science Data	- Legacy Payload Data - Payload Buy/Build/Reuse Options	- Science Planning/Budget/ Schedule/Risk et al. Data - Science Status/Issues	- Payload Operations Data - Instrument Commands/ Timelines	- Science Content of CSR - Science Resource Needs/Status - Science Discoveries/ Revelations
- Product Design Data - Payload Accommodation Design Data	***Technical Solution Viewpoint***	- Design Specifications	- Engineering Planning/Budget/ Schedule/Risk et al. Data - Engineering Status/Issues	- Product Design Data - V&V Data - CONOPS	- Technical Content of CSR - Engineering Resource Needs/ Status
- Functional Design Data - Payload Accommodation Design Data	- Product Design Constraints - Refined Specifications	***Product Realization Viewpoint***	- Realization Status/Issues	- Operational/ Functional Design Data - V&V'd System Data - System Test Data	- Technical Content of CSR - Engineering Resource Needs/ Status
- PM Guidance - Risk/S&MA Status - Science-Engineering Issue Resolution	- PM Guidance - Implementation Constraints	- PM Guidance - Implementation Constraints - HW and SW to Assembly/ Integration/ Verification	***Project Implementation Viewpoint***	- PM Guidance	- Project Status Reports - Project Resource Needs/ Status
- CONOPS - Mission Operations Status - Payload Schedules	- CONOPS - Operations Constraints - Legacy System Definitions	- CONOPS - Operations Constraints	- CONOPS - Operations Plans - Mission Operations Status - Observatory Schedules	***Mission Operations Viewpoint***	- Mission Operations Resource Needs/ Status
- Agency Science Goals/ Priorities/ Guidance - Mission Opportunity - Science Resources - Mission Science Guidance	- S&MA Expectations (Mission Class) - Technical Solution Constraints	- Technical Realization Constraints - Realization Resources	- Policy/Guidance/ Direction (NPR 7120) - Mission Assurance Requirements - Implementation Resources	- Mission Operations Policy/ Guidance - Operational Infrastructure	***Enterprise/ Mission Concept Viewpoint***

Figure 13—Summary of Mission Architecture Framework Content Exchanged by Viewpoints (from the Source Viewpoint, read horizontally to the column of the receiving Viewpoint)

Example: Consider the flow of SMA guidance offered by a Mission Directorate through an AO. This example assumes an SMA process is required for the mission. This guidance flows from the

Enterprise/Mission Concept Viewpoint (Mission Directorate) down to and through other Viewpoints:

a. Mission Directorate (Enterprise/Mission Concept Viewpoint): The NASA program or Mission Directorate division sponsoring a project issues an AO or other directive that provides overall SMA guidance based on the Mission Class and other factors.

b. Center (Enterprise/Mission Concept Viewpoint): A NASA Center enlists the support of an SMA specialist to assist the project in planning and executing the project to comply with the requirements.

c. Project Implementation Viewpoint: The Project Manager ensures that a compliant Safety and Mission Assurance Plan (SMAP) or MAIP is developed and approved.

d. Engineering Viewpoint:

(1) Technical Solution View: The SE Team accounts for SMA requirements in the project requirements baseline and in the development of the mission concept and design solution, including V&V.
(2) Product Realization View: The SE Team ensures that the physical system fully implements SMA requirements, including design, fabrication, integration and test.

e. Other Viewpoints: The Science and Mission Operations Viewpoints incorporate SMA requirements in their activities and work products (WPs). For example, the Mission Operations Team ensures that planning for all phases of mission operations fully satisfy SMA requirements. All SMAF Viewpoints have SMA concerns defined.

Another illustration of Viewpoint responsibilities and interactions concerns the project WBS and the engineering product breakdown structure (PBS). The WBS organizes the work scope of a project into definable product elements and related services and data. The PBS defines the system structural hierarchy, with products that typically result from completion of WBS elements. Accordingly, the Project Implementation and Product Realization Viewpoints interact closely to ensure the full scope of system development is correctly planned and executed.

Table 2, Participant Responsibilities for SMAF Views, identifies Participants who have primary responsibility and those who use and contribute to each View.

Table 2—Participant Responsibilities for SMAF Views

Participants	*SMAF Views*					
	Science	*Technical Solution*	*Product Realization*	*Project Implementation*	*Mission Operations*	*Enterprise/ Institution*
NASA Headquarters, SMD, Program	**S**				**S**	**P**
Center Director	**S**				**S**	**S**
PI/Science Team/Science Community	**P**	**S**	**S**	**S**	**S**	
PM/Project Team		**S**	**S**	**P**	**S**	**S**
CSO		**S**	**S**	**S**		
MSE/SE Team		**P**	**P**	**S**	**S**	
Mission Ops Team		**S**	**S**	**S**	**P**	

Legend: P = Primary, S = Secondary

A.5.2 SMAF Taxonomies

Three distinct but related structural taxonomies are involved in a mission and a mission architecture. These involve the structural decomposition of a system, the decomposition and approval of requirements, and the organizational structure that defines, approves, and carries out a project to achieve the objectives of the mission. Recognizing that there is wide variation in the nomenclature applied to the levels of these taxonomies across missions and projects, this NASA Technical Handbook adopts a naming convention shown in Table 3, SMAF Taxonomies for Systems, Requirements, and Organizations, and is defined in the following paragraphs.

Table 3—SMAF Taxonomies for Systems, Requirements, and Organizations

	System Structure Decomposition		**Requirements Levels**			**Organization Levels**
	System Level	*Example*	*Requirements*	*Example*	*Approval*	
0	Program	Heliophysics Program	Major Program/Goal	Heliophysics Science Goals	Agency/Center	NASA
1	Mission System	Specific Mission/ Project	Mission/Project	Specific Mission/ Project	Program Office	Mission Directorate
2	Segment	Flight Segment	Segment	Flight Segment	Project/MSE	Project Team
3	Element	Spacecraft Bus	Element	Spacecraft Bus	MSE/PDL	PDL
4	Subsystem	Propulsion	Subsystem	Propulsion	PDL	PDL
5	Assembly	Propellant Handling	Assembly	Propellant Handling	PDL	PDL
6	Subassembly	Propellant Tank	(As required)			
7	Component	Valve	(As required)			
8	(Lower levels)		(As required)			

In each phase of the project life cycle, the mission architecture description is extended to greater levels of structural and functional detail as shown in Table 3. The maturity expected of each Viewpoint, View, and Product at the completion of various life-cycle phases is spelled out in Appendix B. Although some aspects of a mission system, especially the instrument payload, mature earlier than others, traceability across segments at a given level of structural definition has to be ultimately achieved.

This NASA Technical Handbook is compatible with system structures, requirements trees, and project organizations that are typical in an uncrewed project as defined in the following levels:

a. **Levels of System Structure Decomposition**

(1) Level 0 – Program: The Mission Directorate program that sponsors a project; this enterprise context is not part of an individual system.
(2) Level 1 – Mission System: Includes all resources and functions that constitute a system.
(3) Level 2 – Segment: Primary constituents of a system, commonly flight, ground, and launch segments; the flight segment may consist of a single observatory or a constellation of two or more observatories.
(4) Level 3 – Element: The primary constituents of a segment; examples include a spacecraft bus, an instrument, a MOC, an SOC, a launch vehicle (LV), and a launch facility or range. Note that this level may be organized with one or more groups of instruments constituting an instrument suite or payload.
(5) Level 4 – Subsystem: The next level of decomposition of an element; examples include an instrument subsystem (detector, embedded electronics, etc.), bus subsystem (propulsion system; electrical power system; guidance, navigation, and control; thermal control system; command and data handling; etc.), a launch vehicle stage, a payload adapter, etc.
(6) Level 5 – Assembly: The next level of decomposition of a subsystem; an example is a propellant handling assembly consisting of tanks, lines, valves, and pressure transducers.
(7) Level 6 – Subassembly: The next level of decomposition of an assembly; an example is a propellant tank with installed lines.
(8) Level 7 – Component: The next level of decomposition of a sub-assembly; an example is an individual flow control valve.
(9) Levels 8 and below: When required to completely describe a system, structural decomposition may be carried to lower levels; an example is a part such as the seat inside a flow valve that opens or closes to allow or prevent flow, followed by material, i.e., the raw stock that makes up a part.

b. **Levels of Requirements**:

(1) Level 0 – Major Program or Scientific Goal: This level accounts for high-level or overarching requirements associated with a primary Agency strategic direction and investment; it is included to allow mission requirements to show traceability

to the highest levels. Level 0 requirements are approved by the Agency, or in some cases by a Center, and reflected in strategic plans and science roadmaps.

(2) Level 1 – Mission/Project: The root baseline requirements for a mission and the project that formulates and implements a mission system. Level 1 requirements are approved by a Program Office, typically within a NASA Mission Directorate, that sponsors a project for which a mission architecture is desired.

(3) Levels 2 and below: Level 1 requirements are progressively decomposed to align with the system structural taxonomy and are derived and allocated to successively lower levels of that structure. Level 2 requirements are typically approved by the Project Team and specifically by the MSE. Lower levels may be approved, as appropriate, by the MSE or by Product Development Leads (PDLs). If necessary, requirements decomposition can be carried below Level 5.

c. **Levels for Organizations**:

(1) Level 0: The highest level of the organization, i.e., the Agency.

(2) Level 1: Within NASA Headquarters, a Mission Directorate such as SMD, or a Mission Support Office. This level also includes the Program Office that sponsors a specific project.

(3) Level 2: The Project Team assembled for a specific project. This level includes science, engineering, and PM teams and other project-level entities such as resource management, scheduling, and cost analysis, as well as key personnel such as segment managers, instrument payload manager, and an assigned SMA specialist.

(4) Levels 3 and Below: Depending on the nature of a specific system, the organization is further detailed out in terms of product development leads, e.g., instrument team leads, and other key individuals with specific responsibilities, as well as their teams.

The high-level structure of a typical uncrewed space system is summarized in Figure 14, Mission System Decomposition. Figure 15 shows the level of definition addressed by SMAF View Products. This content conforms to NASA procedural requirements, the process definitions of the SE Engine, and other applicable directives.

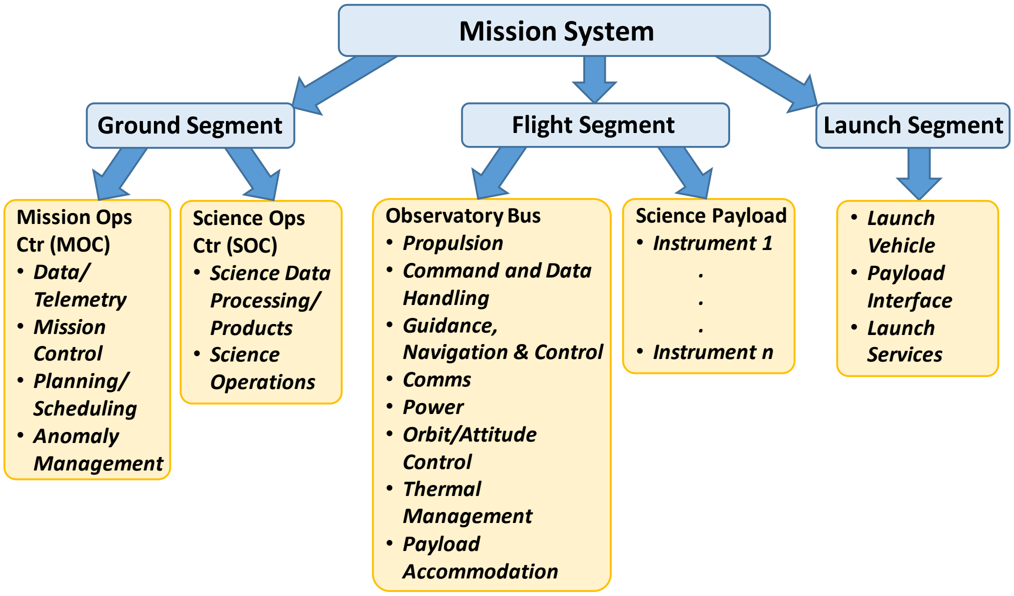


Figure 14—Mission System Decomposition

As shown in Figure 14, the mission system consists of a flight segment composed of one or more observatories each hosting one or more scientific instruments; a ground segment generally composed of an MOC, an SOC, and other required facilities; and a launch segment responsible for placing the observatories in their intended orbits or trajectories. This initial high-level functional description may include functional statements (Launch Segment Function—place spacecraft in space; Flight Segment Function—observe space phenomenon and send data to ground segment; Ground Segment Function—process data and disseminate science data products to the PI and the concerned science community).

A.5.3 Focused Viewpoints

The SMAF recognizes the reality that individual projects commonly have special areas of focus or concern that are not readily captured in the primary Viewpoints. When this is the case, a project can define additional specialized Viewpoints, referred to as focused Viewpoints, whose content deals with those specific concerns. While not an exhaustive list, the following are examples of potential focused Viewpoints:

a. Cybersecurity Viewpoint: If a mission or system has data or functions whose sensitivity requires a higher-than-normal level of protection, the features and functions are implemented to achieve an acceptable level of security risk; products in this Viewpoint constitute the factual basis for a decision to allow the system to operate with the intended sensitive content. Reference NASA-STD-1006. Additionally, NPR 7150.2 discusses cybersecurity requirements.

b. SMA Viewpoint: If more than normal attention to the SMA aspects of a mission or system is required, a dedicated Viewpoint that defines an SMA View to collect the relevant information may be useful. See NASA-STD-8739.8, Software Assurance and Software Safety Standard (replaced cancelled NASA-STD-8739.13, NASA Software Safety Standard).

c. Interoperability Viewpoint: When a mission or system functions as an element of a larger enterprise and has to interact correctly with other systems in the enterprise, a Viewpoint and View dedicated to communications, data definitions and formats, enterprise operating modes, shared use of telemetry and other resources, and other aspects of enterprise functionality may be needed.

d. Software Viewpoint: For a system with large or exceptionally complex ground and flight SW content, a focused Viewpoint defining a Software View whose products document the SW development, integration, and test environment; algorithms to be used; a standard hosting and runtime environment; on-orbit SW updating; and other aspects may be useful. See NPR 7150.2 and NASA-STD-7009.

APPENDIX B

GUIDANCE FOR CREATING SMAF PRODUCTS

B.1 PURPOSE

This Appendix provides guidance on creation of the Products that comprise a SMAF View, responding to the Stakeholder concerns in a Viewpoint. In general, this is a three-step process:

a. Define the required content of each Product for a specific project based on its role in defining a Mission Architecture, particularly in satisfying the direction in NPR 7120.5 and 7123.1.

b. Map this content to the artifacts of the NASA SE process, especially the key documents in Appendix B of this NASA Technical Handbook.

c. Select and apply an appropriate methodology to create the content, using the descriptions in this Appendix and examples from the [TBD] repository.

To promote consistency across projects and mission architectures, each product has a recommended structure or Table of Contents and an assigned individual or organization responsible for its creation and maintenance. Views and the products they contain evolve at successive points in the Project Life Cycle at which they are created, baselined, and updated, generally in conjunction with major Project Reviews. The modeling approaches and examples are based on a variety of tools and methodologies that are documented in other related NASA Technical Handbooks. Each View also has a set of Completion Criteria to be used to verify that the required content has been provided.

B.2 SMAF VIEWPOINTS, VIEWS AND PRODUCTS

B.2.1 View and Product Templates

A Viewpoint is created by identifying and documenting the Stakeholder/Participant concerns that it addresses and specifying one or more Views whose products address those concerns. A Viewpoint can be created using any convenient format. This Appendix presents the SMAF Views and View Products using the following standardized organization to promote quality, consistency, and ease of understanding across mission architectures and projects:

a. **View Template**:

View Name

(1) <u>Description</u>: A concise summary of the purpose and content of the View, including its role in a space mission architecture. It traces to the concerns in the defining Viewpoint in the areas of scope, technical, SMA, PM, and resources as

well as a context diagram showing relationships of the View to other Views and project elements; these are repeated from Section 4 in the interests of making this Appendix usable as a stand-alone document.

(2) Products: A list with descriptions of the products within the View that express the architecture of the system from the perspective of the particular Viewpoint. See section B.2.1b, Product Template.

(3) Completion Criteria: A list of the tangible content of the View that has to be created and approved for it to serve its intended functions, e.g., in supporting project life-cycle reviews.

(4) Project Life-Cycle Evolution: A summary of the status of the View and its products in Phases Pre-A through F, especially at major project life-cycle reviews and decision points.

(5) Review Entrance and Acceptance Criteria: A tabulation of the specific criteria for primary reviews per NPR 7123.1B, Appendix H, that are satisfied in whole or in part by the products of the Viewpoint. These are consolidated in Appendix E.

Examples: In addition to the guidance provided in this Appendix for the creation of SMAF products, a set of examples in various formats will assist users of this NASA Technical Handbook in applying the SMAF to specific projects and missions. To make these readily available, a SMAF Repository will be established on the NASA Engineering Network (NEN) at https://nen.nasa.gov/web/nen.

b. **Product Template**:

Product Identifier and Name

(1) Description: A concise summary of the specific purpose and content of the product. In general, a product is the result of a specific project activity, which may be associated with a task, a Work Package in an Integrated Master Plan, or a WBS element.

(2) Structure and Format: A description of the structure and format of the product, including acceptable alternatives. For large products, this may take the form of a Table of Contents. Some products are defined as informal, meaning that they are working materials not intended for delivery to stakeholders or presentation at reviews. Consistent structure and format are essential aspects of achieving SMAF objectives such as reusability of architecture materials and effective communication and review processes at life-cycle reviews and key decision points (KDPs).

(3) Modeling: A description of the modeling applicable to the product, the individual or organization responsible for the content, and the types of models and tools that may be employed. Established processes defined in NASA/SP-6105, Revision 2, and other directives and process standards apply.

(4) Key Documents: This section specifies whether the product is a key document and identifies any other key documents to which it contributes. A key document (see Appendix B) is an established element of the NASA project life cycle as defined in NPR 7120.5, NPR 7123.1, NASA/SP-6105, Revision 2, and other process directives and standards. A key SMAF goal is to support quality, consistency, and efficiency in generating these essential materials.

