# Defining Essential Systems Engineering using Model-Based Systems Engineering

Stevens Institute of Technology
SYS 800 – Special Problems in Systems Engineering

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# Table of Contents

# List of Figures

# List of Tables

# 1 Abstract

This research presents a new approach to simplify the implementation of systems engineering using model-based systems engineering tools. The concept of systems engineering facets is introduced to provide a framework for identifying and grouping related systems engineering activities, deliverables and assessments throughout a project lifecycle. Collectively these are referred to as essentials within the research. The project management and systems engineering processes are analyzed to identify the essentials, and are then organized by facets. Next, using a model-based systems engineering tool this information is stored in a central location called a Systems Engineering Lifecycle Template. The purpose of the Systems Engineering Lifecycle Template is to tell the story of a project from start to finish by clearly capturing, connecting and communicating all of the essentials required to enable the realization of the system. The template is a living document within the MBSE tool that is updated regularly by the project team as essentials are completed and serves as the starting and ending point for all systems engineering related activities. The motivation for this research is the NanoMet academic case study. NanoMet is a 3U CubeSat platform developed jointly by the USAF Academy Department of Astronautics and an Industry team. It is used in classrooms around the world to teach space systems engineering and to provide a complete mission lifecycle experience. Every aspect of NanoMet is modeled using the MBSE tool Innoslate. Innoslate is based on the open-source Lifecycle Modeling Language (LML). NanoMet uses the NASA Procedural Requirements for its project management and systems engineering processes. This research was developed in response to a need to organize the NanoMet system model, teach MBSE methodologies and help systems engineers transition from document-centric systems engineering methodologies to model-based systems engineering methodologies. The research concludes by providing the framework and guidance to applying the new approach to the NanoMet system model in Innoslate. The goal of this research is to simplify systems engineering by developing the modeling tools and approaches necessary to effectively use model-based systems engineering, and to provide a project team with an effective method to communicate vital information about a project. A successful project is one that can effectively communicate and this research provides a method to achieve success.

# 2 Introduction

## 2.1 Purpose

The purpose of this research project is to develop a new approach to simplify systems engineering when using model-based systems engineering (MBSE). Applying MBSE methodology to a project can be a daunting task. A project team can become overwhelmed when transitioning from traditional systems engineering methodologies to MBSE methodologies and tools. To overcome this hurdle, this research introduces the concept of systems engineering facets to provide a framework for identifying and grouping related systems engineering activities, deliverables, and assessments throughout a project lifecycle. The facets provide a top-level view of a project that benefits the entire team and can be used throughout the project lifecycle. There are two main types of facets called Essentials and Assessments. Each facet type consists of several sub-facets, which are collections of related artifacts (essentials) the project team produces over the project lifecycle. The facets are combined with the project lifecycle into a new modeling tool called a Systems Engineering Lifecycle Template (SELT). The SELT is an entity within the overall system model that provides a comprehensive "road map" to all the essentials, organized according to the project lifecycle and facets in a single location. The SELT is the single location within the model to communicate the project lifecycle, identify essentials and assess the health of the project over its lifecycle. This research was motivated by the need to organize the system model for the Nanosatellite Applications for Meteorological Support (NanoMet) academic case study. NanoMet is an academic case study to teach space systems engineering, is based upon the NASA processes and lifecycles, and is modeled in the MBSE tool Innoslate. This research concludes by providing the framework and guidance to apply the new approach to the NanoMet system model.

## 2.2 Goals

This research has several goals in support of furthering the use of model-based systems engineering methodologies and tools to real-world applications including:

- Eliminating the hurdle to using MBSE
- Develop methods to incorporate project management and systems engineering processes using MBSE
- Provide a foundation for applying the new approach into projects

## 2.3 Development

The research project is divided into the following areas:

- Provide background information on model-based systems engineering and the NASA Procedural Requirements as they apply to this research
- Discuss the concept of systems engineering facets, including the definitions for all the facets and guidelines for identifying and categorizing the essentials
- Analyze the NASA Procedural Requirements to identify and categorize the essentials, and provide the results of the analysis
- Apply the concepts and analysis towards the development of the Systems Engineering Lifecycle Template
- Provide instructions on how to apply the new approach to NanoMet

# 3 Background

## 3.1 Model-Based Systems Engineering

"Model-based systems engineering is the formalized application of modeling to support system requirements, design, analysis, verification and validation activities beginning in the conceptual design phase and continuing throughout development and later life cycle phases" (INCOSE, 2007, p. 15). MBSE is a departure from existing document-centric systems engineering practices. Instead of using documents to store and communicate information about a system, models are used to represent individual aspects of a system. A model is a "physical, mathematical or otherwise logical representation of a system, entity, phenomenon, or processes" (Department of Defense, 2009, p. 10). The models provide an abstraction of a system complexity to a level that enables systems engineers to better understand the overall system (NDIA, 2011, p. 22). The models describe any aspect of the system including the specifications, design, analysis, test, manufacturing or maintenance of the system (NDIA, 2011, p. 11) and relationships to other models. Collections of these models define the overall system and are maintained in specialized MBSE tools. MBSE facilitates systems engineers to handle the demand of developing increasingly complex systems.

MBSE provides many benefits when compared to existing document-centric approaches. The key benefit of MBSE is it allows systems engineers to enable the adaption of the classic development "V" (NDIA, 2011, p. 19) as shown in Figure 1. The "waterfall" approach decomposes the system into its components down the left side of the "V" and then integrates and tests these components up the right side of the "V". Using this method it can be difficult to locate issues early because it relies on having physical components to test. On a complex system, it can be difficult to perform the crosscutting functions in the "V" such as verification and validation. MBSE overcomes the limitations of the "waterfall" approach by enabling incremental testing and automating the crosscutting processes. For example, during development models of components can be virtually tested against their requirements, interfaces and other defining aspects. The results can be fed back into the model to refine it. This process can be expanded to perform virtual integrations of subsystems, elements and systems. This helps to mitigate the risk associated with the system, discover unforeseen emergent behaviors and build confidence the finished system will operate as intended (NDIA, 2011, p. 19).