B.2.2 Science View

a. **Description:** This View describes the science content of a mission, starting with high-level or overarching science needs, goals, and objectives. It is closely related to the Enterprise/Mission Concept View, specifically to an AO that defines the nature and purpose of a proposed mission. It identifies options and priorities for de-scoping mission science activities if the full set of goals and objectives cannot be satisfied. It defines the instruments and related elements of an observatory science payload and defines science data collection and processing to support creation of a science concept that becomes a key part of a mission concept. It provides science-related SMA considerations, supports development of a Project Plan, and identifies resources required to accomplish the science objectives of the mission. Figure 15, Context Diagram for the Science View, shows the primary relationships of the Science View to other project elements and Views.

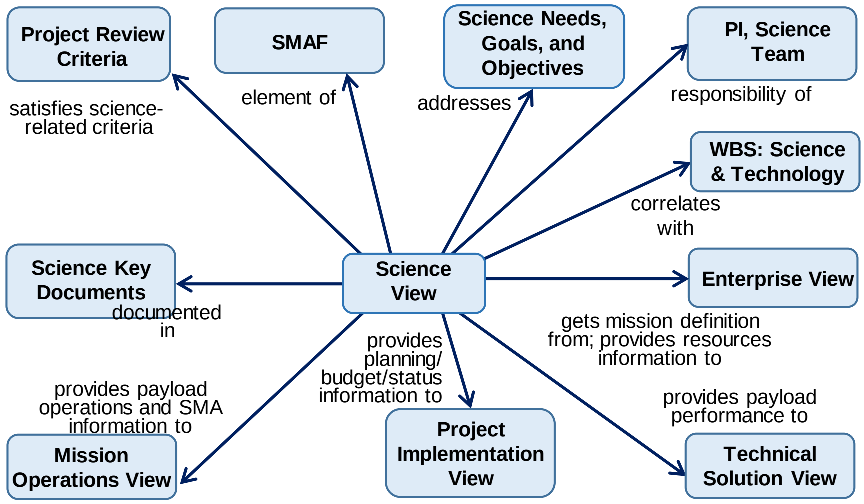


Figure 15—Context Diagram for the Science View

(1) Scope Concerns: The scope of the Science View is the science content of the mission and therefore the fundamental purpose and context of a project aimed at delivering that science content. It includes the overarching science goal and the primary science objectives that seek to answer the questions for which the project is carried out, as well as the place of the project and mission in higher level NASA strategic plans and roadmaps.

(2) Technical Concerns: The scope concern flows naturally into a set of technical concerns dealing with how mission objectives will be achieved through data collection, data processing and communications, and the creation and dissemination of data products. Science Technical concerns are ultimately expressed in terms of requirements allocated to an instrument payload and its products as the starting point for defining and implementing a technical solution.

(3) Safety and Mission Assurance Concerns: For the Science View, these deal with any safety, quality, or reliability issues associated with the instrument payload. These might include workmanship, supplier quality and supply chain management, and many others.

(4) PM Concerns: Science PM concerns involve ensuring that the Science Team has the organization, processes, plans, schedules, coordination and issue resolution mechanisms, and other required means to effectively produce products and to interact with the project organizations across the project life cycle.

(5) Resource Concerns: The Science Team needs the workforce, facilities, equipment, administrative support (e.g., travel budgets), and any specialized resources (e.g., access to high performance computing) needed to perform its tasks.

b. **Products:**

(1) Sci-1 Science Concept:

A. Description: This product defines the fundamentals of a science investigation, starting with overall needs, goals, and objectives, and laying out the phenomena to be investigated, measurements to be taken, science data processing and management, and the instrument payload, including such particulars as legacy instrument reuse, calibration, and required spacecraft accommodation (e.g., the need for specific sensors to be boom-mounted). This product also addresses any aspects of flight dynamics such as required orbits and constellation formations required to meet mission objectives. It includes a prioritized list of options for de-scoping the project if necessary while still achieving a successful mission. In short, this product defines the science data to be collected, the instruments to do the collecting, and the places in space where collection has to occur.

B. Structure and Format: This is an informal product that may be documented in text, briefing charts, simulations, and other forms as appropriate to the science content of the mission. It presents the Science Team perspective on the mission in terms of overall goals, science objectives, required measurements and data processing, required orbital characteristics, required instrument capabilities, science data products, and other aspects.

C. Modeling: The PI and Science Team are primarily responsible for this product. Modeling and simulation is commonly an important supporting activity. Depending on the nature of a mission, these may include models of physical phenomena, flight dynamics models, environmental models, system architecture model, and instrument models.

D. Key Documents: This product provides primary input to the STM and CSR. It also supports the Project Plan; the SMAP; Center Facilities, Equipment and Staffing Plans; and the System Requirements Document. It uses the Project Scope Document as a primary input. Analysis models and reports generated from them may be treated as key documents when they furnish information that is important to satisfying review criteria, e.g., by showing adequate mass and power margins, feasible performance parameters, supportable network data rates, and compatibility with launch vehicles.

(2) Sci-2 Science Traceability Matrix (STM):

A. Description: This product is a central part of the Science Viewpoint and an important element of the transition to the Technical Solution View. It relates the overall Science Goal of the mission to individual Science Objectives, phenomena and analysis steps, and measurement parameters. It then captures the transformation of mission science content into performance specifications for the instrument payload and other aspects of the mission, including orbit design.

B. Representative Structure and Format:

i. Overarching Mission Science Goal – brief statement of desired mission outcome, reflecting the mission science concept and traceable to higher level program goals and to needs and opportunities identified by the larger science community.
ii. Science Objectives – specific objectives that the mission seeks to satisfy to achieve the overarching goal.
iii. Science Actions – the activities required to satisfy each Science Objective.
iv. Analysis Steps – detailed measurement and analysis activities required by each Science Action.
v. Parameter Matrix – performance parameters for instruments and other mission system resources to implement the Analysis Steps. This matrix represents the science side of the interface between the Science and Engineering Teams of a project.
vi. Instrument Matrix – performance specifications for the elements of the instrument payload to achieve the results defined in the Parameter Matrix. This matrix represents the engineering side of the science-engineering interface.
vii. Mission Matrices – additional requirements for the spacecraft, ground segment, flight dynamics, mission operations, and any other technical considerations involved in implementing a system to meet mission objectives.

A variety of formats may be used depending on the specific methodology adopted by a project; the STM is commonly created using spreadsheets or tables.

C. Modeling: This product is developed directly from the Science Concept. The PI and Science Team develop the first five areas of the product. The Science and Engineering Teams then collaborate to develop the remaining two areas. With some modeling tools, an STM can be exported as a report defined in a template. Supporting models such as a Design Reference Architecture (DRA) can provide reusable content to accelerate STM development.

D. Key Documents: The STM is a Key Document and is incorporated in a CSR.

(3) Sci-3 Science Datasets and Data Products:

A. Description: This product is composed of a number of more specific products that document and communicate the science return of a mission. Datasets specify the content and format of databases or other information entities containing the data; the data may be further processed and formatted to create other data products needed by specific Stakeholders. Typically, Level 0 products are raw or preprocessed instrument data; Level 1 products are created by the MOC and format the data for further processing. Higher level products transform the data to other coordinate systems, fuse data from multiple instruments, incorporate phenomenological and analytical models, and otherwise process the data to create the desired products for use by the Science Team and the larger science community.

B. Structure and Format: These are defined by the Science Team in accordance with the nature and objectives of the mission. These products may use a variety of documents or electronic media.

C. Modeling: The PI and Science Team create this product based on the goals and objectives of the mission and the intended uses of the science outcomes. These products generally use appropriate phenomenological and analytical models in creating specific science data products.

D. Key Documents: Science datasets and data products are Key Documents.

(4) Sci-4 Science Data Management Plan (SDMP):

A. Description: This product describes how the project will manage, archive, and disseminate science data products, including functions allocated to both flight and ground segments, in accordance with NPD 2200.1, Management of NASA Scientific and Technical Information; NPR 2200.2, Requirements for Documentation, Approval and Dissemination of Scientific and Technical Information; and NPR 1441.1., NASA Records Management Program Requirements, product Sci-1.

B. Structure and Format: Defined in NPR 7120.5E, Appendix H, section 3.14.

C. Modeling: The content of this product is largely created by the Science Team and has to be consistent with the mission science concept. The Science Team develops a science data model incorporating datasets along with other science data products, typically at levels 1, 2, 3, and 4. The data model also defines the data collection, processing, communication, and other processes involved.

D. Key Documents: The SDMP is a Key Document and is provided to the PM Team as a Project Control Plan.

c. **Completion Criteria**: This View is complete when the products have the following content, as well as any other descriptions of mission science required by the nature of the mission:

(1) Relevant NASA science goals identified and specific mission science objective(s), questions, and expected outcomes defined.
(2) Science Concept defined that supports a viable mission concept.
(3) Testable hypothesis(es) for a science investigation defined.
(4) Scientific measurement requirements described.
(5) Instrument functional performance requirements defined and validated to support integration into a full mission concept, including integration with the spacecraft bus and estimates of mass, power, cost, and risk.
(6) Modeling and analysis tools and methods identified, including algorithms, and used to create products.
(7) Data products and their management and dissemination procedures defined.
(8) Spacecraft bus requirements to support the science investigation defined, including required flight dynamics, environmental parameters, instrument payload accommodation, networks and data rates, and other relevant factors.
(9) When appropriate, partnerships defined.
(10) Sci products created and coordinated.
(11) Required inputs to other Views created and provided.
(12) Basis for an effective acquisition strategy for system segments and payload elements established.

d. **Project Life Cycle Evolution**:

(1) Pre-Phase A: A Science Concept for the mission is developed and used to create an initial STM which is approved as part of an initial mission concept at Mission Concept Review (MCR).
(2) Phase A: The science content of the mission is documented in a CSR. Stakeholder expectations, system concept, MoEs, and other initial content are approved at Mission Definition Review (MDR).
(3) Phases B through D: The Sci-1 product is updated as appropriate. If required, this may include exercising de-scoping options.

e. **Review Entrance and Acceptance Criteria**: See Appendix E for the review criteria that are satisfied in whole or in part by the products in the Science View.

B.2.3 Technical Solution View

a. **Description**: The Technical Solution View focuses on operational and functional architectures. It supports the Product Realization View, which completes the system solution in a physical architecture. The products of the Technical Solution View functionally define system components and other structural entities, behaviors of the system and its constituent products, data content and flows, internal and external interfaces, and constraints that impact the design trade space. Figure 16, Context Diagram for the Technical Solution View, shows the primary relationships of this View to other project elements and Views.

(1) Scope Concerns: The scope concerns for the Technical Solution View center around a proposed mission concept and on defining and controlling the associated system boundary. This View deals primarily with conceptual and functional architecture dimensions of the mission concept.

(2) Technical Concerns: This View is concerned with developing the specifications and the supporting activities that establish the foundation for system implementation. The products in this View deal with system modeling and analysis, risk and technical readiness assessments, technical planning, and technical support to project life-cycle reviews and key decisions in Phases Pre-A through B.

(3) SMA Concerns: The Technical Solution View ensures that the system concept and functional design satisfy SMA requirements, including the Mission Assurance Requirements (MAR) flowed down from Office of Safety and Mission Assurance (OSMA).

(4) PM Concerns: PM concerns in this View principally involve achieving the proposed design solution within budget and schedule constraints. Engineering planning identifies cost and schedule parameters for engineering activities and provides key input to the SEMP, Risk Management Plan (RMP), Technology Development Plan, and other Project Control Plans.

(5) Resource Concerns: This View is concerned with availability of workforce, facilities, equipment, analysis and design tools, computational capabilities, and other resources needed to execute engineering activities. These resources are defined in a specific Engineering Plan product.

Figure 16 shows the primary relationships to other project elements and Views.

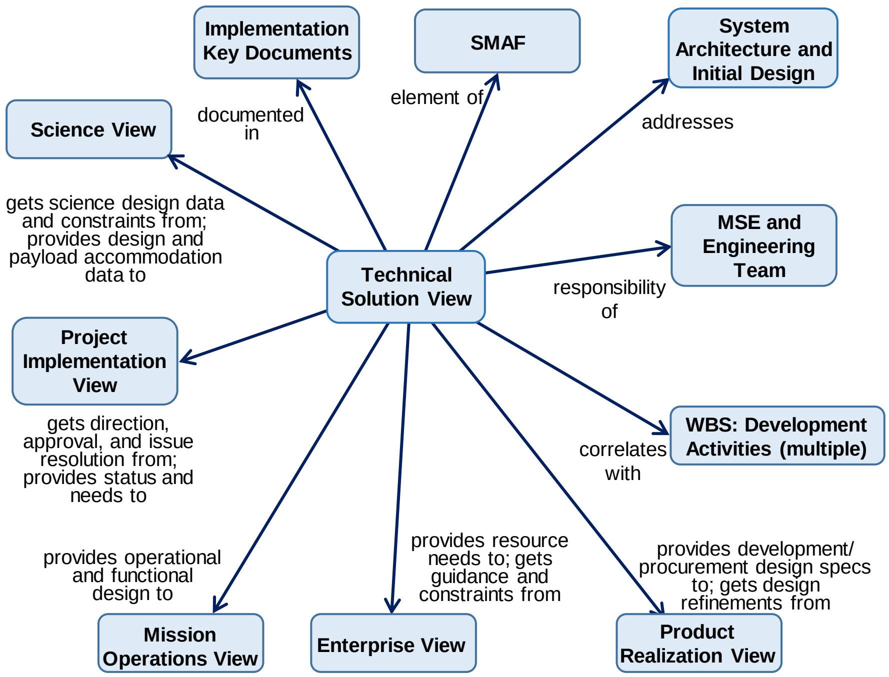


Figure 16—Context Diagram for the Technical Solution View

b. **Products:**

(1) Soln-1 Systems Engineering Management Plan (SEMP):

[NOTE: The SEMP applies to the entire Engineering Viewpoint but is primarily developed in conjunction with the Technical Solution Viewpoint.]

A. Description: This product documents how the project will carry out engineering activities, including processes, tools, organization, roles and responsibilities, metrics, and other aspects.

B. Structure and Format: The SEMP is defined in NPR 7120.5E, Appendix H.3.6, and NASA/SP-6105, Revision 2, Appendix J.

C. Modeling: The MSE and Engineering Team develop the SEMP by completing the content of each section in accordance with the cited directives. The contents are specific to the mission class, goals and objectives, engineering organization (including partner organizations), schedule, budget, status reporting requirements, and other details of a particular project. This product can use models, including SysML® structural and behavioral diagrams, to document SE processes. In addition, it can contain a Modeling Plan that specifies the models and associated tools, methodologies, metrics, etc., to be used in carrying out SE activities.

D. Key Documents: The SEMP is a Key Document and is incorporated in data packages for various reviews and decision points. It is provided to the Project Implementation Viewpoint as a Project Control Plan.

(2) Soln-2 Analysis of Alternatives (AoA):

A. Description: The AoA supports the development of a viable mission concept that will meet stakeholder expectations within technical and resource constraints. It documents the assessment of alternative concepts against the needs, goals, and objectives of the mission. It is a key input to the CSR and to a proposal responding to a competitive AO. It defines the trade space for the operational, functional, and physical architectures and is closely related to the Science View. In addition, AoAs may be updated or created for use with an MCR and Preliminary Design Review (PDR).

B. Structure and Format: The AoA is commonly documented in a report, and the results are often incorporated in a CSR. The specific organization and format depend on the concept development methodology adopted by the project. It is important that trade studies conducted as part of the AoA be documented as part of the rationale for the selected mission concept.

C. Modeling: The MSE and Engineering Team are primarily responsible for conducting and documenting the AoA, working closely with the Science Team and other project organizations to ensure all relevant factors are incorporated. A representative methodology is defined in the Space Mission Analysis and Design (SMAD) process. AoA development typically employs a wide range of models depending on the specific nature and goals of a project. These commonly include:

i. System Architecture Model (product Soln-3) – frames and captures alternatives, which can be captured as various versions of the model.
ii. CAD/ CAM models – represent and analyze physical designs.
iii. Electrical Models – analyze electrical power and data communications.
iv. Dynamic Models – analyze operational scenarios and conditions.
v. Performance Models – analyze system functions and ability to meet requirements.
vi. Prototypes.

D. Key Documents: The AoA is an essential input to a CSR and supports other key documents such as the SRD and project review data packages.

(3) Soln-3 System Requirements Document (SRD):

A. Description: The requirements baseline follows the process in NASA/SP-6105, Revision 2, section 4.2, to describe the desired system design and implementation.

B. Structure and Format: This product uses a format consistent with the methodology adopted by the project, which may include a database in a requirements management tool such as DOORS™, Cradle®, Jama Software™, Jira®, ReQtest, and Visure (this list does not constitute an endorsement by NASA); tables or spreadsheets; or artifacts generated by an architecture modeling tool. Requirements are expressed as single, clear, unambiguous, and verifiable "shall" statements and include rationale.

C. Modeling: The SE Team is primarily responsible for this product in collaboration with the entire Project Team. The SRD is a requirements model and may employ supporting models such as traceability diagrams/matrices, spider diagrams, and others.

D. Key Documents: The SRD is a Key Document.

(4) Soln-4 Verification and Validation (V&V) Plan:

A. Description: This product describes how the project will perform V&V of project products against the requirements baseline, including the methodology to be used (test, analysis, inspection, or demonstration) for each product as defined in NPR 7123.1 and the NASA/SP-6105, Revision 2, section 5.4. The V&V Plan has to be consistent with the SEMP.

B. Structure and Format: Defined in NPR 7120.5E, Appendix H, section 3.9.

C. Modeling: The Engineering Team analyzes the products to be produced in accordance with the Project WBS to determine the appropriate V&V approach for each. The V&V Plan may incorporate a Verification Cross Reference Matrix (VCRM) or equivalent and is supported by the architecture model and the models used to support system design.