Some other benefits of MBSE include:

- Reduce the time to implement planned and foreseen changes in systems (NDIA, 2011, p. 14)
- Identifying, mitigating, and resolving risks, issues, and errors earlier to reduce development time and cost, and enhance reliability (NDIA, 2011, p. 15)
- Verifying requirements and interfaces earlier and continuously throughout the life cycle to enhance reliability and interoperability (NDIA, 2011, p. 15)
- Reducing the time and cost to design, develop, deliver, and support capabilities (NDIA, 2011, p. 15)

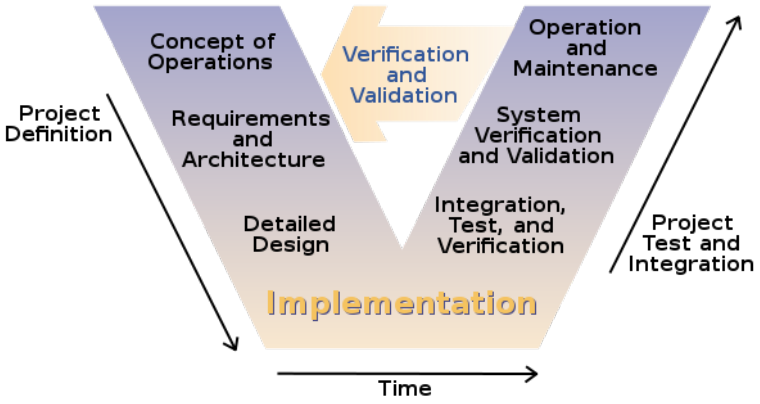



**Figure 1: Systems Engineering V-model**

This research develops an approach to facilitate the crosscutting technical management aspects of systems engineering when using MBSE methodologies. This is accomplished by:

- Incorporating the project lifecycle as defined by the project management processes
- Identifying the essential products a project must produce as defined by the systems engineering processes
- Developing a method for categorizing systems information
- Combining the above into a new modeling tool to organize and locate system information

### 3.1.1 MBSE Tools

MBSE tools are an essential element of MBSE. It would be difficult, if not impossible to use MBSE methodologies without a MBSE tool. A MBSE tool is an integrated software application to provide the means to develop a system model. The tool consists of three main parts: the modeling language, a repository, and an interface.

- The modeling language provides the ontology to define the models
- The repository is the database where the models reside
- The interface is a graphical user interface for the systems engineers to interface with the models and repository, perform analyses and simulations, and to create systems engineering artifacts

Together these parts allow systems engineers to develop complex systems by defining models that represent different aspects of the system and use the tool to analyze, simulate, verify and validate the system. Simply put, a MBSE tool is a database to store systems engineering information and has a specialized front end to interact with the database to perform systems engineering tasks. A MBSE tool is a powerful application that enables systems engineers to use MBSE methodologies and to develop increasingly complex systems.

### 3.1.2 Innoslate

This research utilizes the MBSE tool *Innoslate* [1] from SPEC Innovations (www.innoslate.com). *Innoslate* is a web-based application with "integrated solutions for the full systems development lifecycle, requirements management, requirements analysis…and real-time collaboration" (SPEC Innovations, 2015). *Innoslate* includes many powerful features including:

- Ability to model behavioral and physical aspects of a system
- Create diagrams including Action, Sequence, N2 and IDEF0 to visualize the system
- Perform event simulations and Monte Carlo analysis
- Automatically generate requirements based on behavioral and physical aspects of the system
- Manage requirements
- Provide traceability for entire lifecycle

Additional information about *Innoslate* is available in the Innoslate User's Guide.

### 3.1.3 Modeling Language

The modeling language for *Innoslate* is the Lifecycle Modeling Language (LML). The LML supports the full system lifecycle from concept through decommissioning, and integrates all disciplines including program management, systems and design engineering, verification and validation into a single framework (LML Steering Committee, 2013, p. 3). The ontology is based around the entity, relationship, and attribute (ERA) meta-model (LML Steering Committee, 2013, p. 5). The LML uses common language to define its modeling elements, which makes it easier to be understood by all stakeholders, not just systems engineers. The modeling constructs consist of boxes to represent entities and directed arrows to represent relationships as shown in Figure 2. The use of simple language and modeling constructs contributes to the simplicity of the language.

[1] Version 3.4

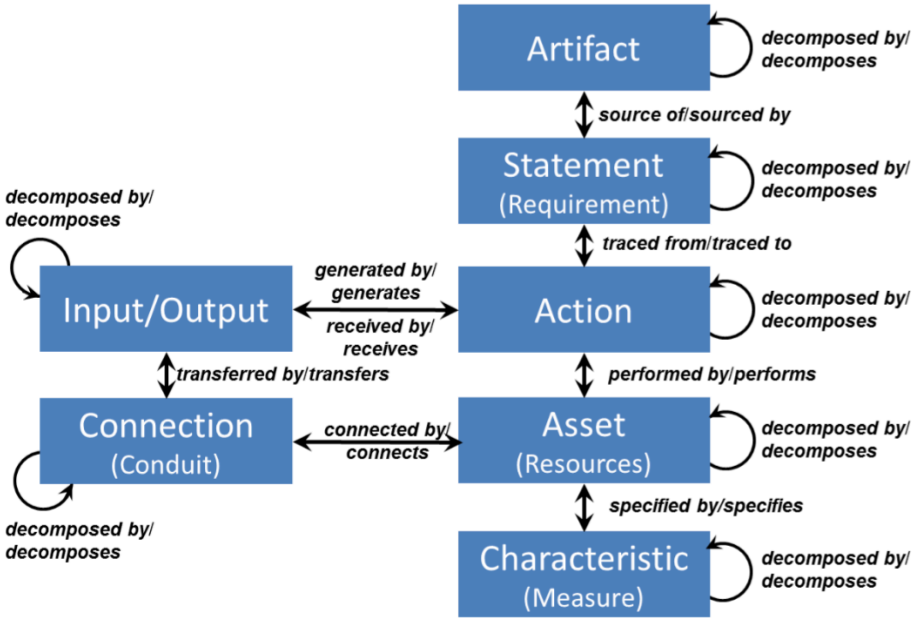



**Figure 2: LML Principle Entities and Relationships**

The three main parts of the LML ontology are summarized below:

- Entity
  - Something that can exist by itself and is uniquely identifiable (LML Steering Committee, 2013, p. 6)
  - Analogous to a noun
  - 12 basic types
    - Commonly used ones include actions, artifacts, assets, characteristics, inputs/outputs, statements
  - In Innoslate all entities have attributes and relationships
- Attribute
  - An inherent characteristic or quality of an entity (LML Steering Committee, 2013, p. 6)
  - Analogous to an adjective
  - In Innoslate, all entities have a name, number and description attribute
- Relationship
  - Connects entities to each other (LML Steering Committee, 2013, p. 6)
  - Analogous to a verb
  - All relations are defined in both directions
  - Innoslate automatically maintains the two-way relations between entities

A detailed description of LML is outside the scope of this research. Additional information about LML is available in the LML Specification.

## 3.2 NASA Procedural Requirements

The NanoMet project discussed in this research applied the NASA Procedural Requirements (NPR), therefore it is necessary to introduce the NPRs, identify the applicable NPRs, and provide a brief description of the NPRs used by this research. The NPRs are supporting documents to the NASA Strategic Management System. The NASA Strategic Management System is a collective set of processes that establish the framework to enable NASA to establish goals and objectives, develop and implement strategies, and accomplish successful programs and projects (NASA, NPD 1000.0B, 2014, p. 16). At the top level, four main policy documents establish the Strategic Management System and are shown in Figure 3. Below these policy documents are additional NPDs and NPRs that provide additional guidance on the policies, requirements, processes and procedures established by the NASA Strategic Management System (NASA, NPD 1000.0B, 2014, p. 16). The requirements flow down below the four main policy documents is shown in Figure 4. The NASA Engineering and Program/Project Management Policy Document, NPD 7120.4, establishes the policy and responsibilities for all management and engineering disciplines. From this NPD several NPRs implement this policy. This research utilizes the following two NPRs.

- NASA Space Flight Program and Project Management Requirements (NPR 7120.5)
- NASA Systems Engineering Processes and Requirements (NPR 7123.1)

These NPRs are important because they are required for all NASA projects. The NanoMet project referenced throughout this research is modeled after a NASA project, which follows these documents. Together, these NPRs establish the project lifecycle, identify lifecycle reviews, identify the artifacts the project team must product, and establish the criteria to evaluate the technical maturity of a project. NPR 7120.5 establishes the program/project management processes. NPR 7123.1 establishes the systems engineering processes. Each NPR is discussed in more detail in the following sections. For additional information about the NPDs and NPRs refer to the NASA Online Directives Information Systems Library at http://nodis3.gsfc.nasa.gov.

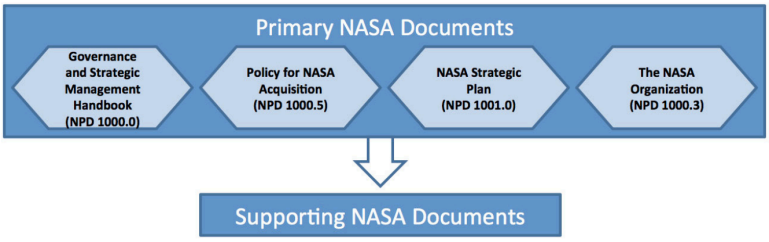



**Figure 3: NASA Strategic Management Requirements**

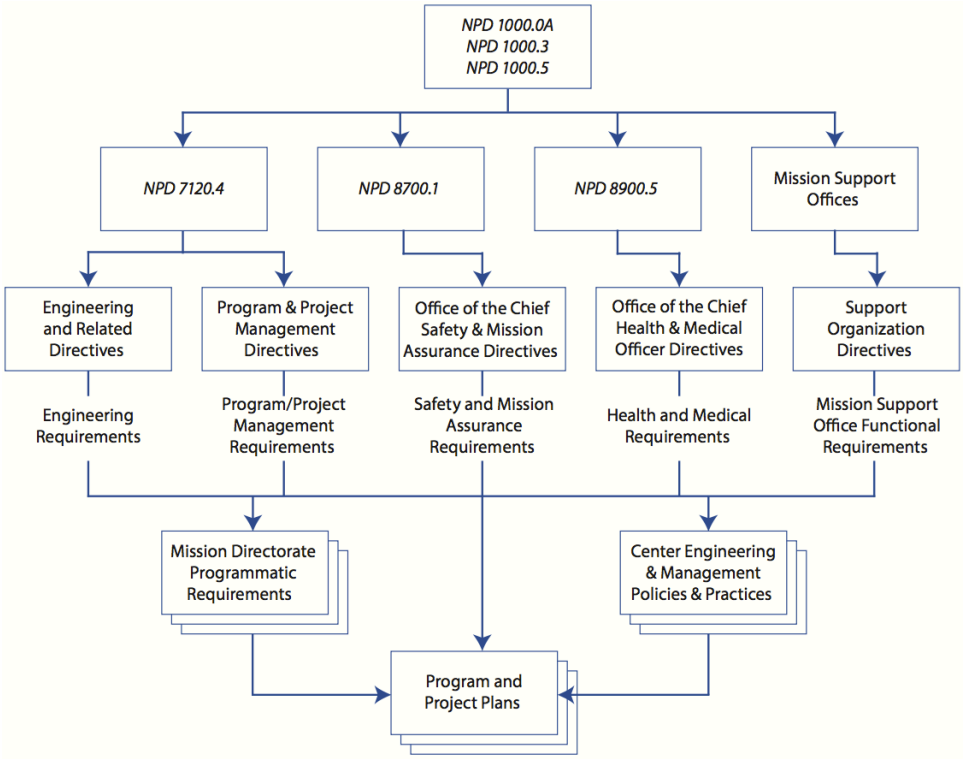
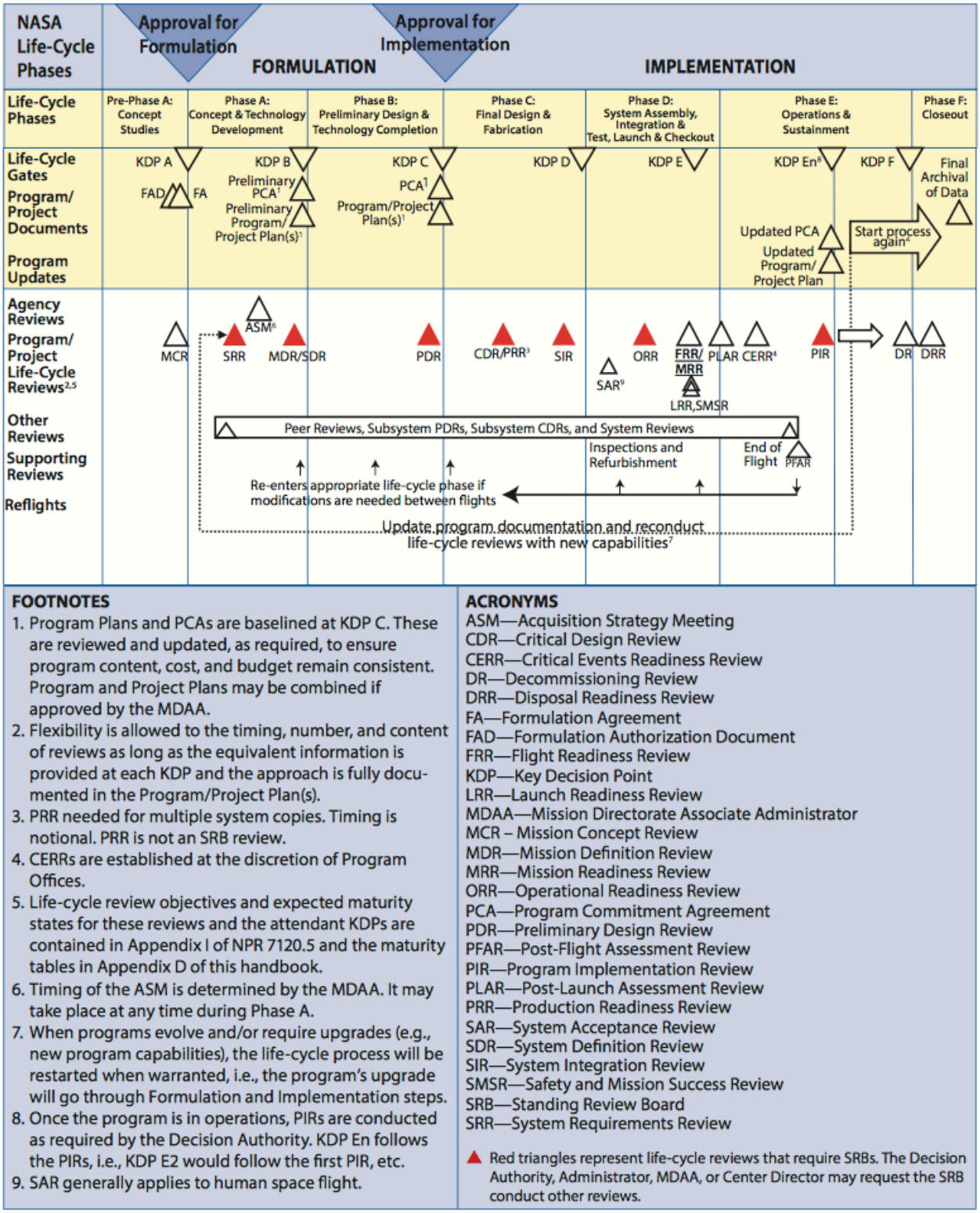