D. Key Documents: The V&V Plan is a Key Document. It is provided to the PM Team as a Project Control Plan. Related documents include those for TPM tracking, defect tracking, test plans and procedures, and C&T databases.

(5) Soln-5 Test Plan:

A. Description: This product documents the approach to be taken by the project to test the system and its components as system integration proceeds from development of lower-end through higher-end products in the system structure and through operational test and evaluation (T&E) into production and acceptance. It may combine the verification and validation plans into a single document. It may be created as a Test and Evaluation Master Plan (TEMP) and commonly includes appropriate Test Procedures, product Real-6.

B. Structure and Format: This product documents the overall structure and objectives of project T&E, including scenarios that establish test conditions and items to be tested, data collection, success criteria, and results of the evaluation of each Item Under Test (IUT) against these criteria.

C. Modeling: The SE Team commonly uses models of many types, initially to verify the soundness of a planned test event, to predict the test outcome, and as part of the analysis of test results to understand how the test results came about.

D. Key Documents: This product is a key document and is closely linked to (or may incorporate) the V&V Plan, product which is a Key Document, soln-4. It also satisfies Entrance and Success Criteria for a variety of project life-cycle reviews.

(6) Soln-6 Architecture Model:

A. Description: This product is an architecture model of a mission system. Following the SMAF model-based systems engineering (MBSE) approach, one or more system alternatives resulting from an AoA are defined in greater detail in an architecture model using the methodology adopted by the project. The Architecture Model is initially created under the Technical Solution View and evolves and matures as mission formulation and implementation activities progressively define the system and complete the physical architecture. At any point in the project life cycle, the Architecture Model is the authoritative baseline for the mission system. Architecture content includes system structure, internal and external interfaces, functions and processes, data and information content, physical product data, timing, networking and telemetry, and other aspects. It is organized in terms of Flight, Ground, and Launch Segments and follows the system levels in Appendix A, Table 3, of this NASA Technical Handbook. Depending on the methodology adopted by the project, this model can include mission requirements with allocations to the system design, as well as safety and security features, operational modes and command structure, and any other information needed to fully describe a particular mission system. A fully defined and validated mission architecture model can serve as a Single Source of Technical Truth (SSTT) for the project.

B. Structure and Format: The following is a recommended structure for a mission system architecture:

i. *Architecture Overview and Summary (AO&S).* This is a document that defines the architecture content of the project, including system/mission overview and context, programmatic relationships, objectives, constraints, architecture process and methodology, schedule, resources, architecture products, architecture rules, independent reviews, and any other pertinent aspects of the role architecture will play in the project. A complete AO&S includes a metamodel that establishes rules, constraints, framework(s), and other overall characteristics of the modeling process. It should also include a governance process to be used to maintain the technical integrity of the system over time. This document should represent a consensus of the project's stakeholders and be approved by project technical and management leaders at the earliest feasible point in the schedule.

ii. *Requirements.* This will generally be the SRD, product Soln-3, and can be referenced by the architecture model. It should include a VCRM or equivalent showing how each requirement will be verified to establish compliance of the products comprising the system.

iii. *Structure.* System organization and structural decomposition is commonly documented using block diagrams, with a specification for each block; the content of these specifications evolves and becomes more detailed as the project proceeds. Block specifications include requirements allocations. Internal and external interfaces are documented in Interface Control Documents (ICDs) or other suitable documents and specifications. The model should include descriptions of the roles and qualifications of personnel who will interact with the system. It should also include an operational context diagram identifying all the external entities with which the system interacts and the nature of the interactions.

iv. *Functions.* The functions and processes executed by the system are documented in functional flow diagrams, state machines, timing diagrams, and other formats. A check on architecture completeness and correctness is obtained by verifying that every functional requirement in the SRD is associated with a system function or behavior. Functions can be brought together in use cases that are key content of a CONOPS. They can also be leveraged to build test cases based on functional refinement of the requirements and their allocation to Blocks in the system. Behavioral diagrams support interface definitions where flows of functions and data cross internal and external boundaries.

v. *Data Model.* It is a system architecture best practice to begin development of a system data model early in the system development. Data can be modeled in a data dictionary/glossary, in Entity-Relationship Diagrams (ERDs), and in other formats. The data model begins with relatively high-level data entities or information categories, and these are progressively decomposed into specific data items in the system as the development proceeds.

vi. *Services.* If a project elects to use a service model to describe the creation and consumption of capabilities internally and with external entities, an appropriate format for defining service content and interfaces has to be adopted.

vii. *Supporting Documents*. The final of model content contains any external documents that contribute to the mission architecture definition.

C. Modeling: The MSE, supported by a system architect or architecture group, is responsible for defining the architecture process, methodology, and artifacts, and for maintaining the architecture model through the project life cycle. The architecture model may be supported by analytical tools and models used to define specific architecture features and content.

D. Key Documents: The Architecture Model supports multiple Key Documents, including the CONOPS, Review Data Packages, the SEMP, Project Reports, and others that require a current and accurate description of the mission system architecture and baseline.

(7) Soln-7 Design Specifications:

A. Description: This product is composed of a set of design specifications that transform requirements into a sound foundation for system implementation. They define a specific solution approach within which the products comprising the system can be developed, procured, reused from legacy projects, or supplied by partners. Design specifications trace rigorously to stakeholder expectations and therefore provide the basis for validating the compliance of products with their allocated requirements.

B. Structure and Format: Design specifications are typically documents that may incorporate design description, allocated requirements, design drawings or models, and other forms of product specification. For the software content of a system, specifications may include software requirements specifications, Software Design Description, Software and Interface Design Description, Software Architecture, Software Acceptance Criteria and Conditions, Software Reuse Report, Software Model and Simulation Data and Documentation, Credibility Plan for Software Model and Simulation and models, etc. In the Product Realization View, design specifications are completed as system and product specifications with the addition of content such as manufacturing drawings, assembly drawings or instructions, bills of materials, software documentation, vendor specifications for procured products, component models, etc. Specifications are created at various levels of the system structure as appropriate and are commonly incorporated in a document tree.

C. Modeling: Design specifications may be created by the SE Team or by discipline engineers (mechanical; electrical; propulsion; guidance, navigation, and control; etc.). Specifications for instruments that are reused or modified from previous programs may be provided by the Science Team. New design specifications are created from the requirements allocated to the products involved using established SE processes. Ultimately, design specifications are needed for every hardware and software item that goes into the system. These specifications are then handed off to the appropriate development, procurement, or other organizations as part of the transition to the Product Realization View. A wide variety of models, including phenomenology, structures and materials, electronics, optics, CAD/CAM, component, computational, et al., may be used in creating design specifications. These specifications should be captured in the system Architecture Model for ease of access, using a method consistent with the architecture methodology. Software Model and Simulation Data and Documentation for Software Models and Simulations should be part of the design specification. See NASA-STD-7009 and NPR 7150.2.

D. Key Documents: Design specifications may be treated as Key Documents in themselves. In addition, they support or are incorporated in the Architecture Model, project review data packages, V&V Plans, a Configuration Management Plan, and other key documents. They furnish important data for compiling and maintaining a Master Equipment List (MEL).

(8) Soln-8 Interface Control Documents (ICDs):

A. Description: ICDs define and control internal and external interfaces. They bring the parties from each side of an interface together to agree on the location, functions, mechanical, electrical, data, fluid, and other aspects and to specify who is responsible for this content. In a fashion similar to design specifications, ICDs are initially created functionally as part of the Technical Solution Viewpoint and completed with physical detail in the implementation phase of a project. In the early stages of a project, these may be called Interface Requirements Documents (IRDs).

B. Structure and Format: ICDs are typically organized in document form but draw from mechanical interface drawings, electrical schematics, software descriptions, as well as interface requirements. A typical ICD is organized into areas such as:

i. General description and purpose,
ii. Mechanical interface,
iii. Electrical interface, and
iv. Functional and signal interface (command and software interfaces).

Interfaces offer a prime opportunity for a system to benefit from appropriate standardization to implement an open architecture, and an ICD should identify applicable standards. Also, security properties such as confidentiality, integrity, and availability can be embedded in interface definitions and leveraged to generate security documentation in accordance with FIPS 199, Standards for Security Categorization of Federal Information and Information Systems.

C. Modeling: The SE Team has primary responsibility for ICDs, in collaboration with the Science Team and the other Engineering Teams. As with design specifications, ICDs may be reused from legacy systems or created using established SE processes. An IxI matrix is a model of interactions among system components and may be helpful in identifying and characterizing interfaces. Every significant interface should have a defining ICD. These are then handed off to the Product Realization View for implementation in the system. ICDs are commonly incorporated with design specifications in a document tree. ICD development is supported by the system architecture model as well as product or component models, timing and performance analysis models, and others, depending on the nature of a given interface.

D. Key Documents: ICDs are Key Documents and should be baselined not later than PDR. They are incorporated in project review data packages.

(9) Soln-9 Document Tree:

A. Description: This product combines specifications and ICDs in a hierarchy showing derivation and other relationships.

B. Structure and Format: This is an informal product that can use a variety of graphic, tabular, and other formats.

C. Modeling: The SE Team compiles and maintains the document tree as the specifications and ICDs are developed.

D. Key Documents: The document tree is a Key Document.

(10) Soln-10 Master Equipment List (MEL), Preliminary:

A. Description: Because of the importance of mass, power, data rates, and other system parameters, a MEL is created early in the project life cycle, and margins are tracked against system goals. The MEL is updated as the design evolves and product data becomes available. A Preliminary MEL is started in Pre-Phase A as part of the Technical Solution Viewpoint and handed off to the Product Realization View for finalization. This product is a listing of all the parts of a system and includes pertinent information such as serial numbers, model numbers, manufacturers, equipment types, locations in the system structural hierarchy, power consumption, mass, and other properties. It is commonly used to track system and component mass and power and to compute margins against allocations for these key properties.

B. Structure and Format: This product is created as a table or spreadsheet. The MEL organization reflects the structural hierarchy of the system and therefore incorporates a Product Breakdown Structure.

C. Modeling: The MSE and SE Team have primary responsibility for creating the MEL. As the system design evolves and becomes more detailed, the MEL is maintained in accordance with the latest system baseline. The MEL is modeled using tools and formats consistent with the SE methodology adopted by the project.

D. Key Documents: The MEL may be treated as a Key Document in itself and is incorporated in project review data packages and other key documents.

(11) Soln-11 Supporting Analysis:

A. Description: This product is a collection of reports documenting analyses conducted in specific areas as required by the nature of a particular mission system, including focused analyses performed by engineers in specialty disciplines such as health and safety, medical, reliability, maintainability, quality assurance, IT, security, logistics, environmental, et al.

B. Structure and Format: This is an informal product that combines text, graphics, tables, simulation reports, and other formats as appropriate to a particular analysis. These can be stored in the system architecture model or conducted in external tools with results imported into and synchronized with the model.

C. Modeling: A Discipline Engineering Team performs a specific analysis using models appropriate to the subject and compiles and maintains a report.

D. Key Documents: A supporting analysis report may be incorporated in key documents such as a project review data package.

(12) Soln-12 Supporting Review Data Package:

A. Description: This product assembles the materials needed for supporting reviews that are conducted by the Engineering Team. These are conducted as necessary to evaluate design solutions and identify potential challenges. They can occur at the system, subsystem, or lower levels.

B. Structure and Format: This is an informal product whose organization depends on the content of a review and is designed to enable an effective review.

C. Modeling: The Engineering Team, in collaboration with other project organizations, defines the objectives of the review, the materials needed to enable the review team to function effectively, and the sequence and formatting of the review data package. Review materials commonly incorporate artifacts from the architecture model and various analysis, design, product, environmental, and other models.

D. Key Documents: Not Applicable.

(13) Soln-13 Concept of Operations (CONOPS):

A. Description: This product describes the overall high-level concept of how the system will be used to meet stakeholder expectations, usually in a time-sequenced manner. It describes the system from an operational perspective and helps facilitate an understanding of the system goals. It stimulates the development of requirements and architecture content related to the user elements of the system. It serves as the basis for subsequent system definition and documentation as well as supporting long-range operational planning.

[NOTE: NPR 7120.5 defines an Operational Concept (Ops Con) and does not use the term CONOPS. NPR 7123.1 does the opposite. NASA/SP-6105, NASA Systems Engineering Handbook, Revision 2, provides a detailed CONOPS structure in an appendix. The two documents are similarly defined, and both are called for early in the Project Life Cycle, during Pre-Phase A. A CONOPS is routinely created for a project, while an Ops Con is generally incorporated in a CSR. The SMAF therefore defines a CONOPS product but captures Ops Con content in the CSR.]

B. Structure and Format: NPR 7120.5E, Appendix S, defines the structure and content of a CONOPS.

C. Modeling: The Engineering Team works closely with the Science and Mission Operations Teams to develop a CONOPS, which is a model of the entire system and its functions. Models that support analysis and design activities can contribute much of the content of this product. In a model-based approach, any design changes need only be captured in the model, after which artifacts like a CONOPS document can be re-exported with no additional effort.

D. Key Documents: The CONOPS is a Key Document.

(14) Soln-14 Technology Readiness Assessment (TRA):

A. Description: This product documents the technical maturity of products and technologies that are candidates for inclusion in a mission system. TRLs are a method of estimating technology maturity of critical technology elements (CTEs) of a program based on a scale from 1 to 9 with 9 being the most mature technology. The use of TRLs enables consistent, uniform, discussions of technical maturity across different types of technology. The TRL scale is defined in NPR 7123.1, Appendix E.

B. Structure and Format: Structure and format are defined in NASA/SP-6105, Revision 2, Appendix S; see also Final Report of the NASA Technology Readiness Assessment (TRA) Study Team, March 2016, and NPR 7120.8, NASA Research and Technology Program and Project Management Requirements.

C. Modeling: The MSE and SE Team have primary responsibility for creating a TRA. NASA Headquarters has announced that a TRA Handbook is in preparation, based on the TRA Study Team Final Report. In the interim, a TRA can be performed using guidance from the sources cited above. The assessment process is spelled out in NPR 7120.8. NPR 7120.5 defines TRA products that are required at KDPs A, B, and C. This product does not use models directly. A variety of component and analytical models may be involved in generating the data used in the assessment.

D. Key Documents: The TRA is a Key Document and is included in other key documents such as an RMP and project review data packages.

(15) Soln-15 Technical Risk Analysis:

A. Description: This product responds to NPR 8000.4B, Agency Risk Management Procedural Requirements, and is a central element of Technical Risk Management, which is a crosscutting technical management process of the NASA SE Engine. Technical risk analyses identify and characterize risks that result from the design solution and associated technology implementation choices. These results inform formal project risk assessments and, if done as part of a risk-informed design approach, this information can be used to optimize the design solution to achieve mission objectives with acceptable risk. Risks can be associated with multiple mission execution domains, including technical, safety, cost, and schedule. When appropriate, this product may include a specific hazard analysis dealing with hazards to operators, the system, the environment, and the public.

B. Structure and Format: A Technical Risk Analysis is typically documented in a formal report that defines the risk and the scenario(s) through which it may be realized, assesses probability and consequence of occurrence, and identifies candidate risk mitigations. Risks are commonly summarized using a "risk cube" or "risk matrix" with scales of one to five for probability and consequence of occurrence and color coding for risk severity, from "no impact" to "critical."

C. Modeling: The SE Team is primarily responsible for this product, and some risks require collaboration with the Science Team, Mission Operations Team, discipline engineering, and other project organizations. The risk management process is described in NASA/SP-6105, Revision 2, section 6.4; NASA/SP-2010-576, NASA Risk-Informed Decision Making Handbook; and NASA/SP-2011-3422, NASA Risk Management Handbook. The risk assessment methodology has to support rigorous examination of all such risks that could potentially degrade the mission. Many of the models used in system design also support risk quantification by showing the effects of a risk occurrence. Tools are available to model a system for failure modes and effects analysis (FMEA), failure modes and effects criticality analysis (FMECA), fault tree analysis (FTA) and program/

project risk analysis (PRA). The system architecture model supports risk analysis by identifying dependences among system elements that help establish risk consequences, by providing information on environmental stresses, by identifying critical failure modes that may require redundancy or other mitigations, and by baselining the system configuration that results from implementing changes to minimize risk. See NPR 7150.2 and NASA-STD-7009 for software aspects of this product.

D. Key Documents: A Technical Risk Analysis or Hazard Analysis report may be treated as a Key Document when risk is a critical factor in mission success. These reports also contribute to project review data packages and other key documents.

(16) Soln-16 Technology Development Plan (TDP):

A. Description: This product describes how the project will implement assessment, development, management, and acquisition of technologies needed to achieve mission objectives. It is typically related to technical risks managed under the RMP and may deal with technology needs identified by both the Science and Engineering Teams, including those recognized in the Science Concept and CSR. In general, NASA policy requires that TRL 6 be demonstrated by a project's PDR for each element of the spacecraft. The TDP includes timely reporting of new technologies to the Center Technology Transfer Office in accordance with NPR 7500.2, NASA Technology Transfer Requirements. It also accounts for plans to leverage ongoing technology efforts and to transition technologies from development to manufacturing and production. Where appropriate, it defines alternative paths if technologies fail to mature when needed. Finally, the TDP addresses technology exchanges, contracts, partnership agreements, and compliance with all export control laws and regulations.

B. Structure and Format: Defined in NPR 7120.5, Appendix H, Section 3.5.

C. Modeling: The MSE and Engineering Team analyze project technology needs, shortfalls, and opportunities to identify required activities and define their details. This product uses results from TRAs and generally uses science and engineering analysis models to assess technologies in the context of intended system applications. It may also use an architecture model to examine system dependencies for proposed technologies and assess the impacts and alternatives arising from failure of a technology to mature on time.