**Figure 4: NASA Requirements Flow Down**

### 3.2.1 NASA Space Flight Program and Project Management Requirements

The purpose of NPR 7120.5 is to establish the requirements and processes for the management team to develop and successfully execute a NASA program/project. The NPR makes a distinction between programs and projects. A program is a strategic investment that supports one or more projects that support the agency's goals and objectives (NASA, NPR 7120.5E, 2012, p. 17). A project is a specific investment having defined requirements, lifecycle, and management structure that produce new or revised products that address the agency's strategic goals (NASA, NPR 7120.5E, 2012, p. 17). Additional guidance on using NPR 7120.5 is available in the NASA Space Flight Program and Project Management Handbook.

The requirements and processes defined in this NPR emphasize project management based on lifecycles, lifecycle reviews, and evolving products during a project lifecycle. This style of project management is applied to this research in the development of facets and the Systems Engineering Lifecycle Template discussed in the later sections. This research assumes the NanoMet project is classified as a category 3, class D project and follows the lifecycle shown in Figure 5 (NASA, NPR 7120.5E, 2012, p. 18). The research focuses on lifecycle Phase A but is applicable to all lifecycle phases.




**FOOTNOTES**

1. Program Plans and PCAs are baselined at KDP C. These are reviewed and updated, as required, to ensure program content, cost, and budget remain consistent. Program and Project Plans may be combined if approved by the MDAA.
2. Flexibility is allowed to the timing, number, and content of reviews as long as the equivalent information is provided at each KDP and the approach is fully documented in the Program/Project Plan(s).
3. PRR needed for multiple system copies. Timing is notional. PRR is not an SRB review.
4. CERRs are established at the discretion of Program Offices.
5. Life-cycle review objectives and expected maturity states for these reviews and the attendant KDPs are contained in Appendix I of NPR 7120.5 and the maturity tables in Appendix D of this handbook.
6. Timing of the ASM is determined by the MDAA. It may take place at any time during Phase A.
7. When programs evolve and/or require upgrades (e.g., new program capabilities), the life-cycle process will be restarted when warranted, i.e., the program's upgrade will go through Formulation and Implementation steps.
8. Once the program is in operations, PIRs are conducted as required by the Decision Authority. KDP En follows the PIRs, i.e., KDP E2 would follow the first PIR, etc.
9. SAR generally applies to human space flight.

**ACRONYMS**

ASM—Acquisition Strategy Meeting
CDR—Critical Design Review
CERR—Critical Events Readiness Review
DR—Decommissioning Review
DRR—Disposal Readiness Review
FA—Formulation Agreement
FAD—Formulation Authorization Document
FRR—Flight Readiness Review
KDP—Key Decision Point
LRR—Launch Readiness Review
MDAA—Mission Directorate Associate Administrator
MCR – Mission Concept Review
MDR—Mission Definition Review
MRR—Mission Readiness Review
ORR—Operational Readiness Review
PCA—Program Commitment Agreement
PDR—Preliminary Design Review
PFAR—Post-Flight Assessment Review
PIR—Program Implementation Review
PLAR—Post-Launch Assessment Review
PRR—Production Readiness Review
SAR—System Acceptance Review
SDR—System Definition Review
SIR—System Integration Review
SMSR—Safety and Mission Success Review
SRB—Standing Review Board
SRR—System Requirements Review

▲ Red triangles represent life-cycle reviews that require SRBs. The Decision Authority, Administrator, MDAA, or Center Director may request the SRB conduct other reviews.

**Figure 5: NASA Project Lifecycle**

### 3.2.2 NASA Systems Engineering Processes and Requirements

The purpose of NPR 7123.1 is to establish the requirements for performing systems engineering. This NPR complements NPR 7120.5 by establishing the common technical processes and common systems engineering model for implementing all NASA projects (NASA, NPR 7123.1B, 2013, p. 8). Figure 6 shows the systems engineering model with the 17 common technical processes divided into three main processes: systems design, technical management and product realization. Additional guidance on using NPR 7123.1 is available in the NASA Systems Engineering Handbook.