D. Key Documents: The TDP is a Key Document and is provided to the PM Team as a Project Control Plan.

(17) Soln-17 Software Plans and Documents:

A. Description: This product describes how the project will develop or manage the acquisition of software to meet mission objectives in accordance with NPR 7150.2, NASA-STD-8739.8, and NPR 2200.2. A key product in this area is a Software Management Plan (SMP). The SMP has to be consistent with the SEMP. Depending on the specific nature of a system and project, other software products may include Software Requirements Mapping Matrix; Software Classification and Safety Critical Determination; Software Cybersecurity Assessment; Modeling and Simulation Criticality Assessment (NASA-STD-7009); Modeling and Simulation Credibility Assessment (NASA-STD-7009); Determination of NASA-STD-1006 applicability; and Software Model and Simulation Data and Documentation, including the Verification, Validation, and Credibility Plan for Software Model and Simulation. Additional items that can be added as discussed in NPR 7150.2, Chapter 6, include Software Schedule, Software Cost Estimate, Software Configuration Management Plan, Software Change Reports, Software Test Plans, Software Test Procedures, Software Test Reports, Software Version Description Reports, Software Maintenance Plan, Software Assurance Plan(s), Software Safety Plan, Software Requirements Specification, Software Data Dictionary, Software and Interface Design Description (Architectural Design), Software Design Description, Software User's Manual, Records of Continuous Risk Management for Software, Software Measurement Analysis Results, Record of Software Engineering Trade-off Criteria and Assessments (make/buy decision), Software Acceptance Criteria and Conditions, Software Status Reports, Programmer's/Developer's Manual, and Software Reuse Report.

B. Structure and Format: Defined in NPR 7120.5, Appendix H, Section 3.8.

C. Modeling: The software engineering personnel of the Engineering Team create an SMP that defines the actions to be taken to provide the software and ensure it meets NASA software quality standards. This product is supported by the system architecture model and by models of the software engineering process employed by the project, e.g., an agile software process.

D. Key Documents: The SMP Plan is a Key Document, and the Credibility Plan for Software Models and Simulations also may be considered a Key Document.

(18) Soln-18 Specific Engineering Plans:

A. Description: This product includes a variety of plans for various aspects of the approach used by the Engineering Team to develop a technical solution that satisfies the system requirements baseline. The content may involve multiple specific plans as required to deal with specific engineering tasks, depending on the nature of a mission and project. These plans commonly contain engineering-related content of the overall Project Plan and Project Control Plans and are used by the MSE to manage the project's technical efforts.

B. Structure and Format: This is an informal product that typically includes:

i. Overall project engineering strategy and approach – methodologies, models, system development sequence, metrics and governance, issue resolution, assumptions and constraints, etc.
ii. Engineering organization, roles and responsibilities, and interfaces to other project organizations.
iii. Resources – engineering workforce, specialized expertise, tools, facilities, equipment, administrative support and funding, etc.
iv. Schedule – subset of the project integrated master schedule for engineering activities.
v. Engineering products.

C. Modeling: The MSE, supported by the Engineering Team and in coordination with other project organizations, decides on the Engineering strategy for the project and documents it in a plan. This product may draw upon PM models such as an Integrated Master Plan and Schedule.

D. Key Documents: This product is coordinated with the Project Plan and other products of the Project Implementation View.

c. **Completion Criteria**: This View is complete when the following have been satisfied:

(1) System design is complete and documented to a level of detail that allows implementation to begin.
(2) All system requirements are allocated to appropriate levels of the system architecture.
(3) Operational and functional system architecture models and an initial physical architecture incorporating available product and design data are complete.
(4) Development and procurement specifications for products to be incorporated in the system solution are complete and have been reviewed.
(5) Internal and external interfaces are defined and documented in functional interface specifications.
(6) All materials required for successful completion of project reviews and key decisions in Pre-Phase A through Phase B have been created, reviewed, and approved/ baselined.
(7) TRLs have been assessed in a TRA process and support an acceptable level of technical risk to the project.
(8) Risk and hazard assessments are complete and establish that the project is feasible.
(9) Design data to support establishing a configuration management process have been provided to the PM Team, and an initial Configuration Baseline has been approved.

d. **Project Life-Cycle Evolution**: The Technical Solution View is mainly concerned with Pre-Phase A and with the Formulation Phase, Phases A and B, of the project life cycle.

Once system requirements are defined, the products of this View mature the technical solution to the point where a successful PDR and KDP C decision can be completed.

e. **Review Entrance and Acceptance Criteria**: See Appendix E for the review criteria that are satisfied in whole or in part by the products in the Technical Solution View.

B.2.4 Product Realization View

a. **Description**: This View describes mission system realization in the Implementation Phase of the project life cycle. It takes the design specifications from Phase B as captured in the products of the Technical Solution View and transforms them into a physical point design that provably complies with the system requirements baseline. It focuses on completing the details of a physical architecture based on aggregate requirements and the verification approach adopted by the project. The products of this Viewpoint document the actual mission system, including a flight segment ready to be placed in orbit, a launch segment ready to perform the launch, and a ground segment ready to monitor and control the observatories and to create and disseminate science data products. Figure 17, Context Diagram for the Product Realization View, shows the primary relationships to other project elements and Views.

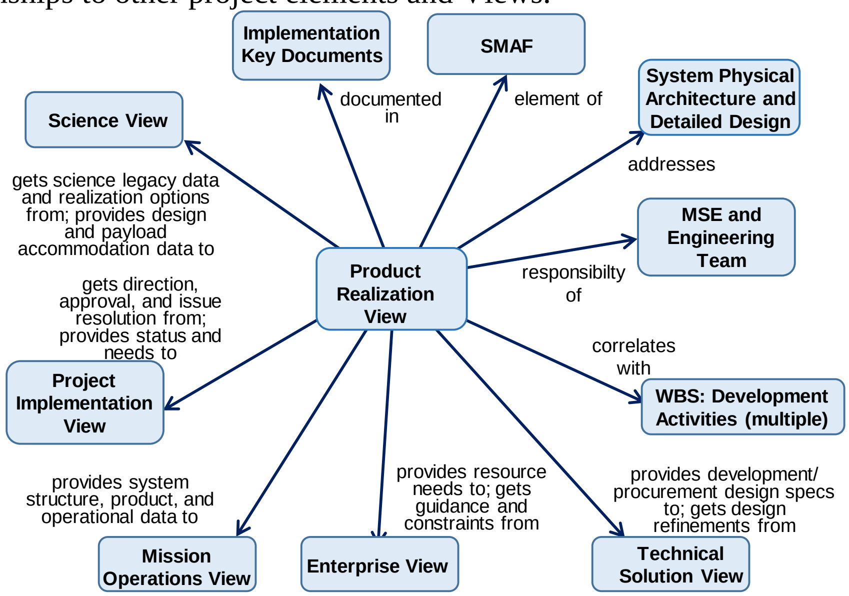


Figure 17—Context Diagram for the Product Realization View

(1) Scope Concerns: The scope of the Product Realization View encompasses the physical design detail of the mission system and associated plans and processes. This includes all of the engineering data required to define a system that can be fabricated, integrated, tested, launched, and operated to achieve the science objectives of the mission.

(2) Technical Concerns: In keeping with the scope, the technical content of this View consists primarily of specifications and supporting design and product data. Collectively, these products provide the foundation for and capture the results of the Implementation Phase of the Project Life Cycle.

(3) Safety and Mission Assurance Concerns: SMA requirements are enforced through project-specific mission assurance requirements during the Implementation Phase. They are in place to assure quality, safety, and reliability during the design, testing, and operation of flight hardware and ground support equipment. The employed processes include, but are not limited to, design for manufacturability, workmanship requirements, supply chain risk analysis and control, inspection plans, quality engineering and control, assurance for electrical, electronic and electromechanical (EEE) parts and printed circuit boards, reliability analyses, and metrology and calibration.

(4) PM Concerns: PM concerns in this View are a continuation of those under the Technical Solution View, dealing with realizing the proposed design solution within budget and schedule constraints. The Engineering Team coordinates closely with the PM Team to track project status, mitigate risks, allocate resources, identify and resolve issues, and prepare for and execute project reviews and key decisions. The Specific Engineering Plans product (Soln-18) continues to be updated and used in the Implementation Phase.

(5) Resource Concerns: These are essentially the same as described under the Technical Solution View, with the addition of resources required for Product Realization activities.

b. **Products**:

(1) Real-1 System and Product Specifications:

A. Description: As the project proceeds through development, procurement, selection, and modification of products that comprise the mission system, this product captures the point design detail in a set of specifications at all levels of the system hierarchy. Together with ICDs, these specifications populate the project Document Tree.

B. Structure and Format: A typical product specification has the following content:

i. Nomenclature – unique identifier, e.g., a product identification code.
ii. Description – general information about the product.
iii. Functional and performance data.
iv. Physical data – size, mass, power consumption, materials, mounting provisions, environmental tolerance, etc.
v. Test and qualification data.
vi. Integration and interface data.
vii. Implemented standards.

C. Modeling: The SE Team prepares documents at each level of the system hierarchy, following the outline defined in the preceding paragraph. For newly developed products, these specifications document the outcomes of product development efforts. For procured or partner-supplied products, the specifications are provided by the source. If legacy or existing products are modified, their specifications are updated accordingly. Lower level product specifications are aggregated to create system-level design/product specifications. A wide variety of phenomenological, analytical, behavioral, and component models may be used in creating specifications. Incorporation of these specifications is a key aspect of employing the architecture model as an SSTT.

D. Key Documents: System and product specifications are the primary content of a design solution definition that is baselined at the Critical Design Review (CDR). They are part of a Document Tree and can be incorporated in an architecture model. They also commonly provide input to other key documents such as project review data packages.

(2) Real-2 Final MEL:

A. Description: This product completes the Preliminary MEL by adding physical data on product mass, power, data rates, and other parameters and performing the computations to verify that system budgets are satisfied with adequate margins.

B. Structure and Format: See product Soln-10.

C. Modeling: As products are developed or selected, the SE Team populates the MEL with their physical data, computes margins, identifies any exceedances or other issues, and develops mitigations, which may include product redesign, adjustments to budget allocations, or other measures. The MEL is a model in itself and part of a system architecture model.

D. Key Documents: The MEL is a key document and may be incorporated in other key documents such as project review data packages.

(3) Real-3 Standards Profile:

A. Description: This product compiles the standards that have been selected for implementation in the mission system design and the interfaces, products, data items, services, or other system content to which they are applied. Appropriate standardization is essential to achieving an open, interoperable, and robust mission system architecture.

B. Structure and Format: The Standards Profile is created as a table and usually sorted by categories of standards. It may be a table or spreadsheet.

C. <u>Modeling</u>: The Engineering Team, as part of developing the system design, is responsible for developing and maintaining the standard's profile. The analysis supporting this product may employ a variety of component, functional, and other models.

D. <u>Key Documents</u>: The standards profile should be incorporated in the architecture model and may be used in other key documents such as project review data packages.

(4) Real-4 Integration Plan:

A. <u>Description</u>: This product defines the integration strategies for a project as lower-level elements are progressively assembled into higher-levels, ultimately to achieve the complete system. Each stage of integration has associated verification activities, and a key goal is to identify and correct problems at the lowest level and earliest time feasible. This includes the coordinated integration effort that supports the system implementation strategy, descriptions of what participants in the process do at each integration step, and identification of required resources and when and where they will be needed. This product is central to a Center Integration Process as required by NPR 7123.1B, section 3.2.7, and satisfies Entrance Criteria for Integration Plans at various life-cycle reviews.

B. <u>Structure and Format</u>: Defined in NASA/SP-6105, Revision 2, Appendix H.

C. <u>Modeling</u>: The Engineering Team develops this product. The Architecture Model, product Soln-3, provides critical support to integration planning, including defining key interfaces and providing a framework to develop the optimum sequence of integration steps.

D. <u>Key Documents</u>: The Integration Plan is a Key Document and is provided as a Project Control Plan under the Project Plan.

(5) Real-5 Final ICDs:

A. <u>Description</u>: Functional interface definitions are initially created under the Technical Solution View. Full interface definitions incorporating physical design data are completed as part of the Product Realization View. Interface standards are also identified in final ICDs.

B. <u>Structure and Format</u>: See product Soln-8. This product incorporates physical design data.

C. <u>Modeling</u>: The SE Team completes ICDs with physical data as it becomes available. ICDs are supported by the models used in system design.

D. Key Documents: ICDs are combined with specifications in a document tree. They may also be included in other key documents such as project review data packages.

(6) Real-6 Test Procedure:

A. Description: This product completes the definition of a test event by specifying the steps to be performed, the detailed data to be collected and the data processing and analysis to be performed. A set of test procedures forms the core content of a test plan.

B. Structure and Format: See product Soln-15. This product incorporates the detailed sequence of activities involved in executing a Test Plan.

C. Modeling: The SE Team completes planning, preparation, and execution of system testing by developing a detailed procedure for each test activity in the project's Test Plan(s).

D. Key Documents: This product supports the V&V Plan, which is a Key Document, and satisfies test plan Entrance Criteria for a variety of life-cycle reviews.

(7) Real-7 Peer Review Data Package:

A. Description: This product assembles the materials needed for peer reviews and other supporting reviews that are conducted by the Engineering Team during system implementation. These are conducted as necessary to evaluate design solutions and identify potential challenges. They can occur at the system, subsystem, or lower levels.

B. Structure and Format: This is an informal product whose organization depends on the content of a review and is designed to enable an effective event that satisfies the review's goals.

C. Modeling: The Engineering Team, in collaboration with other project organizations, defines the objectives of the review, the materials needed to enable the review team to function effectively, and the sequence and formatting of the review data package. Review materials commonly incorporate artifacts from the architecture model and various analysis, design, product, environmental, and other models.

D. Key Documents: Not Applicable.

c. **Completion Criteria**: This View is complete when the following have been satisfied:

(1) System development is complete, fully documented, and under configuration control in preparation for KDP E and an affirmative launch decision.
(2) V&V is complete and documented.
(3) All products are validated against the applicable stakeholder expectations.
(4) All MoEs, MoPs, Key Performance Parameters (KPPs), TPMs) and other performance measures have been shown to be satisfied.
(5) The system and all products have received required certifications for flight or use.
(6) MARs have been satisfied and the design has been approved by the responsible SMA authority.

d. **Project Life-Cycle Evolution**: The Product Realization View has its basis in the products of Technical Solution View that are developed through Phase B. Product Realization products are primarily created and used in Phases C and D. They are baselined not later than CDR and subsequently updated to reflect decisions made during system implementation. System design documentation, various models, supporting data, and other content continue to be used in support of mission operations and project completion in Phases E and F.

e. **Review Entrance and Acceptance Criteria**: See Appendix E for the review criteria that are satisfied in whole or in part by the products in the Product Realization View.

B.2.5 Project Implementation View

a. **Description**: The products in this View define the way in which a PM and Team will accomplish the planning, budgeting, scheduling, monitoring and control, and reporting activities required to formulate and execute a project in accordance with NPR 7120.5. The primary product is a Project Plan, which includes up to 27 Project Control Plans depending on the nature of the project. Some of these control plans are developed as part of other Views; e.g., a SEMP is a Project Control Plan under the Project Plan but is primarily developed by the MSE and Engineering Team (product Soln-1). The Project Implementation Viewpoint responds to a Project Scope Document (PSD) (product Ent-1 derived from an AO or other project direction, as well as other Agency and Center goals, strategies, plans, policies, directives, process descriptions, and other guidance. Figure 18, Context Diagram for the Project Implementation View, shows the primary relationships to other project elements and Views.

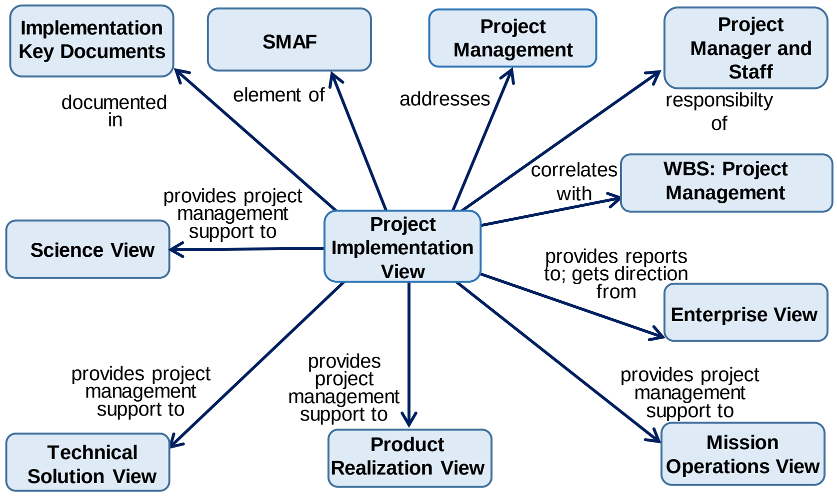


Figure 18—Context Diagram for the Project Implementation View

(1) Scope Concerns: The scope of the Project Implementation View is comprehensive, since the PM and PM Team are responsible for overall management and control of the project. This includes coordinating the activities of the Project Team, interfacing the project to Center and Agency organizational levels, and managing the project's progress through the life cycle, especially project reviews and key decisions.

(2) Technical Concerns: The technical dimension of PM deals primarily with integrating science and engineering activities into a comprehensive and cohesive Project Plan, tracking and reporting the status of those activities, and facilitating resolution of any issues that arise among the Science, Engineering, Mission Operations, Launch Services, and other teams and organizations within the project.

(3) SMA Concerns: The PM Team ensures that SMA requirements and guidance are properly accounted for, including ensuring the creation of a satisfactory SMAP or MAIP.

(4) PM Concerns: These concerns are the core of this Viewpoint and the subject matter of its products. The PM Team collects, harmonizes, and addresses PM concerns from the entire Project Team.

(5) Resource Concerns: The PM Team identifies, prioritizes, and takes action to secure the resources needed to execute the project. This includes both near-term needs for workforce, facilities, equipment, support services, administrative services, and other resources and longer term resource projections that support Center and Agency resource planning. The PM, supported by cost, schedule, earned value management (EVM), and other resource specialists, also performs internal management of allocated resources, including Unallocated Future Expenses (formerly referred to as Management Reserve).

b. **Products**:

(1) Proj-1 Stakeholder Expectations Document:

A. Description: This product identifies a project's stakeholders and their needs, goals, and objectives. This information is baselined at MCR and updated at subsequent project reviews. It is the primary criterion for requirements validation and the starting point for a science concept. This product addresses the concerns of the Stakeholders identified in Table 1, section 4, of this NASA Technical Handbook and any other Center and Agency organizations and individuals specifically concerned with the project, as well other Government Agencies, national and international partners, and any other entities with a recognized interest in the project.

B. Structure and Format: This is an informal product which may be created as a text document, briefing slides, or in other forms. It includes the identities of project stakeholders, their interests in the project, and their specific needs, goals, and objectives, stated as quantitatively as possible. For the science stakeholders, this will include the baseline science outcomes that represent a successful mission and the desired enhanced outcomes to be pursued within constraints of resources, schedule, and risk. This product may be incorporated in a PLRA.

C. Modeling: This product does not directly employ models. The PM and staff identify the stakeholders, at all organizational levels, and solicit their expectations. For example, the PI will identify the data to be collected, the essential characteristics of that data, the processing to be performed to create science data products, and the ways those products will be used, disseminated, and archived. OSMA will be contacted to identify SMA concerns that will be formally provided as MAR. Other Center and Agency stakeholders will be similarly contacted to elicit their expectations. The product will then be created in an appropriate form and presented for approval and baselining at MCR.

D. Key Documents: This product is the starting point for the concept development and especially for the STM and CSR. It is also a major input to the Project Plan and various Project Control Plans.

(2) Proj-2 Project Plan

A. Description: This product is the overall management plan for the project, defined in NPR 7120.5, Appendix H. Content includes a project overview and baselines for requirements, WBS, schedule, resources, and joint cost/schedule confidence levels. Most other products in this Viewpoint are project control plans under the Project Plan. This product includes a waivers and deviations log, a change log, and appendices. The SMAF treats Project Control Plans that are not called out in other Views as part of the Project Plan product, e.g., the Technical, Schedule, and Cost Control Plan.

B. Structure and Format: Defined in NPR 7120.5, Appendix H.

C. Modeling: The PM and Team compile the Project Plan based on the OA or other project direction, the PSD, and related Agency and Center policies, processes, directives, and standards. The Project Plan may use cost, schedule, risk, and other models depending on the specifics of the project.

D. Key Documents: The Project Plan is a Key Document.

(3) Proj-3 Project Review Data Package:

A. Description: This product assembles the materials needed for project reviews.

B. Structure and Format: Each review data package is defined by the Entrance and Success Criteria of the associated review, as defined in NPR 7123.1B, Appendix G, and any supplemental direction and guidance.

C. Modeling: The entire Project Team is responsible for this product, providing content in their various areas of responsibility, under the overall supervision of the PM, PI, and MSE. Creating the data package consists of preparing, assembling, and reviewing the materials. Under SMAF, a large part of the data package is provided by various Viewpoints and their products. Review materials commonly include artifacts of the architecture model and multiple models supporting system analysis and design, PM, and other project activities.

D. Key Documents: This product is a Key Document or set of key documents used to communicate the content of a life-cycle review to a Review Team and to support the conduct of the review.

(4) Proj-4 Project Status Report:

A. Description: This product documents the current status of the project to be provided primarily to higher organizational levels (program, Center, and Agency). It complements other reports such as EVM by providing a means of reporting status information of any kind.

B. Structure and Format: This is an informal product responding to direction in an OA or other directive for content and timing of status reporting. It is commonly presented in memorandum form.

C. Modeling: The PM compiles a status report drawing information from the entire Project Team and forwards it to the appropriate higher level organizations.

D. Models: This product does not generally employ models unless a specialized topic that uses model-supported analysis is warranted.

E. Key Documents: A Project Status Report is a Key Document.

(5) Proj-5 Compliance Matrix:

A. Description: This product documents the program's or project's compliance with the requirements of NPR 7120.5 or how the program or project is tailoring the requirements in accordance with paragraph 3.5.

B. Structure and Format: Defined in NPR 7120.5, Appendix C.

C. Modeling: The PM maintains the Compliance Matrix using the Appendix C template and updates it with inputs from the entire Project Team for project reviews or when required for status reporting. This product does not employ models.

D. Key Documents: A Compliance Matrix may be a Key Document if so directed, or it may be incorporated in project reviews and key decision data packages, status reports, or other key documents.

c. **Completion Criteria**: This product is complete when the products have the following content, as well as any other descriptions of mission science required by the nature of the mission:

(1) Project Plan defining objectives, technical and management approach, project operational environment, and project commitments to the sponsoring program completed, coordinated, and approved by the Mission Directorate Associate Administrator , Center Director(s), program manager, and PI.
(2) Project Plan updated to reflect latest project direction and status.
(3) Required Project Control Plans completed/updated, coordinated, and approved.
(4) Effective acquisition strategy for system segments and payload elements established.
(5) Project control and reporting processes established, e.g., EVM, TRL assessment, risk management, SMA, project reviews, cost estimation, etc., commensurate with the project category.
(6) Project team established, including partners, with roles and responsibilities defined.

d. **Project Life-Cycle Evolution**: The products in the Project Implementation Viewpoint evolve over the project life cycle as follows:

(1) Pre-Phase A: Initial project requirements, cost, schedule, and risk baselines, along with project organization and basic PM processes, are established to support a Formulation Agreement to begin formulation in Phase A upon approval of an MCR and KDP A.
(2) Phase A: The Project Plan is refined and most Project Control Plans are initiated or updated in preparation for an MDR and a KDP B decision. NPRs 7120.5 and 7123.1 provide guidance on the timing of creation, updating, and baselining of these plans.
(3) Phases B – F: The products in this Viewpoint are updated following project reviews, KDP decisions, and other events to ensure the management foundation of the project remains current and valid.

e. **Review Entrance and Acceptance Criteria**: See Appendix E for the review criteria that are satisfied in whole or in part by the products in the Project Implementation Viewpoint.

B.2.6 Mission Operations View

a. **Description**: This View is concerned with the activities associated with launching, operating, maintaining, and ultimately disposing of a spacecraft or constellation. It begins with a CONOPS and continues through the operational employment of a mission system to achieve mission objectives. It is primarily the responsibility of the ground segment, including a Mission Operations Team; and the products are focused on interactions with observatories in specific time periods and for specific activities. Mission operations are fundamentally tactical, emphasizing a near-term time window and reacting to immediate needs to configure and schedule observatory functions, detect and respond to anomalies, maintain required Flight Dynamics parameters, transition observatories among operating modes as appropriate, employ telemetry networks, and otherwise “fly” the spacecraft and process the downlinked science data. Figure 19, Context Diagram for the Mission Operations View, shows the primary relationships to other project elements and Views. As the figure shows, multiple facilities and organizations are involved in mission operations.

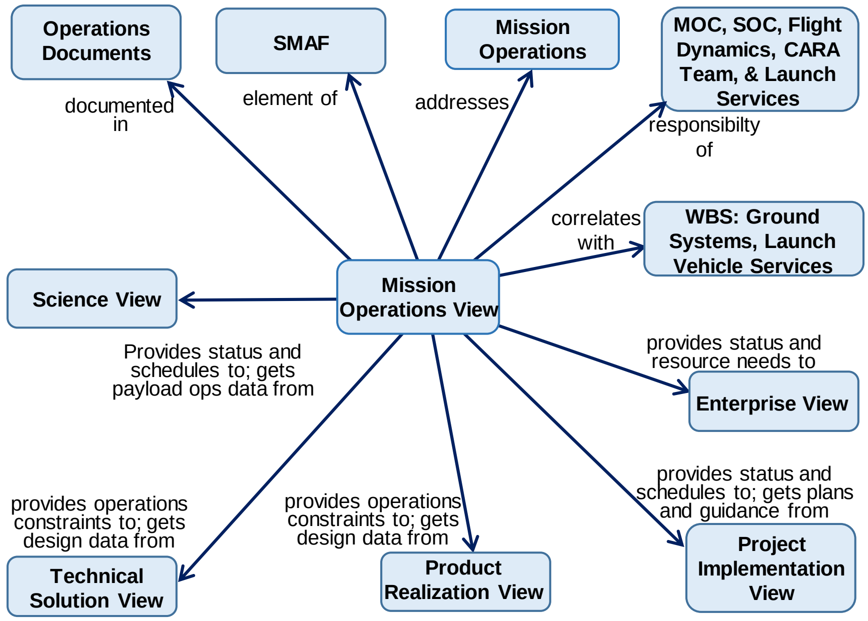


Figure 19—Context Diagram for the Mission Operations View

(1) Scope Concerns: This View addresses all aspects of defining and performing the mission operations through which a mission system is employed to accomplish mission objectives. The scope embraces requirements levied on the system to ensure safe and effective mission accomplishment, creation of a CONOPS (also referred to as an Operational Concept), development of processes and procedures for monitoring and controlling the system (especially the flight segment), processes and procedures for housekeeping and anomaly management, collaboration among ground segment elements, and any other aspects of mission operations.

(2) Technical Concerns: The technical content of this Viewpoint involves the data, processes, facilities and resources, workforce skills, and other engineering aspects of mission operations. The focus is on understanding the full set of mission requirements associated with operations and on verifying that those requirements are satisfied. Examples include flight dynamics processes required to maintain observatory orbital parameters and orientation; means to identify, diagnose, and respond to on-orbit anomalies; algorithms and processes that convert instrument data into science data processes; and network protocols and management techniques associated with telemetry.

(3) Safety and Mission Assurance (SMA) Concerns: OSMA provides high level SMA requirements and expectations aligned with assigned risk classification that are flowed down by project SMA into a MAR, and subsequently a MAIP (as applicable). The MAR and/or MAIP is/are enforced by the project SMA team under the leadership of the CSO. Examples include conjunction analysis to prevent collisions with other space objects; health and status monitoring to ensure

observatories remain capable of meeting mission objectives; proper resolution of on-orbit anomalies and capture of lessons learned; and provisions to ensure safe decommissioning and de-orbiting of observatories at mission completion.

(4) PM Concerns: The Mission Operations Team coordinates with the PM Team to ensure operations planning, operational status reporting, issue resolution, and other aspects of PM are properly performed.

(5) Resource Concerns: The Mission Operations Team defines the resources necessary to accomplish their tasks and coordinates with the PM Team to make those resources available when needed. This may include access to external organizations and resources such as the Combined Space Operations Center.

b. **Products**:

(1) Ops-1 Operational Schedule:

A. Description: This is a generic product that accounts for any schedule of system activities or events used in the course of mission operations. This includes scheduled use of telemetry networks, orbital schedules, scheduled observatory maintenance and updates, shift schedules in ground segment facilities, etc. Details will vary with the particulars of a given mission.

B. Structure and Format: This product has no established structure; each schedule is defined by the Mission Operations Team based on specific system operations.

C. Modeling: As part of mission planning, the Mission Operations Team identifies and coordinates the required schedules. Each schedule is created or updated when required during the mission, and coordinated with other Project Team organizations that are interested or involved in the scheduled activities.

D. Models: This product generally uses operational models, e.g., for flight dynamics, to support creation and assessment of schedules.

E. Key Documents: Not Applicable.

(2) Ops-2 Observatory Command Sequence:

A. Description: This product contains a command or sequence of commands to be uplinked to an observatory to invoke and control functions, change the operating mode, respond to fault conditions, or cause any other action. This may include thruster burns; attitude control; science operations; calibration; housekeeping; data collection, selection, and processing; and any others, depending on the mission. Special commands are used to put an observatory in Safe mode or to return it to normal operations. Distinct command sequences may be defined for various mission phases, e.g., launch, orbit insertion and commissioning, science operations, and deorbiting or disposal. NASA-STD-1006 spells out requirements governing commands in specific situations.

B. Structure and Format: This product has no established structure; each command sequence is defined by the Mission Operations Team, in coordination with the Science Team and possibly other project organizations. Once a command sequence is defined, it will normally be formatted as a message for transmission by a telemetry network, conforming to applicable standards such as the Consultative Committee for Space Data Systems (CCSDS).

C. Modeling: This product is created as needed in the course of controlling mission operations. The MOC has primary responsibility, working in collaboration with the SOC, Flight Dynamics, CARA analysts, and, during the launch phase, Launch Services. The Science Team creates payload commands, based on the current situation, mission science goals and status, instrument anomalies, opportunities for data collection, or other circumstances. The Science Team may also request adjustments to orbit and attitude to ensure planned data collections can be executed. Flight Dynamics determines maneuvers required to maintain orbital and attitude parameters, and CARA assesses current orbits and planned maneuvers to determine if a conjunction risk is present and requires mitigation. The Spacecraft Bus Team may request commands to various subsystems, e.g., to adjust usage of consumables or perform diagnostics, based on observatory status and other factors. This product generally uses physical and component models, e.g., observatory mass and thruster capabilities, in creating commands and setting parameter values.

D. Key Documents: Not Applicable.

(3) Ops-3 Conjunction Assessment Risk Analysis (CARA):

A. Description: This product documents the results of an analysis of risks of collision of an observatory with another object. The CARA Team, working with the Mission Operations Team and the Combined Space Operations Center, performs conjunction assessments and risk assessments and recommends risk mitigations based on current satellite ephemeris data.

B. Structure and Format: Defined by the CARA Team.

C. Modeling: Flight Dynamics provides current ephemeris data and a Maneuver Plan to achieve required orbital corrections to the CARA Team. If the CARA

Team identifies a risk, recommended mitigation maneuvers are fed back to Flight Dynamics; and the Maneuver Plan is refined accordingly. This product uses Flight Dynamics Models, the current space object catalog (maintained by the Combined Space Operations Center), orbital propagation models, and others to identify potential conjunctions and perform risk analysis and mitigation planning.

D. Key Documents: Not Applicable.

(4) Ops-4 Mission Operations Plan (OPlan):

A. Description: This product incorporates planning for mission operations from launch preparations through decommissioning and disposal. Multiple specific operations plans are required by various life-cycle review Entrance and Success Criteria.

B. Structure and Format: This product has no established format. It may be created as a single document with sections for various mission phases or as a set of stand-alone plans. Detailed operations planning is typically required in the areas of pre-launch and launch site preparations; launch operations; observatory checkout, activation, and early operations; events, activities, and contingencies; and decommissioning and disposal.

C. Modeling: This product is created by the Mission Operations Team in collaboration with Science, Engineering, and PM Teams. If the Mission Operations Team has not been established early in a project, the SE Team may be assigned to complete the initial version. This product uses the same model categories as the CONOPS.

D. Key Documents: The OPlan or Plans are commonly treated as Key Documents and are reviewed at project reviews, beginning with KDP C and PDR.

(5) Ops-5 Range Flight Safety Risk Management Process Documentation:

A. Description: This product describes how the project will implement a Range Flight Safety Risk Management process in accordance with NPR 8715.5, Range Flight Safety Program.

B. Structure and Format: Defined in NPR 7120.5, Appendix H, section 3.24, and NPR 8715.5.

C. Modeling: The Mission Operations Team, supported by the Safety and Mission Assurance Directorate and other range safety organizations, identifies range flight safety concerns associated with the payload and develops a process to ensure protection of the public, workforce, and property during range flight operations. This product does not normally employ models.

D. Key Documents: The Range Flight Safety Process Documentation package is a Key Document.

(6) Ops-6 Expendable Launch Vehicle Payload Safety Process Deliverables:

A. Description: This product applies to projects that fly on expendable launch vehicles and are managed by NASA, including contractor and other agency-developed systems, in accordance with NPR 8715.7, Payload Safety Program; and NASA-STD-8719.24, Annex A to NASA-STD 8719.24, NASA Expendable Launch Vehicle Payload Safety Requirements: Requirements Table. It includes deliverables from the project's payload safety process.

B. Structure and Format: Defined in NPR 7120.5, Appendix H, section 3.25, and NPR 8719.7.

C. Modeling: The Management Team, supported by the Safety and Mission Assurance Directorate and other range safety organizations, identifies payload safety concerns associated with payload design, fabrication, testing, launch vehicle integration, launch processing, launch operations, and planned recovery, if applicable. It includes payload-provided upper stages, payload-provided interface hardware, and ground support equipment.

D. Models: This product does not normally employ models.

E. Key Documents: The Expendable Launch Vehicle Payload Safety Process Deliverables Documentation package is a Key Document.

c. **Completion Criteria**: This View is complete when the following are satisfied:

(1) The CONOPS is complete, reviewed, and baselined.
(2) Operational Plans are complete, reviewed, and baselined.
(3) If required, Disposal and Decommissioning Plan is complete, reviewed, and baselined.
(4) Operational procedures are complete, reviewed, and baselined.
(5) Requirements allocated to Mission Operations have been verified and validated.
(6) All elements of the ground segment have been established, staffed, exercised, and declared operational.
(7) All elements of the launch segment are defined, available, and certified for flight.
(8) All required Mission Operations resources are defined and available.

d. **Project Life-Cycle Evolution**: This View begins in Pre-Phase A with initial operational concept development and coordination, much of which is reflected in a CSR. Early planning is updated and reviewed as the project proceeds through Phase A. By Phase B, a Mission Operations Team should be established, and the CONOPS and OPlans are refined as the mission is defined in more detail. The remaining products are created and used during Phases D, E, and F.

e. **Review Entrance and Acceptance Criteria**: See Appendix E for the review criteria that are satisfied in whole or in part by the products in the Requirements View.

B.2.7 Enterprise View

a. **Description**: The products in this View define the interactions of a project with higher organizational levels. Those include the Agency (NASA Headquarters), SMD, the Division or Program sponsoring the project, and the Center that is leading the project, including the Director and staff. Enterprise View products document the downward flow of direction and the upward flow of project status, resource needs, and any other information that has to be exchanged. Importantly, this View establishes the traceability of a project to plans, strategies, needs, goals, and objectives of the higher organization. Figure 20, Context Diagram for the Enterprise View, shows the primary relationships to other project elements and Views.