The technical assessment process is used to monitor the technical progress and provide status of a project over its lifecycle (NASA, NPR 7123.1B, 2013, p. 22). The key components of the technical assessment process are the lifecycle reviews as defined by the project type in NPR 7120.5. These lifecycle reviews provide a periodic assessment of the project's technical status and health throughout the project lifecycle. The reviews are event based and occur when all the entrance criteria for an applicable review are met (NASA, NPR 7123.1B, 2013, p. 29). NPR 7123.1 provides the guidelines for the entrance and success criteria for the lifecycle reviews, and identifies the technical products the team produces over the project lifecycle. Section 4 describes how the research uses this information to develop facets. A detailed analysis of this NPR is performed in section 5.

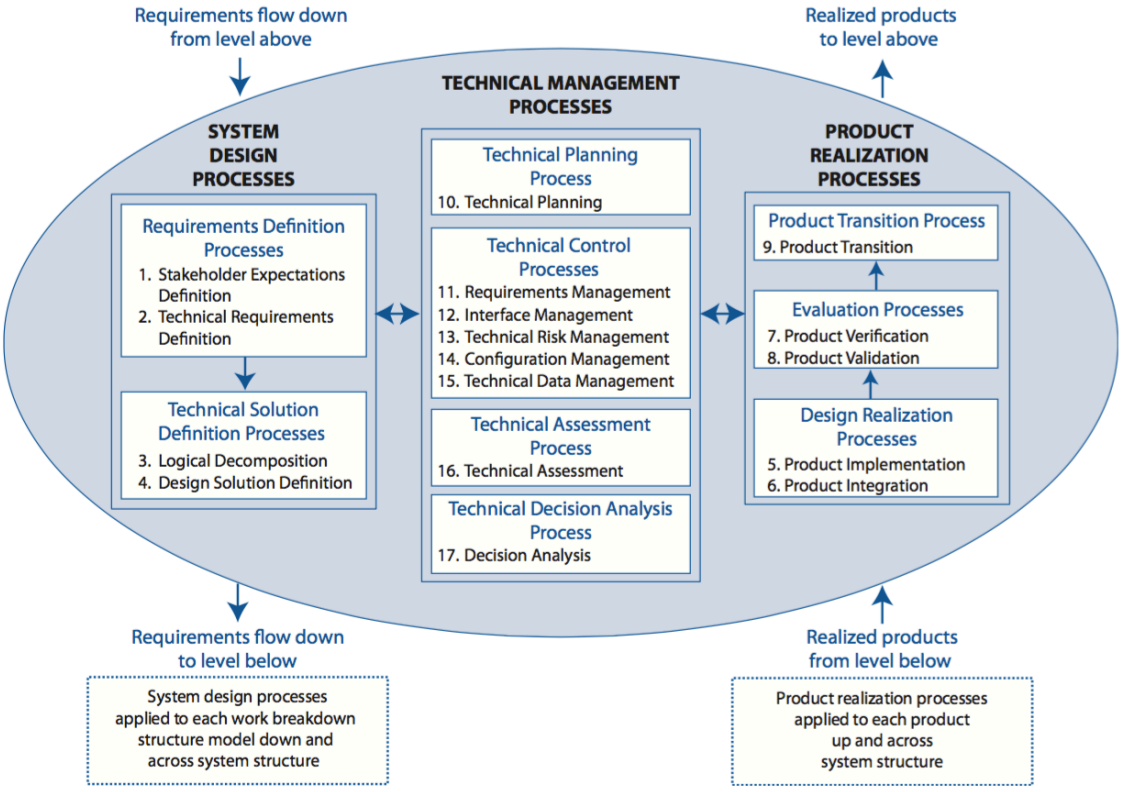



**Figure 6: NASA Systems Engineering Process**

# 4 Discussion

## 4.1 Introduction to Facets

During a project lifecycle various artifacts are generated by a project. In a document-centric systems engineering approach, these artifacts are organized into individual documents maintained within a configuration management tool. Examples of these documents includes concept of operations, system and component specifications, various types of plans, procedures and component drawings. At first thought, it's logical to recreate this approach in a model-based systems engineering approach. However, there is a major difference between a document-centric approach and a model-based approach. In a model-based approach, a MBSE tool stores and organizes the artifacts in a database. Within the MBSE tool each artifact is represented by a model, with its own set of information and relationships to other models within the overall system model. The models are not associated with a specific document which systems engineers are accustomed. Therefore, there is a need to develop a method to bridge the gap between document-centric and model-based approaches.

This research introduces the concept of facets to organize project artifacts, referred to as essentials in this research, within an MBSE tool. Merriam-Webster defines a *facet* as "any of the definable aspects that make up a subject or an object" (Merriam-Webster, 2015). Applied to this research, facets are the top-level views of a project. Facets are composed of a collection of essentials. Together, these essentials provide proof, or evidence, of the technical maturity of the project.

A top-down approach is used to develop the facets. There are many possible ways to define facets, which affects how the essentials are organized and used by the project team. For example, the facets can be defined to represent one of the systems engineering views of a project such as the physical, functional, operational, requirements, verification and validation, and project view. Each of these views is specific to an aspect of the project. These views tend to benefit only one area of the project and provide minimal use to other areas. Therefore it is necessary to develop facets with the following characteristics:

- Benefits the entire project team
- Flexibility with respect to point of view
- Applicability to the entire project lifecycle
- Ability to mature throughout the lifecycle
- Minimum number of facets to fully characterize the project (without overwhelming project team)

At the top most level the facets are divided into two broad categories called *Essential Facets* and *Assessment Facets*. The essential facets allow systems engineers to track the technical and managerial maturity of a project. The assessment facets track the lifecycle maturity of a project and provide success criteria at each phase. Each facet type is then further defined by adding additional sub-facets. The facets model is shown in Figure 7. Essential and assessment facets are discussed in more detail in the following sections.