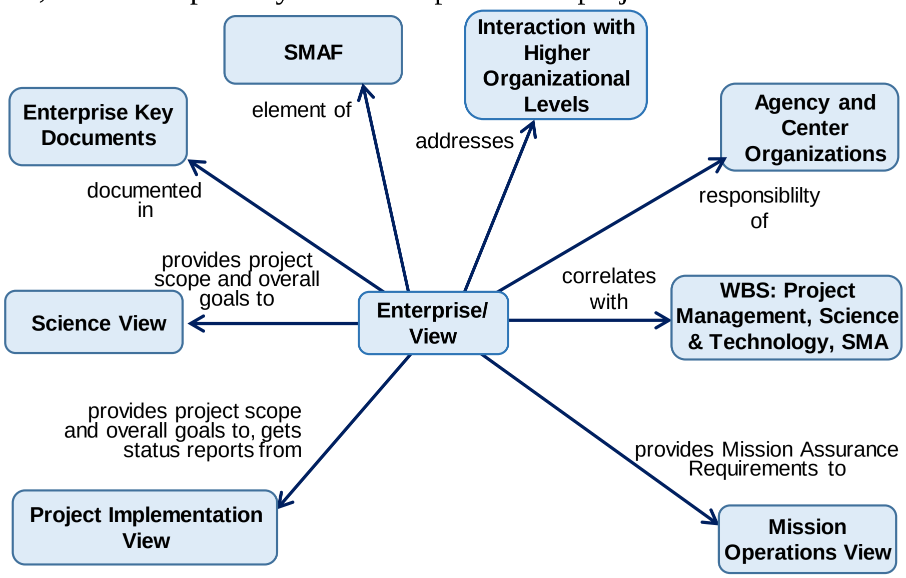


Figure 20—Context Diagram for the Enterprise View

(1) Scope Concerns: Agency, Program, and Center leadership establishes the scope of a given project through an AO, for a competed project, or other direction for a directed project. This becomes the Project Scope Document.

(2) Technical Concerns: For the Enterprise View, technical concerns largely deal with applicable standards and processes that are to be complied with by a project. There may also be a need to verify that a given project supports overall Agency and Center goals, strategic plans, and roadmaps.

(3) Safety and Mission Assurance Concerns: OSMA provides MAR to a project and assesses the implementation of those requirements by the project to ensure compliance.

(4) PM Concerns: Agency and Center leadership provide guidance, policy, and other high-level inputs to a project to ensure planning and execution are satisfactory and have adequate confidence of success.
(5) Resource Concerns: Ultimately, the Center and Agency have to plan for and provide the resources needed by projects. There is a dialog in which project organizations identify their needs and the Center and Agency address how those needs will be met.

b. **Products**:

(1) Ent-1 Project Scope Document (PSD):

A. Description: This product initiates a project and defines its scope by either directing the project to a Center or soliciting competitive proposals using an AO. An AO can use either a one-step process in which proposals defining a mission concept are evaluated at the end of Phase A, with the winning concept approved to proceed into formulation in Phase B, or a two-step process in which an initial downselect at the end of Pre-Phase A leads to funded concept studies for a second downselect at the end of Phase A. An AO or other PSD contains the project's MAR.

B. Structure and Format: An AO or other PSD typically begins with approvals and summary front matter with key graphics that convey the nature, goals and motivation of the mission. A competitive AO defines the evaluation criteria that will be used to select the winning mission concept. The remainder of the document includes an Executive Summary, description of the science investigation and its implementation, other aspects of mission implementation (including engineering and operations), the approach to project management, various other factors such as student participation, directions for a cost proposal, and a request for current technology and concept development status.

C. Modeling: This product is created by a Program Office within a Mission Directorate at NASA Headquarters. This product typically is not developed using models, unless the Program Office performs model-based analysis in defining the document.

D. Key Documents: The PSD is a Key Document that may take the form of an AO or other project directive.

(2) Ent-2 Concept Study Report (CSR):

A. Description: This product is the response of a project to an AO and can be used to define a mission concept for a non-competitive project. For a competitive project, creating a System Concept and CSR is a central activity in developing a project proposal. The Science Investigation and Science Implementation sections of the CSR describe the approach to data collection and analysis, instrument payload design and integration, options for de-scoping while maintaining a satisfactory science outcome, and other aspects of mission science. The Mission Implementation section describes the engineering approach to realize a system that will achieve the science goals and objectives. The Management section describes how the project will be planned and controlled to execute the mission within budget and schedule constraints. All project organizations contribute to the CSR, which is normally compiled by the MSE. The CSR normally represents a firm technical baseline for the system to be developed that is only changed when directed by life-cycle reviews. The CSR product is assigned to the Enterprise View because it represents all organizations and participants within the project and is the central product for establishing a common understanding of a mission between the project and higher echelons.

B. Representative Structure and Format: The CSR normally follows the organization of the AO or other PSD to which it responds.

C. Modeling: A variety of science, engineering, and management models support the content of the CSR. The PI and Science Team develop Sections C and D of the CSR with inputs from other project organizations, especially the Engineering Team. The Science, Engineering, and Management Teams collaborate to develop the complete CSR using results of design, environmental, cost and schedule, and other models. Modeling and simulation for this product continue the activities from the Science Concept and STM with further development of the details that describe the system concept.

D. Key Documents: The CSR is a key document. It uses input from the Project Scope Document, the System Architecture Model, and other sources. It provides input to the System Requirements Document, the CONOPS, the Project Plan, the MAIP/SAMP, and various Mission Operations Plans, including Range Safety, Payload Safety, and Communications.

(3) Ent-3 Decision Memorandum:

A. Description: Following a KDP Review, the project Decision Authority issues a Decision Memorandum documenting a determination of whether and how the project proceeds into the next phase and approves any additional actions.

B. Structure and Format: Decision Memorandum templates may be found at NASA's Office of the Chief Financial Officer community of practice site; also see NPR 7120.5, section 2.4.

C. Modeling: The Decision Authority reviews the KDP Review Data Package (product Ent-5) and completes discussions with concerned parties. The Decision Authority then makes the appropriate determination about the future of the project and creates this product following the applicable template. This product does not typically use models.

D. Key Documents: The Decision Memorandum is a Key Document.

(3) Ent-4 Strategic Plan:

A. Description: This product encompasses the NASA Strategic Plan, supplemented by the NASA Science Plan and Roadmaps for various NASA mission areas. Collectively, these provide the highest level context and guidance for formulation of programs and projects. Project goals, objectives, requirements, and plans ultimately trace to these overarching plans.

B. Structure and Format: Established by the Agency.

C. Modeling: Any required modeling activities are established by the Agency.

D. Key Documents: This product provides context and guidance for all the Key Documents of a project.

(4) Ent-5 KDP Data Package:

A. Description: This product encompasses the materials that are presented at each KDP Review (A through F).

B. Structure and Format: KDP Data Packages are substantially the same as those for the associated project life-cycle reviews, as defined in NPR 7120.5, Tables 2.3 through 2.6. Specific content for a particular KDP Review for a specific project may be directed by the Decision Authority.

C. Modeling: The PM and the entire Project Team assemble the data package from the material presented at the associated project review (e.g., MCR for KDP A, MDR for KDP B, PDR for KDP C, etc.). The same tools and methods used to prepare for the associated project review apply to this product for a specific KDP review.

D. Key Documents: A KDP Data Package is a Key Document.

(5) Ent-6 Center Facilities, Equipment, and Staffing Plans:

A. Description: This product consists of Center resource plans to which a project provides its resource needs and required availabilities to have the means to meet mission objectives.

B. Structure and Format: Established by the Center.

C. Modeling: Established by the Center.

D. Key Documents: N/A.

c. **Completion Criteria**: This View is complete when the following have been accomplished:

(1) Agency and Center strategic plans provided to the project as appropriate for product formulation and execution.
(2) AO or other project directive issued, including the content of a Project Scope Document, and project initiated.
(3) MAR baselined and used as the basis for MAIP/SMAP.
(4) KDP data packages created for each key decision.
(5) Project resource needs compiled and provided to the Center organizations responsible for facility, equipment, and staffing plans.

d. **Project Life-Cycle Evolution**: The products of this View, except those associated with KDPs, are normally complete by the end of Phase A unless circumstances during project formulation and execution require changes, e.g., to required resources. KDP Data Packages and Decision Memoranda are created for each KDP.

e. **Review Entrance and Acceptance Criteria**: There are no review criteria associated with this View.

APPENDIX C

KEY DOCUMENTS ASSOCIATED WITH THE SPACE MISSION ARCHITECTURE FRAMEWORK (SMAF)

C.1 PURPOSE

This Appendix provides a listing of key documents that are associated with SMAF Views and Products. Where available, an authority or source reference is listed for each document.

C.2 KEY DOCUMENTS

a. Concept Study Report (CSR). *Reference:* NPR 7120.5 [NOTE: Specifics of the CSR for a given project are spelled out in an AO or other directive.]

b. Science Traceability Matrix (STM). *Reference:* NPR 7120.5 [NOTE: Specifics of the STM for a given project are spelled out in an AO or other directive.]

c. Project Scope Document (PSD). *Reference:* NPR 7120.5, Appendix E, section 3 [NOTE: Specifics of the scope of a given project are spelled out in an AO or other directive such as a Decision Memorandum.]

d. Project Plan. *Reference:* NPR 7120.5, Appendix H; includes 24 Project Control Plans applicable to missions that are incorporated in multiple SMAF Viewpoints:

(1) Technical, Schedule, and Cost Control Plan.
(2) Safety and Mission Assurance (SMA) Plan.
(3) Risk Management Plan (RMP). *Reference:* NPR 8000.4.
(4) Acquisition Plan.
(5) Technology Development Plan (TDP).
(6) Systems Engineering Management Plan (SEMP). *Reference:* NASA/SP-6105, Revision 2, Appendix J.
(7) Information Technology Plan.
(8) Software Management Plan. *Reference:* NPR 7150.2.
(9) Verification and Validation Plan. *Reference:* NASA/SP-6015, Revision 2, Appendix I.
(10) Review Plan.
(11) Mission Operations Plan (OPlan).
(12) Environmental Management Plan.
(13) Integrated Logistics Support Plan (ILSP).
(14) Science Data Management Plan (SDMP).
(15) Integration Plan.

(16) Configuration Management Plan (CMP), *Reference:* NASA/SP-6105, Revision 2, Appendix M.
(17) Security Plan.
(18) Project Protection Plan.
(19) Technology Transfer Control Plan.
(20) Knowledge Management Plan.
(21) Range Flight Safety Risk Management Process Documentation.
(22) Expendable Launch Vehicle Payload Safety Process Deliverables.
(23) Education Plan.
(24) Communications Plan.

e. Concept of Operations (CONOPS). *Reference:* NASA/SP-6015, Revision 2, Appendix S.

f. System Requirements Document (SRD). *Reference:* NASA/SP-6105, Revision 2, section 4.2; NPR 7120.5, Table 1-1; may consist of documentation (e.g., Mission Design Requirements Agreement), requirements database(s), or architectural requirements model(s).

g. Master Equipment List (MEL) with Mass Properties Control Plan and Reports. Conventional product defined for a specific system.

h. Standards Profile. *Reference:* NASA NPR 7123.1.

i. NASA Spacecraft Systems Analysis Plan and Reports. *Reference:* NASA/SP-6105, Revision 2.

j. Mission Assurance Requirements (MAR). *Reference:* Local Center SMA processes.

k. Safety and Mission Assurance Plan (SMAP). *Reference:* NPR 7120.5, Appendix H, section 3.2.

l. Announcement of Opportunity (AO). *Reference:* NPR 7120.5, Section 2.1.4.

m. Decision Memorandum. *Reference:* NPR 7120.5, Section 2.4.

n. Project Review (Life-cycle Review) Data Package. *Reference:* NPR 7120.5, Chapter 2.

o. Key Decision Point (KDP) Review Data Package. *Reference:* NPR 7120.7, Chapter 6.

p. Conjunction Assessment Risk Analysis (CARA) Report. *Reference:* https://satellitesafety.gsfc.nasa.gov/cara.html

q. Technology Readiness Assessment (TRA)/Technology Readiness Level (TRL) Report. *Reference:* NASA NPR 7123.1, section 5.1.6.

r. Stakeholder Expectations Document. *Reference:* NPR 7120.5 (NOTE: This document does not have a prescribed format.)

s. Formulation Agreement. *Reference:* NASA NPR 7120.5, Appendix F.

t. Science Data Products. Defined by the science objectives of a specific mission.

u. Requirements Verification Matrix (RVM)/Verification Cross Reference Matrix (VCRM). *Reference:* NASA/SP-6105, Revision 2, Appendix D.

v. Interface Control Document (ICD). *Reference:* NASA/SP-6105, Revision 2, section 6.3.1.3.

w. Document Tree. *Reference:* NPR 7123.1, Appendix G.

x. Project Status Report. *Reference:* NASA Project Planning and Control Handbook.

APPENDIX D

MODELS USED WITH SPACE MISSION ARCHITECTURE FRAMEWORK (SMAF) PRODUCTS

D.1 PURPOSE

This Appendix provides a listing of the primary model types used in conjunction with developing and using SMAF products. In some cases, models may be deliverable in their own right, but they primarily provide analysis and documentation for products.

D.2 SMAF MODELS

The following are the primary categories of models associated with SMAF and their intended uses:

a. Operational Models: Used to define and analyze operational environments and mission scenarios, including flight dynamics/orbit design/orbit propagation and control, space environment and weather, telemetry and networking, launch services, CARA, and other operational factors.

b. Architecture Models: Used to define, analyze, document, and visualize a mission or system architecture. These may be based on documents or SysML®. Reference Architectures are used to achieve reuse of proven architecture materials.

c. Component Models: Used to define and analyze the characteristics of individual system components.

d. Analysis Models: Algebraic models and simulations used for a wide range of analysis tasks, including mathematical analysis, computational fluid dynamics, physical phenomenon analysis, network and communications analysis, performance and interface analysis, environmental tolerance and effects analysis, and many others. This category can be further divided into structural and functional or behavioral models.

e. CAD and CAM: Tools and their outputs used to design and manufacture prototypes, finished products, and production runs.

f. T&E Models: Used to design and implement testing at various levels of the system structural hierarchy, as well as to analyze and interpret test results.

APPENDIX E

SPACE MISSION ARCHITECTURE FRAMEWORK (SMAF) VIEWPOINTS MAPPED TO PROJECT REVIEW CRITERIA

E.1 PURPOSE

This Appendix relates the SMAF Viewpoints to the Entrance and Success Criteria of the primary project reviews as defined in NPR 7123.5, Appendix H, and lists to principal products used in each review.

E.2 MCR CRITERIA

Table 4 provide MCR criteria.

Table 4—MCR Criteria

Viewpoints to MCR Entrance and Success Criteria	MCR.EC.00 MCR Entrance Criteria	MCR.EC.01 Agenda	MCR.EC.02 Reviews	MCR.EC.03 Primary Products	MCR.EC.03.A Stakeholders and Expectations	MCR.EC.03.B Mission Concept	MCR.EC.03.C Key Performance Parameters	MCR.EC.04 Programmatic Products	MCR.EC.05 Technical Products	MCR.EC.05.A Goals and Objectives	MCR.EC.05.B Alternative Concepts	MCR.EC.05.C Cost and Schedule Estimates	MCR.EC.05.D Descope Options	MCR.EC.05.E Risk Assessment and Mitigation	MCR.EC.05.F V and V Approach	MCR.EC.05.G SEMP	MCR.EC.05.H Technology Development Plan	MCR.EC.05.I TRL Assessment	MCR.EC.05.J Engineering Development Assessment	MCR.EC.05.K Support Strategy	MCR.EC.05.L Software Products	MCR.SC.0 MCR Success Criteria (Concerns)	MCR.SC.01 Mission Objectives	MCR.SC.02 Concept Meets Expectations	MCR.SC.03 Concept Feasibility	MCR.SC.04 Evaluation Criteria	MCR.SC.05 Mission Need	MCR.SC.07 Compliance with Guidance	MCR.SC.08 TBD/TBR Disposition	MCR.SC.09 Alternative Concepts	MCR.SC.10 Technical Planning	MCR.SC.11 Risk Assessment and Mitigation	MCR.SC.12 Software
Science Viewpoint						X	X			X			X										X				X						
Requirements Viewpoint							X			X					X								X										X
Technical Solution Viewpoint						X			X		X			X		X	X	X	X		X			X	X	X				X	X	X	X
Product Realization Viewpoint																																	
Project Implementation Viewpoint					X			X				X		X						X								X	X			X	
Mission Operations Viewpoint						X																											
Enterprise Viewpoint																											X	X					

SMAF Products:			**Review Criteria**:
a.	Sci-1	Science Concept	MCR.EC.03B, MCR.EC.05.A, MCR.EC.05.D, MCR.SC.01
b.	Sci-2	Science Traceability Matrix	MCR.EC.03.C, MCR.EC.05.A, MCR.SC.01, MCR.SC.05
c.	Reqt-1	System Requirements Document	MCR.EC.03.C, MCR.EC.05.A, MCR.SC.12
d.	Reqt-2	Verification and Validation Plan	MCR.EC.05.F
e.	Proj-1	Stakeholder Expectations Document	MCR EC.03.A
f.	Proj-2	Project Plan (including Project Control Plan products)	MCR.EC.04, MCR.EC.05.K, MCR.SC.07, MCR.SC.08
g.	Proj-3	Technical, Schedule, and Cost Control Plan	MCR.EC.05.C, MCR.SC.06
h.	Proj-5	Risk Management Plan	MCR.EC.05.E
i.	Proj-12	Integrated Logistics Support Plan	MCR.EC.05.K
j.	Soln-1	Systems Engineering Management Plan	MCR.EC.05.G, MCR.EC.05.J

k.	Soln-2	Analysis of Alternatives	MCR.SC.04, MCR.SC.09
l.	Soln-11	Technology Readiness Assessment	MCR.EC.05.I, MCR.SC.03, MCR.SC.11
m.	Soln-12	Technical Risk Analysis	MCR.EC.05.I, MCR.SC.03, MCR.SC.11
n.	Soln-13	Technology Development Plan	MCR.EC.05.H, MCR.SC.03, MCR.SC.11
o.	Soln-14	Software Management Plan	MCR.EC.05.L, MCR.SC.12
p.	Soln-16	Engineering Planning	MCR.EC.05.J, MCR.SC.10
q.	Ent-1	Project Scope Document	MCR.SC.05,
r.	Ent-2	Concept Study Report	MCR.EC.03.B, MCR.EC.05.B, MCR.EC.05.D, MCR.SC.02, MCR.SC.05
s.	Ent-4	Decision Memorandum	MCR.SC.07

E.3 SYSTEM REQUIREMENTS REVIEW (SRR) CRITERIA

Table 5 provides SRR criteria.