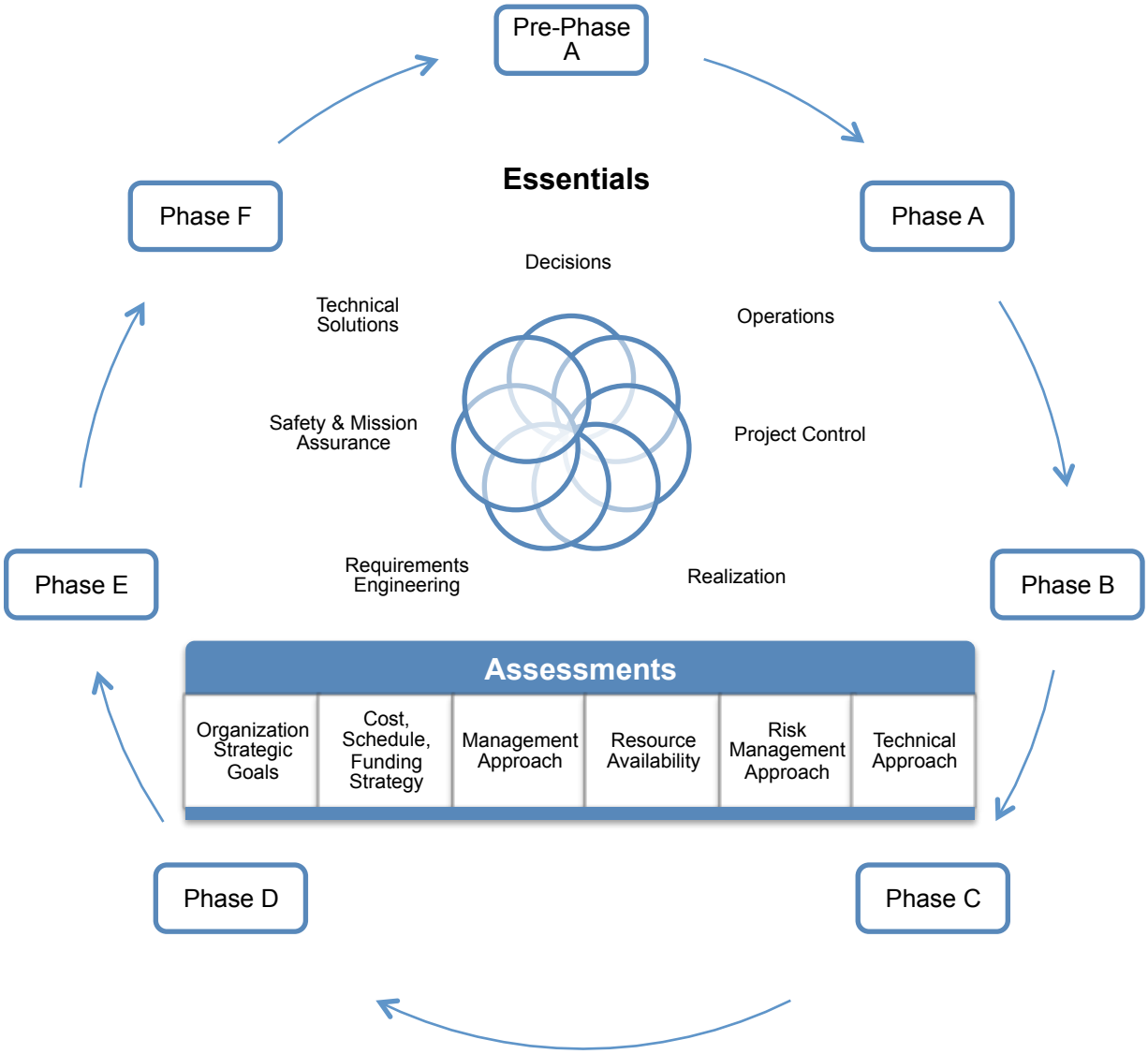



**Figure 7: Facet Model**

## 4.2 Essential Facets

Essential facets are comprised of key evidence produced by the project to establish the technical baselines throughout the lifecycle. The essential facets can be organized in many different ways and the challenge is determining an organization that benefits the entire team for the duration of the project lifecycle. A good starting point is to look at the primary project activities, identify common areas and extrapolate types of essential facets. The processes employed by the project define the required products a project must produce.

The NASA Systems Engineering process from NPR 7123.1B was shown in Figure 6 of section 3.2.2. At the top level there are three broad activities: Systems Design, Technical Management, and Product Realization. This is too broad of a view for the essential facets, so the next step is to look within each activity. At the next level there are 4 activities for system design, 8 for technical management and 5 for product realization for a total of 17 categories. While this does provide a very detailed view of the project, this may be cumbersome to implement.

The essential facets need to be organized in way to balance ease of use with providing enough detail to characterize the project. The NASA Systems Engineering "engine" provides a good starting point for defining the essential facets. The "engine" follows the classic systems engineering v-model that describes product design, product implementation and the crosscutting processes to manage the technical processes. The challenge with this approach is that at the top level, the "engine" is too broad and at the lower levels it provides too much detail. To maintain familiarity with existing systems engineering processes, the approach this research implements to organize the essential facets is to take the top-level processes and provide 2-3 ways to refine each. The result is the seven essential facets listed below.

- Decisions
- Operations
- Project Control
- Realization
- Requirements Engineering
- Safety and Mission Assurance
- Technical Solutions

The following sections describe each of the essential facets.

### 4.2.1 Decisions

The Decision facet captures the technical and non-technical trade-offs made that guide the direction of a project. Examples include trade studies and analyses.

### 4.2.2 Operations

Operations facets are the evidence to support the operation of the system in its intended environment. Examples include concept of operations, operation procedures and integrated logistics support plans. This includes information typically found in a Concept of Operations (ConOps) document.

### 4.2.3 Project Control

The Project Control facet includes the evidence to support all project management tasks. Examples include information typically found in a project management plan (PMP), systems engineering management plan (SEMP), schedules, and budgets.

### 4.2.4 Realization
The Realization facet captures information that supports the realization of the system from detailed design up to the operations facet. Examples include verification and validation plan, fabrication plans, assembly plans and integration plans.

### 4.2.5 Requirements Engineering
The Requirements Engineering facet includes all information related to establishing, managing and maintaining the project requirements. Examples include identifying stakeholder expectations, identifying mission/project goals and allocation and traceability of requirements.

### 4.2.6 Safety and Mission Assurance
The Safety and Mission Assurance (S&MA) facet captures evidence related to managing and monitoring the risk and quality of the project. Examples include risk management plan, risk assessment, in-process inspections, and system certification plans.

### 4.2.7 Technical Solutions
The Technical Solution facet captures the design of the system. Examples include system architecture, allocation of functions, build-to documentation and as-built documentation.

## 4.3 Assessment Facets
Assessment facets define success criteria used to periodically evaluate the project technical and managerial status during its lifecycle to establish the lifecycle maturity of a project. As with essential facets, there are many ways to organize assessment facets and a good place to start with the project processes. The processes will identify what is important for a project as it advances through its lifecycle and it should be possible to identify common areas and extrapolate types of success criteria facets.

The NASA Space Flight Program and Project Management Requirements define six success criteria to evaluate a project throughout its lifecycle (NASA, NPR 7120.5E, 2012, p. 24). In addition, the NASA Space Flight Program and Project Management Handbook describe the criteria and provide guidelines for evaluation during each phase of a project. This research utilizes these criteria because they provide a broad, yet detailed range of criteria to evaluate a project. The six success criteria are transferred into the assessment facets listed below.

- Organization Strategic Goals
- Cost, Schedule and Funding Strategy
- Management Approach
- Resource Availability
- Risk Management Approach
- Technical Approach

The following sections provide a summary of each success criteria. For additional details refer to Table E-2 in Appendix E of the NASA Space Flight Program and Project Management Handbook (NASA, NASA/SP-2014-3705, 2014, p. 451).

### 4.3.1 Organization Strategic Goals

The Organization Strategic Goals facet reviews the evidence demonstrating the project is aligned with higher lever strategic goals, there is a need for the project, and changes in project scope are approved and documented.

### 4.3.2 Cost, Schedule and Funding Strategy

The Cost, Schedule and Funding Strategy facet reviews the evidence demonstrating the project has appropriate cost and schedule plans that are consistent with the project mission and risk level.

### 4.3.3 Management Approach

The Management Approach facet reviews the evidence demonstrating the project is managed and controlled appropriately.

### 4.3.4 Resource Availability

The Resource Availability facet assesses the evidence demonstrating the project has adequate availability of competent and stable staffing, infrastructure and other resources other than budget to carry out the project.

### 4.3.5 Risk Management Approach

The Risk Management Approach facet demonstrates the project has adequate risk management plans, processes, and resources for managing and mitigating risks.

### 4.3.6 Technical Approach

The Technical Approach facet determines whether or not the project has adequate flow down of requirements, architecture and design, and solutions that meet the overall goal of the project.

# 5 Analysis and Results

## 5.1 Analysis

The next step in the research is to apply the concept of facets by analyzing the processes used by a project, identifying the essentials and assigning each to a facet. The NASA Procedural Requirements are analyzed because the NanoMet project began by using these processes. Appendix G of NPR 7123.1B describes the lifecycle and technical review entrance and success criteria for NASA projects. Each technical review entrance and success criterion is an essential that must be identified as one of the facets defined in the previous section. The analysis assumes the NanoMet project is a category 3 / class D project which identifies the lifecycle reviews and essentials for NanoMet. The lifecycle reviews for NanoMet are listed in Table 1. The review entrance criteria are identified as essential facets and the success criteria are identified as assessment facets. At this point in the analysis, the project lifecycle is identified, the essentials are known, and divided into essential facets and assessment facets. The next step is to identify each essential with the appropriate facet.

**Table 1: NanoMet Lifecycle Reviews**

| Phase | Lifecycle Reviews |
|---|---|
| **Pre-Phase A** | MCR |
| **Phase A** | SRR, SDR |
| **Phase B** | PDR |
| **Phase C** | CDR, PRR, SIR |
| **Phase D** | SAR, ORR, FRR |
| **Phase E** | PLAR, CERR, PFAR, DR |
| **Phase F** | DRR |

Identifying each essential with the appropriate facet requires comparing the essentials to the facet descriptions defined in the previous section. It is possible an essential could be identified as one or more facet. It is best to identify essentials to a single facet. This will simplify the analysis process and will maintain a one-to-one relationship between essentials and facets. It is best to use engineering judgment and identify the essential with the facet that matches how the essential represents the project.

## 5.2 Results

The complete results of the analysis are available in Appendix C. The following sections provide a summary of the overall analysis and provide a detailed analysis of Phase A.

### 5.2.1 Overall Results

The analysis identified 423 unique essentials.

#### 5.2.1.1 Evidence Facets Results

There are a total of 255 essential facets. The results are show in two views. The first view shows the essential facets organized by project lifecycle. The second view shows the essential facets organized by lifecycle reviews. Figure 8 and Figure 9 show a normalized area chart for the essential facets organized by project lifecycle and lifecycle

reviews. Table 2 and Table 3 provide a count of each essential facet organized by project lifecycle and lifecycle reviews.