Table 5—SRR Criteria

Viewpoints to SRR Entrance and Success	SRR.EC.00 SRR Entrance Criteria	SRR.EC.01 Milestones	SRR.EC.02 Agenda	SRR.EC.03 Reviews	SRR.EC.04 Programmatic Products	SRR.EC.05 Primary Products	SRR.EC.05.A System Requirements	SRR.EC.05.B SEMP	SRR.EC.06 Technical Products	SRR.EC.06.A Mission Concept	SRR.EC.06.B CONOPS	SRR.EC.06.C Parent Requirements	SRR.EC.06.D Risk Management Plan	SRR.EC.06.E Risk Assessment and Mitigation	SRR.EC.06.F Configuration Management Plan	SRR.EC.06.G Document Tree	SRR.EC.06.H V and V Approach	SRR.EC.06.I Safety Analysis	SRR.EC.06.J Key Performance Parameters	SRR.EC.06.K Specialty Disciplines	SRR.EC.06.L Cost and Schedule Estimates	SRR.EC.06.M Basis of Estimate	SRR.EC.06.N Technology Development Plan	SRR.EC.06.O TRL Assessment	SRR.EC.06.P Support Strategy	SRR.EC.06.Q Human Rating Certification	SRR.EC.06.R Human Systems Integration Plan	SRR.EC.06.S SMA Plan	SRR.EC.06.T Mission Operations	SRR.EC.06.U Engineering Development Assessment	SRR.EC.06.V Software Products	SRR.SC.00 SRR Success Criteria	SRR.SC.01 System Requirements	SRR.SC.02 Requirement Maturity	SRR.SC.03 Requirement Allocation	SRR.SC.04 Interfaces	SRR.SC.05 V and V Approach	SRR.SC.06 Risk Assessment and Mitigation	SRR.SC.07 Compliance with Guidance	SRR.SC.08 TBD/TBR Disposition	SRR.SC.09 Software
Science Viewpoint							X			X																															
Requirements Viewpoint							X					X							X														X	X	X						
Technical Solution Viewpoint								X			X					X		X		X			X	X						X	X					X					X
Product Realization Viewpoint																	X																				X				
Project Implementation Viewpoint					X								X	X	X						X	X			X			X										X	X	X	
Mission Operations Viewpoint																													X												
Enterprise/Institution Viewpoint																																	X						X		

SMAF Products:

			Review Criteria:
a.	Sci-1	Science Concept	SRR.EC.05.A, MCR.EC.06.A
b.	Reqt-1	System Requirements Document	SRR.EC.05.A, SRR.EC.06.C, SRR.EC.06.J, SRR.SC.01, SRR.SC.02, SRR.SC.03
c.	Reqt-2	Verification and Validation Plan	SRR.EC.06.H, SRR.SC.06
d.	Soln-1	Systems Engineering Management Plan	SRR.EC.05.B
e.	Soln-5	Interface Control Documents*	SRR.SC.04
f.	Soln-12	Technical Risk Analysis	SRR.EC.06.I, SRR.EC.06.O
g.	Soln-16	Engineering Planning	SRR.EC.06.U
h.	Soln-13	Technology Development Plan	SRR.EC.06.N
i.	Soln-14	Software Development Plan	SRR.EC.06.V, SRR.SC.09

j.	Soln-10	Concept of Operations	SRR.EC.06B, SRR.EC.06.T
k.	Soln-6	Document Tree	SRR.EC.06.G
l.	Soln-8	Supporting Analysis	SRR.EC.06.K
m.	Proj-2	Program Plan	SRR.EC.04
n.	Proj-3	Technical, Schedule, and Cost Control Plan	SRR.EC.06.L, SRR.EC.06.M
o.	Proj-4	Mission Assurance Implementation Plan	SRR.EC.06.S
p.	Proj-5	Risk Management Plan	SRR.EC.06.E, SRR.SC.07
q.	Proj-8	Review Plan	SRR.SC.08
r.	Proj-11	Integrated Logistics Support Strategy	SRR.EC.06.P
s.	Proj-12	Configuration Management Plan	SRR.EC.06.F
t.	Proj-22	Compliance Matrix	SRR.SC.07
u.	Ops-4	Mission Operations Plan	SRR.EC.06.T
v.	Ent-1	Project Scope Document	SRR.SC.01, SRR.SC.07
w.	Ent-2	System Concept Report	SRR.EC.06.A

* In early stages of a project, including at SRR, interface documentation may consist of IRDs.

E.4 MISSION DEFINITION REVIEW (MDR)/SYSTEM DEFINITION REVIEW (SDR) CRITERIA

Table 6 provides MDR/SDR criteria.

Table 6—MDR/SDR Criteria

Viewpoints to MDR/SDR Entrance and Success	MDR.EC.00 PDR Entrance Criteria	MDR.EC.01 Milestones	MDR.EC.02 Agenda	MDR.EC.03 Reviews	MDR.EC.04 Programmatic Products	MDR.EC.05 Primary Products	MDR.EC.05.A Defined Architecture	MDR.EC.05.B Requirements Allocation	MDR.EC.05.C Key Driving Requirements	MDR.EC.05.D Mass and Power Margin Trends	MDR.EC.06 Technical Products	MDR.EC.06.A Supporting Analysis & Function Allocation	MDR.EC.06.B Updated SEMP	MDR.EC.06.C Updated Risk Management Plan	MDR.EC.06.D Updated Risk Assessment and Mitigation	MDR.EC.06.E Updated Technology Development Plan	MDR.EC.06.F Updated Technology Readiness	MDR.EC.06.G Updated Cost and Schedule	MDR.EC.06.H Preliminary ILSP	MDR.EC.06.I Updated Human Rating Certification	MDR.EC.06.J Preliminary Interface Definitions	MDR.EC.06.K Initial Resource Utilization/Margins	MDR.EC.06.L Updated S&MA Plan	MDR.EC.06.M Updated HSIP	MDR.EC.06.N Preliminary CONOPS	MDR.EC.06.O Preliminary System Safety Analysis	MDR.EC.06.P Software Criteria and Products	MDR.SC.00 Success Criteria	MDR.SC.01 Architecture Credibility	MDR.SC.02 Mission Feasibility Within Resources	MDR.SC.03 Mission/System Concept Maturity	MDR.SC.04 Requirements Allocation	MDR.SC.05 Architecture Tradeoffs	MDR.SC.06 Risk Identification and Management	MDR.SC.07 Technology Development Planning	MDR.SC.08 CONOPS Consistency with Design and Requirements	MDR.SC.09 Compliance with Directives	MDR.SC.10 TBRs/TBDs Identified with Plans	MDR.SC.11 Software
Science Viewpoint																															X								
Requirements Viewpoint								X	X																							X							
Technical Solution Viewpoint							X	X		X		X	X	X	X	X	X				X	X			X	X	X		X		X		X	X	X	X			X
Product Realization Viewpoint																																							
Project Implementation Viewpoint				X	X									X				X	X				X							X				X		X	X	X	
Operations Viewpoint																																							
Enterprise Viewpoint																															X						X		

SMAF Products:

a. Sci-1 Science Concept
b. Reqt-1 System Requirements Document
c. Soln-1 Systems Engineering Management Plan
d. Soln-3 Architecture Model
e. Soln-4 Design Specifications

Review Criteria:

MDR.SC.03
MDR.EC.05.B, MDR.EC.05.C, MDR.SC.04
MDR.EC.06.B
MDR.EC.05.B, MDR.EC.05.A, MDR SC.01
MDR.SC.03

f.	Soln-5	Interface Control Documents	MDR.EC.06.J
g.	Soln-6	Document Tree	MDR.SC.03
h.	Soln-7	Preliminary Master Equipment List	MDR.EC.05.D, MDR.EC.06.K
i.	Soln-8	Supporting Analysis	MDR.EC.06.A
j.	Soln-10	Concept of Operations	MDR.EC.06.N, MDR.SC.08
k.	Soln-11	Technology Readiness Assessment	MDR.EC.06.F
l.	Soln-12	Technical Risk Analysis	MDR.EC.06.C, MDR.EC.06.D, MDR.EC.06.O, MDR.SC.06
m.	Soln-13	Technology Development Plan	MDR.EC.06.E, MDR.SC.07
n.	Soln-14	Software Management Plan	MDR.EC.06.P, MDR.SC.11
o.	Proj-2	Project Plan	MDR.EC.04, MDR.SC.09, MDR.SC.10
p.	Proj-3	Technical, Schedule, and Cost Control Plan	MDR.EC.06.G, MDR.SC.02
q.	Proj-5	Risk Management Plan	MDR.EC.06.C, MDR.SC.06
r.	Proj-8	Review Plan	MDR.EC.03
s.	Proj-11	Integrated Logistics Support Plan	MDR.EC.06.H
t.	Ent-2	Concept Study Report	MDR.SC.03
u.	Ent-3	Decision Memorandum	MDR.SC.09

E.5 PRELIMINARY DESIGN REVIEW (PDR) CRITERIA

Table 7 provides PDR criteria.

Table 7—PDR Criteria

Viewpoints to PDR Entrance and Success Criteria	PDR.EC.00 PDR Entrance Criteria	PDR.EC.01 Milestones	PDR.EC.02 Agenda	PDR.EC.03 Reviews	PDR.EC.04 Programmatic Products	PDR.EC.05 Primary Products	PDR.EC.05.A Preliminary Design	PDR.EC.05.B Mass and Power Margin Trends	PDR.EC.06 Technical Products	PDR.EC.06.A Specifications	PDR.EC.06.B TRL Assessment	PDR.EC.06.C Technology Development Plan	PDR.EC.06.D Risk Assessment and Mitigation	PDR.EC.06.E Cost and Schedule	PDR.EC.06.F Support Strategy	PDR.EC.06.G Technical Planning	PDR.EC.06.H Standards	PDR.EC.06.I Safety Analysis	PDR.EC.06.J Document Tree	PDR.EC.06.K Interfaces	PDR.EC.06.L V and V Plan	PDR.EC.06.M Regulatory Plans	PDR.EC.06.N Disposal Plan	PDR.EC.06.O Margins	PDR.EC.06.P Mission Operations	PDR.EC.06.Q Human Systems Integration Plan	PDR.EC.06.R Human Rating Certification	PDR.EC.06.S Software Products	PDR.SC.00 PDR Success Criteria	PDR.SC.01 System Requirements	PDR.SC.02 Requirement Allocation	PDR.SC.03 Cost and Schedule	PDR.SC.04 Preliminary Design	PDR.SC.05 Interfaces	PDR.SC.06 Technology Development Plan	PDR.SC.07 Risk Assessment and Mitigation	PDR.SC.08 SMA Products	PDR.SC.09 Margins	PDR.SC.10 Mission Operations	PDR.SC.11 Technical Trade Studies	PDR.SC.12 Compliance with Guidance	PDR.SC.13 TBD/TBR Disposition	PDR.SC.14 Specifications	PDR.SC.15 Modeling	PDR.SC.16 Heritage Designs	PDR.SC.17 Manufacturability	PDR.SC.18 Software
Science Viewpoint																																															
Requirements Viewpoint																					X									X	X																
Technical Solution Viewpoint							X			X	X	X	X			X	X	X	X									X					X		X	X	X			X				X	X		X
Product Realization Viewpoint							X	X		X										X				X									X	X				X					X	X		X	
Project Implementation Viewpoint				X	X								X	X		X		X				X										X				X	X				X	X					
Operations Viewpoint															X								X		X														X								
Enterprise Viewpoint																	X																								X						

SMAF Products:

			Review Criteria:
a.	Reqt-1	System Requirements Document	PDR.SC.01, PDR.SC.02
b.	Reqt-2	Verification and Validation Plan	PDR.EC.06.L
c.	Soln-3	Architecture Model	PDR.EC.05.A, PDR.SC.04, PDR.SC.15
d.	Soln-4	Design Specifications	PDR.EC.05.A, PDR.EC.06.A, PDR.SC.04
e.	Soln-6	Document Tree	PDR.EC.06.J
f.	Soln-8	Supporting Analysis	PDR.SC.11, PDR.SC.15, PDR.SC.16
g.	Soln-11	Technology Readiness Assessment	PDR.EC.06.B
h.	Soln-12	Technical Risk Assessment	PDR.EC.06.D, PDR.EC.06.I, PDR.SC.07
i.	Soln-13	Technology Development Plan	PDR.EC.06.C, PDR.SC.06
j.	Soln-14	Software Management Plan	PDR.EC.06.S, PDR SC.18
k.	Soln-16	Engineering Plan(s)	PDR.EC.06.G
l.	Real-1	System and Product Specifications	PDR.EC.05.A, PDR.EC.06.A, PDR.SC.04
m.	Real-2	Final Master Equipment List	PDR.EC.05.B, PDR.SC.09

n.	Real-3	Standards Profile	PDR.EC.06.H
o.	Real-4	Integration Plan	PDR.EC.06.G, PDR.SC.17
p.	Real-5	Final Interface Control Documents	PDR.EC.06.K, PDR.SC.05
q.	Proj-2	Project Plan	PDR.EC.04, PDR.EC.06.G, PDR.SC.12, PDR.SC.13
r.	Proj-3	Technical, Schedule, and Cost Control Plan	PDR.EC.06.E, PDR.SC.03
s.	Proj-4	Mission Assurance Implementation Plan	PDR.EC.06.I, PDR.SC.08
t.	Proj-5	Risk Management Plan	PDR.EC.06.D, PDR.SC.07
u.	Proj-8	Review Plan	PDR.EC.03
v.	Proj-9	Project Review Data Package	All
w.	Proj-10	Environmental Management Plan	PDR.EC.06.M
x.	Proj-13	Security Plan	PDR.EC.06.M
y.	Proj-14	Project Protection Plan	PDR.EC.06.M
z.	Proj-15	Technology Transfer Control Plan	PDR.EC.06.M
aa.	Proj-17	Planetary Protection Plan	PDR.EC.06.M
bb.	Proj-20	Unallocated Future Expenses Status	PDR.EC.06.E, PDR.SC.03
cc.	Proj-22	Compliance Matrix	PDR.SC.12
dd.	Ent-1	Project Scope Document	PDR.EC.06.H
ee.	Ent-3	Decision Memorandum	PDR.SC.12

E.6 CRITICAL DESIGN REVIEW (CDR) CRITERIA

Table 8 provides CDR criteria.

Table 8—CDR Criteria

Viewpoints to CDR Entrance and Success Criteria	CDR.EC.00 CDR Entrance Criteria	CDR.EC.01 Milestones	CDR.EC.02 Agenda	CDR.EC.03 Reviews	CDR.EC.04 Programmatic Products	CDR.EC.05 Primary Products	CDR.EC.05.A Baselined Detailed Design	CDR.EC.05.B Mass and Power Margin Trends	CDR.EC.06 Technical Products	CDR.EC.06.A Build-To Specifications	PDR.EC.06.B Fabrication, Asssembly, Integration& Test Plans/Procedures	CDR.EC.06.C Technical Data Package	CDR.EC.06.D Operational Limits & Constraints	CDR.EC.06.E Updated Resource Utilization/Margins	CDR.EC.06.F Acceptance Plans	CDR.EC.06.G Command and Telemetry List	CDR.EC.06.H Updated Verification Plan	CDR.EC.06.I Updated Validation Plan	CDR.EC.06.J Preliminary Launch Site Operations Plan	CDR.EC.06.K Preliminary Checkout/Activation Plan	CDR.EC.06.L Preliminary Disposal Plan	CDR.EC.06.M Updated Technology Readiness Assessment	CDR.EC.06.N Updated Technology Development Plan	CDR.EC.06.O Updated Risk Assessment and Mitigation	CDR.EC.06.P Updated Human Systems Integration Plan	CDR.EC.06.Q Updated Human Rating Certification Package
Science Viewpoint																										
Requirements Viewpoint																										
Technical Solution Viewpoint																						X	X	X		
Product Realization Viewpoint							X	X		X	X	X	X	X	X	X	X	X								
Project Implementation Viewpoint				X	X												X	X						X		
Operations Viewpoint													X						X	X	X					
Enterprise Viewpoint																										

Viewpoints to CDR Entrance and Success Criteria	CDR.EC.06.R Updated Reliability Analysis	CDR.EC.06.S Updated Life-Cycle Costs and IMS	CDR.EC.06.T Updated Integrated Logistics Support Plan	CDR.EC.06.U Subsystem Operational Safety Analyses	CDR.EC.06.V System and Subsystem Certification Plans	CDR.EC.06.W System Safety Analysis	CDR.EC/.06.X Software	CDR.SC.00 PDR Success Criteria	CDR.SC.01 Design vs. Requirements with Margin	CDR.SC.02 ICD Maturity	CDR.SC.03 Cost and Schedule	CDR.SC.04 Mature System Baseline	CDR.SC.05 V&V Requirements and Plans	PDR.SC.06 Testing Approach and IT&E Planning	CDR.SC.07 Technical and Programmatic Margins	CDR.SC.08 Risk Management	CDR.SC.09 Safety and Mission Assurance	CDR.SC.10 Compliance with Requirements, Standards, Processes & Procedures	CDR.SC.11 TBR/TBD Disposition	CDR.SC.12 Test Units and Simulations	CDR.SC.13 Materials Properties Tests	CDR.SC.14 EEE Parts	CDR.SC.15 Mature CONOPS	CDR.SC.16 Manufacturability	CDR.SC.17 Software
Science Viewpoint																									
Requirements Viewpoint																									
Technical Solution Viewpoint	X						X																X		X
Product Realization Viewpoint				X	X	X			X	X		X			X		X	X		X	X	X		X	
Project Implementation Viewpoint		X	X	X	X	X					X		X	X		X	X	X	X						
Operations Viewpoint																									
Enterprise Viewpoint																									

SMAF Products:

			Review Criteria
a.	Reqt-1	System Requirements Document	CDR.SC.01, CDR.SC.02
b.	Reqt-2	Verification and Validation Plan	CDR.EC.06.L
c.	Soln-3	Architecture Model	CDR.EC.05.A, CDR.SC.04, CDR.SC.15
d.	Soln-4	Design Specifications	CDR.EC.05.A, CDR.EC.06.A, CDR.SC.04
e.	Soln-6	Document Tree	CDR.EC.06.J
f.	Soln-8	Supporting Analysis	CDR.SC.11, CDR.SC.15, CDR.SC.16
g.	Soln-11	Technology Readiness Assessment	CDR.EC.06.B
h.	Soln-12	Technical Risk Assessment	CDR.EC.06.D, CDR.EC.06.I, CDR.SC.07

i.	Soln-13	Technology Development Plan	CDR.EC.06.C, CDR.SC.06
j.	Soln-14	Software Management Plan	CDR.EC.06.S, CDR SC.18
k.	Soln-16	Engineering Plan(s)	CDR.EC.06.G
l.	Real-1	System and Product Specifications	CDR.EC.05.A, CDR.EC.06.A, CDR.SC.04
m.	Real-2	Final Master Equipment List	CDR.EC.05.B, CDR.SC.09
n.	Real-3	Standards Profile	CDR.EC.06.H
o.	Real-4	Integration Plan	CDR.EC.06.G, CDR.SC.17
p.	Real-5	Final Interface Control Documents	CDR.EC.06.K, CDR.SC.05
q.	Proj-2	Project Plan	CDR.EC.04, CDR.EC.06.G, CDR.SC.12, CDR.SC.13
r.	Proj-3	Technical, Schedule, and Cost Control Plan	CDR.EC.06.E, CDR.SC.03
s.	Proj-4	Mission Assurance Implementation Plan	CDR.EC.06.I, CDR.SC.08
t.	Proj-5	Risk Management Plan	CDR.EC.06.D, CDR.SC.07
u.	Proj-8	Review Plan	CDR.EC.03
v.	Proj-9	Project Review Data Package	All
w.	Proj-10	Environmental Management Plan	CDR.EC.06.M
x.	Proj-13	Security Plan	CDR.EC.06.M
y.	Proj-14	Project Protection Plan	CDR.EC.06.M
z.	Proj-15	Technology Transfer Control Plan	CDR.EC.06.M
aa.	Proj-17	Planetary Protection Plan	CDR.EC.06.M
bb.	Proj-20	Unallocated Future Expenses Status	CDR.EC.06.E, CDR.SC.03
cc.	Proj-22	Compliance Matrix	CDR.SC.12
dd.	Ent-1	Project Scope Document	CDR.EC.06.H
ee.	Ent-3	Decision Memorandum	CDR.SC.12

APPENDIX F

REFERENCES

F.1 PURPOSE

This Appendix provides guidance relative to this NASA Technical Handbook. The latest issuances of referenced documents should be utilized unless specific versions are designated.

F.2 REFERENCE DOCUMENTS

Reference documents may be accessed at https://standards.nasa.gov, https://nodis3.gsfc.nasa.gov/, or obtained directly from the Standards Developing Body or other document distributors. When not available from these sources, information for obtaining the document is provided.

Federal

NASA FAR 1852, 204-76	Security Requirements for Unclassified Information Technology Resources
FIPS 199	Standards for Security Categorization of Federal Information and Information Systems

NASA

Borky, J. M. and Bradley, T. H., *Effective Model-Based Systems Engineering*, Springer, 2019

Final Report of the NASA Technology Readiness Assessment (TRA) Study Team, March 2016

Mechanisms of Energetic Mass Ejection – Explorer, Concept Study Report, Submitted in response to the Heliophysics SMEX, AO #NNH16ZDA005O, July 30, 2018

Executive Order 12114	Environmental Effects Abroad of Major Federal Actions
NPD 1000.3	The NASA Organization
NPD 1000.5	Policy for NASA Acquisition
NPD 1600.2	NASA Security Policy
NPD 2200.1	Management of NASA Scientific and Technical Information
NPD 7120.4	NASA Engineering and Program/Project Management Policy
NPD 7120.6	Knowledge Policy for Programs and Projects
NPD 7500.1	Program and Project Life-Cycle Logistics Support Policy
NPD 8020.7	Biological Contamination Control for Outbound and Inbound Planetary Spacecraft
NPD 8720.1	NASA Reliability And Maintainability (R&M) Program Policy
NPD 8730.5	NASA Quality Assurance Program Policy

NPR 1040.1	NASA Continuity of Operations (COOP) Planning Procedural Requirements
NPR 1441.1	NASA Records Management Program Requirements
NPR 1600.1	NASA Security Program Procedural Requirements
NPR 2190.1	NASA Export Control Program
NPR 2200.2	Requirements for Documentation, Approval and Dissemination of Scientific and Technical Information
NPR 2800.1	Managing Information Technology
NPR 7120.5	NASA Space Flight Program and Project Management Requirements
NPR 7120.7	NASA Information Technology Program and Project Management Requirements
NPR 7120.8	NASA Research and Technology Program and Project Management Requirements
NPR 7123.1	NASA Systems Engineering Processes and Requirements
NPR 7150.2	NASA Software Engineering Requirements
NPR 7500.2	NASA Technology Transfer Requirements
NPR 8000.4	Agency Risk Management Procedural Requirements
NPR 8020.12	Planetary Protection Provisions for Robotic Extraterrestrial Missions
NPR 8580.1	Implementing the National Environmental Policy Act and Executive Order 12114
NPR 8705.6	Safety and Mission Assurance (SMA) Audits, Reviews, and Assessments
NPR 8715.3	NASA General Safety Program Requirements
NPR 8715.5	Range Flight Safety Program
NPR 8715.7	Payload Safety Program
NPR 8735.1	Exchange of Problem Data Using NASA Advisories and the Government-Industry Data Exchange Program (GIDEP)
NPR 8735.2	Management of Government Quality Assurance Functions for NASA Contracts
NASA/SP-2010-576	NASA Risk-Informed Decision Making Handbook
NASA/SP-2010-3404	Work Breakdown Structure (WBS) Handbook
NASA/SP-2011-3422	NASA Risk Management Handbook
NASA/SP-2014-3705	NASA Space Flight Program and Project Management Handbook
NASA/SP-6105, Rev 2	NASA Systems Engineering Handbook
NASA-STD-1006	Space System Protection Standard
NASA-STD-7009	Standard for Models and Simulations
NASA-STD-8709.20	Management of Safety and Mission Assurance Technical Authority (SMA TA) Requirements
NASA-STD-8719.24	Annex A to NASA-STD 8719.24, NASA Expendable Launch Vehicle Payload Safety Requirements: Requirements Table
NASA-STD-8739.8	Software Assurance and Software Safety Standard
NASA-STD-8739.13 (Cancelled)	Software Safety Standard

MSFC Form 4657	Change Request for a NASA Engineering Standard

International Organization for Standardization (ISO)

ISO/IEC 12207	Systems and software engineering – Software life cycle processes
ISO/IEC/IEEE 42010	Systems and software engineering – Architecture description
ISO/IEC/IEEE 15288:2015	Systems and software engineering – System life cycle processes

SAE International

SAE EIA-649-2	Configuration Management Requirements for NASA Enterprises
SAE EIA-748	Earned Value Management Systems

APPENDIX G

ACRONYMS, ABBREVIATIONS, SYMBOLS, AND DEFINITIONS

G.1 Purpose

This Appendix provides a listing of acronyms, abbreviations, symbols, and definitions related to this NASA Technical Handbook.

G.2 Acronyms, Abbreviations, and Symbols

%	Percent
AIT	Assembly, Integration, and Test
AO	Announcement of Opportunity
AO&S	Architecture Overview and Summary
AoA	Analysis of Alternatives
C&T	Command and Telemetry
CAD	Computer-Aided Design
CAM	Computer-Aided Manufacturing
CARA	Conjunction Assessment Risk Analysis
CCSDS	Consultative Committee for Space Data Systems
CDR	Critical Design Review
CMP	Configuration Management Plan
Comms	Communications
CONOPS	Concept of Operations
COOP	Continuity of Operations
CSO	Chief Safety and Mission Assurance Officer
CSR	Concept Study Report
CTE	Critical Technology Element
DRA	Design Reference Architecture
EEE	Electrical, Electronic and Electromechanical
Ent	Enterprise
ERD	Entity-Relationship Diagram
EVM	Earned Value Management
FAR	Federal Acquisition Regulations
FFRDC	Federally Funded Research and Development Center
FIPS	Federal Information Processing Standards
FMEA	Failure Modes and Effects Analysis
FMECA	Failure Modes and Effects Criticality Analysis
FTA	Fault Tree Analysis
HDBK	Handbook
HEOMD	Human Exploration and Operations Mission Directorate

HSIP	Human Systems Integration Plan
HW	Hardware
ICD	Interface Control Document
IEC	International Electrotechnical Commission
IEEE	Institute of Electrical and Electronics Engineers
ILSP	Integrated Logistics Support Plan
IMP	Integrated Master Plan
IMS	Integrated Master Schedule
IRD	Interface Requirements Document
ISE	Instrument Systems Engineer
ISO	International Organization for Standardization
IT&E	Integration, Test and Evaluation
IUT	Under Test
KDP	Key Decision Point
KPP	Key Performance Parameter
LV	Launch Vehicle, Low Voltage
MAIP	Mission Assurance Implementation Plan
MAR	Mission Assurance Requirements
MBE	Model-Based Engineering
MBSE	Model-Based Systems Engineering
MCR	Mission Concept Review
MDR	Mission Definition Review
MEL	Master Equipment List
mgmt	Management
MOC	Mission Operations Center
MoE	Measure of Effectiveness
MoP	Measure of Performance
MSE	Mission Systems Engineer
NASA	National Aeronautics and Space Administration
NEN	NASA Engineering Network
NPD	NASA Policy Directive
NPR	NASA Procedural Requirements
OPlan	Operations Plan
Ops	Operations
Ops Con	Operational Concept
OSMA	Office of Safety and Mission Assurance
OSTP	Office of Science and Technology Policy
PBS	Product Breakdown Structure
PDL	Product Development Lead
PDR	Preliminary Design Review
PI	Principal Investigator
PLAR	Pre-Launch Assessment Review
PLRA	Program-Level Requirements Agreement
PM	Program Management
PRA	Program/Project Risk Analysis

Proj	Project
PSD	Project Scope Document
Real	Realization
RMP	Risk Management Plan
Rqmts	Requirements
RVM	Requirements Verification Matrix
S&MA	Safety and Mission Assurance
SAMP	Safety and Mission Assurance Plan
Sci	Science
SDMP	Science Data Management Plan
SDR	System Definition Review
SE	Systems Engineering
SEMP	Systems Engineering Management Plan
SMA	Safety and Mission Assurance
SMAD	Space Mission Analysis and Design
SMAF	Space Mission Architecture Framework
SMAP	Safety and Mission Assurance Plan
SMD	Science Mission Directorate
SMEX	Small Explorer
SMP	Software Management Plan
SOC	Science Operations Center
SoI	System of Interest
Soln	Solution
SP	Special Publication
Spec	Specification
SRD	System Requirements Document
SRR	System Requirements Review
SSTT	Single Source of Technical Truth
STD	Standard
STM	Science Traceability Matrix
STMD	Space Technology Mission Directorate
SW	Software
SysML®	Systems Modeling Language®
T&E	Test and Evaluation
TBD	To Be Determined
TBR	To Be Reviewed
TDP	Technology Development Plan
TEMP	Test and Evaluation Master Plan
TPM	Technical Performance Measure
TRA	Technology Readiness Assessment
TRL	Technical Readiness Level
V&V	Verification and Validation
VCRM	Verification Cross Reference Matrix
WBS	Work Breakdown Structure
WP	Work Product

G.3 Definitions

Architecture: Defines the fundamental concepts or properties of a complex entity in its environment embodied in its elements and relationships and in the principles of its design and evolution.

Architecture Description: The collection of materials used to capture and communicate a specific architecture.

Architecture Framework: Establishes a common practice for creating, interpreting, analyzing and using architecture descriptions within a particular domain of application or stakeholder community. (Source: ISO/IEC/IEEE 42010)

Architecture Model: The collection of data from which architecture viewpoints and products such as visualizations and reports are produced.

Architecture Process: The process of conceiving, defining, expressing, documenting, communicating, certifying proper implementation of, maintaining, and improving an architecture throughout a system's life cycle. NOTE: Architecture development takes place in the context of an organization ("person or a group of people and facilities with an arrangement of responsibilities, authorities and relationships") or a project (a project is to be considered an "endeavor with defined start and finish criteria undertaken to create a product or service in accordance with specified resources and requirements") (Sources: ISO/IEC 12207, ISO/IEC 15288).

Architecture Product: A product expressing information about the architecture from the perspective of one or more specific stakeholder concerns; an element of an architecture description.

Architecture Viewpoint (Viewpoint): A collection of architecture products relevant to the concerns of one or more specific stakeholders.

Authoritative Data: Data that have been designated as valid for specific official programs/projects. The designated data is controlled by processes. (Source: NPD 7120.4, NASA Engineering and Program/Project Management Policy)

Concern: An interest in a system that is relevant to one or more of its stakeholders. Concerns commonly fall into areas such as project scope, technical issues, safety and mission assurance (SMA), project management, and resources. Individual stakeholders may have additional concerns.

Correspondence: Refers to alignment with ISO/ISE/IEEE 42010 or Reference Architecture for Space Data Systems.

Digital Engineering: An integrated digital approach that uses authoritative sources of system data and models as a continuum across disciplines to support lifecycle activities from concept through disposal; it emphasizes continuity of the use of models across the lifecycle to enhance engineering processes in dealing with complexity, uncertainty, and rapid change in deploying and operating systems.

Environment: The context determining the setting and circumstances of all influences upon a system. NOTE: The environment of a system includes developmental, technological, business, operational, organizational, political, economic, legal, regulatory, ecological, and social influences. In terms of its programmatic environment, an individual instance of the SMAF will be focused on a Project of Interest (PoI) and the System of Interest (SoI) with which the project is concerned, as well as the Enterprise of Interest (EoI), which typically includes a Mission Directorate of NASA Headquarters, a Mission Directorate Program that sponsors the project, and one or more NASA Centers or other organizations that implement the project.

Mission: A major activity required to accomplish an Agency goal or to effectively pursue a scientific, technological, or engineering activity directly related to an Agency goal; a mission is a scientific or technical construct that is defined and implemented to deliver the outcomes needed to satisfy a set of scientific or technical objectives.

Mission Architecture Framework: An architecture framework category that describes the essential elements of a mission, including: (1) Science Goals and Objectives, (2) System Architecture, (3) Resources Model, and (4) Project/Organizational Model. The SMAF is a specific framework tailored to NASA missions. A Mission Architecture is a project-specific instance of a framework.

Mission System: A system that is designed and developed to achieve the goals and objectives of a mission.

Model-Based: Generic term for an approach or methodology that is predicated on the use of models to describe, document, analyze, and visualize a system or other complex entity; Model-Based Engineering is the central tenet of Digital Engineering.

Product (Work Product): Collection of one or more documents, models, diagrams, tables, and other artifacts produced in the course of a project that addresses one or more stakeholder concerns and provides content of a viewpoint. In an architecture description, most products are expressed as Views.

Project: A programmatic entity that represents a specific investment of resources with defined goals, objectives, requirements, and life-cycle cost, and that has a beginning and an end. A project implements the scientific or technological requirements of a mission and yields new or revised science outcomes, products, or services that address Agency strategic needs.

Reference Architecture (RA): An instance of an Architecture Framework that abstracts common elements of System Architectures in a specific category or domain of application. An

RA facilitates reuse of proven architecture elements and provides an advanced starting point for new System Architecture developments. An RA commonly includes design patterns that define generalized and reusable solutions to recurring design challenges.

Reference Model: A collection of guidelines, standards, and other common elements of architectures in a given domain of application that governs development of architectures in that domain.

Space Mission Architecture: An architecture that deals with the full dimensionality of the design and implementation trade space for a space mission, including science and exploration goals; requirements; system and operational concepts; functional and physical spacecraft design; orbit design; launch vehicles and services; environmental conditions; operational control; communications, telemetry, and networking; ground operations; and other aspects of emplacing and operating vehicles in space. A Space Mission Architecture establishes the foundation for Systems Engineering (SE) to create an effective Mission System solution to achieve mission goals and objectives.

Stakeholder: An individual, group or organization having a significant and recognized interest in a system or project; this NASA Technical Handbook distinguishes between External Stakeholders who are outside a project organization and Participants, or Internal Stakeholders, who are included in a project organization.

System: The combination of elements that function together to produce the capability to meet a need. The elements include all hardware, software, equipment, facilities, personnel, processes, and procedures needed for this purpose. A system satisfies the requirements of the associated mission and project.

System Architecture: Defines the structure, behavior, and internal and external relationships of a system as well as the principles and guidelines governing its design and evolution over time. A system architecture is commonly organized into operational, functional, and physical architectures.

Viewpoint (Viewpoint): A grouping of models, artifacts, and other architecture content that addresses the needs, concerns, and expectations of a particular stakeholder community. In general, a Viewpoint is made up of Products.