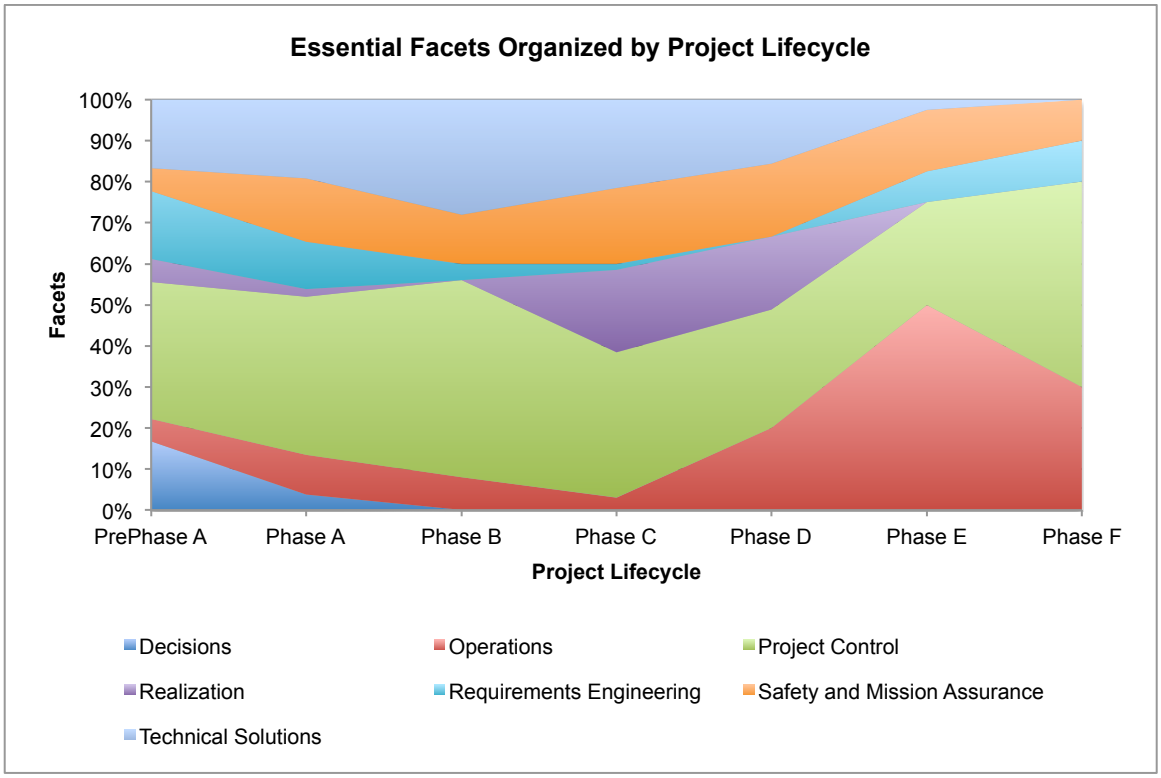



**Figure 8: Essential Facets Organized by Project Lifecycle**

**Table 2: Count of Essential Facets Organized by Project Lifecycle**

| Essential Facet | Pre-Phase A | Phase A | Phase B | Phase C | Phase D | Phase E | Phase F |
|---|---|---|---|---|---|---|---|
| **Decisions** | 3 | 2 | 0 | 0 | 0 | 0 | 0 |
| **Operations** | 1 | 5 | 2 | 2 | 9 | 20 | 3 |
| **Project Control** | 6 | 20 | 12 | 23 | 13 | 10 | 5 |
| **Realization** | 1 | 1 | 0 | 13 | 8 | 0 | 0 |
| **Requirements Engineering** | 3 | 6 | 1 | 1 | 0 | 3 | 1 |
| **Safety and Mission Assurance** | 1 | 8 | 3 | 12 | 8 | 6 | 1 |
| **Technical Solutions** | 3 | 10 | 7 | 14 | 7 | 1 | 0 |
| **Total** | **18** | **52** | **25** | **65** | **45** | **40** | **10** |

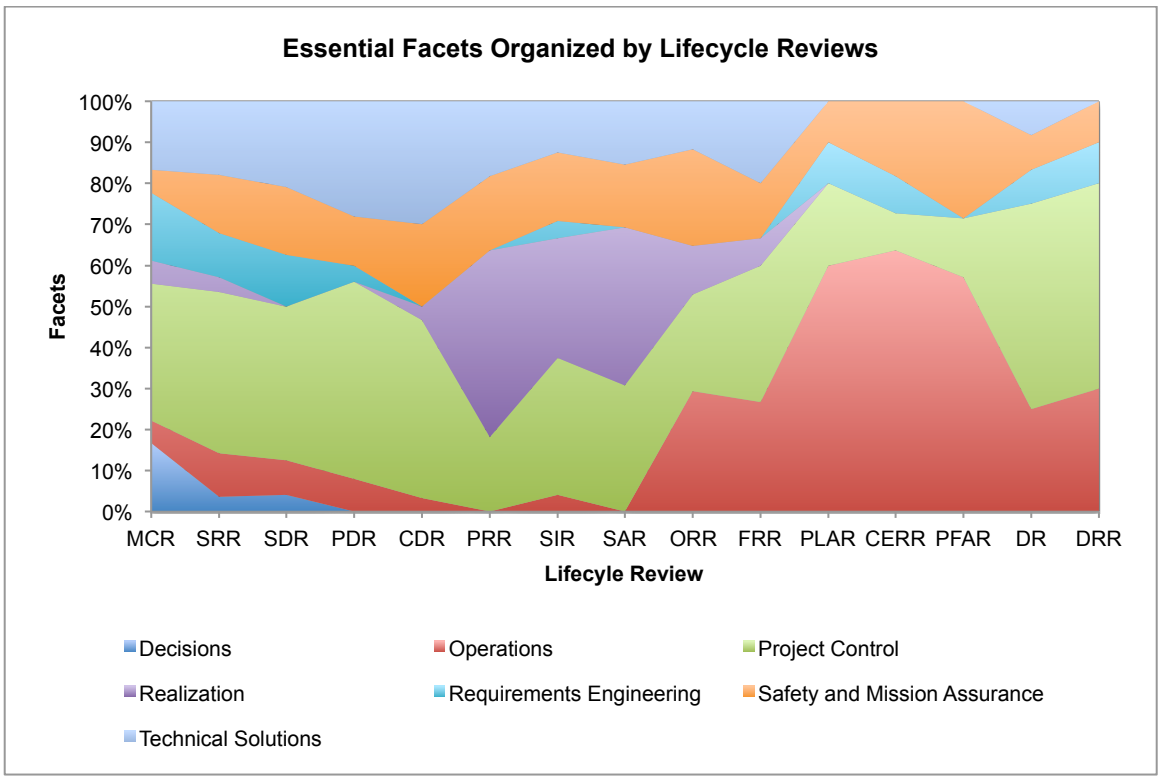



**Figure 9: Essential Facets Organized by Lifecycle Reviews**

**Table 3: Count of Essential Facets Organized by Lifecycle Reviews**

| Essential Facet | MCR | SRR | SDR | PDR | CDR | PRR | SIR | SAR | ORR | FRR | PLAR | CERR | PFAR | DR | DRR |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| **Decisions** | 3 | 1 | 1 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| **Operations** | 1 | 3 | 2 | 2 | 1 | 0 | 1 | 0 | 5 | 4 | 6 | 7 | 4 | 3 | 3 |
| **Project Control** | 6 | 11 | 9 | 12 | 13 | 2 | 8 | 4 | 4 | 5 | 2 | 1 | 1 | 6 | 5 |
| **Realization** | 1 | 1 | 0 | 0 | 1 | 5 | 7 | 5 | 2 | 1 | 0 | 0 | 0 | 0 | 0 |
| **Requirements Engineering** | 3 | 3 | 3 | 1 | 0 | 0 | 1 | 0 | 0 | 0 | 1 | 1 | 0 | 1 | 1 |
| **Safety and Mission Assurance** | 1 | 4 | 4 | 3 | 6 | 2 | 4 | 2 | 4 | 2 | 1 | 2 | 2 | 1 | 1 |
| **Technical Solutions** | 3 | 5 | 5 | 7 | 9 | 2 | 3 | 2 | 2 | 3 | 0 | 0 | 0 | 1 | 0 |
| **Total** | **18** | **28** | **24** | **25** | **30** | **11** | **24** | **13** | **17** | **15** | **10** | **11** | **7** | **12** | **10** |

### 5.2.1.2 Assessment Facets Results

There are a total of 168 assessment facets. The results are show in two views. The first view shows the assessment facets organized by project lifecycle. The second view shows the assessment facets by lifecycle reviews. Figure 10 and Figure 11 show a normalized area chart for the assessment facets organized by project lifecycle and lifecycle reviews. Table 4 and Table 5 provide a count of each assessment facet organized by project lifecycle and lifecycle reviews.

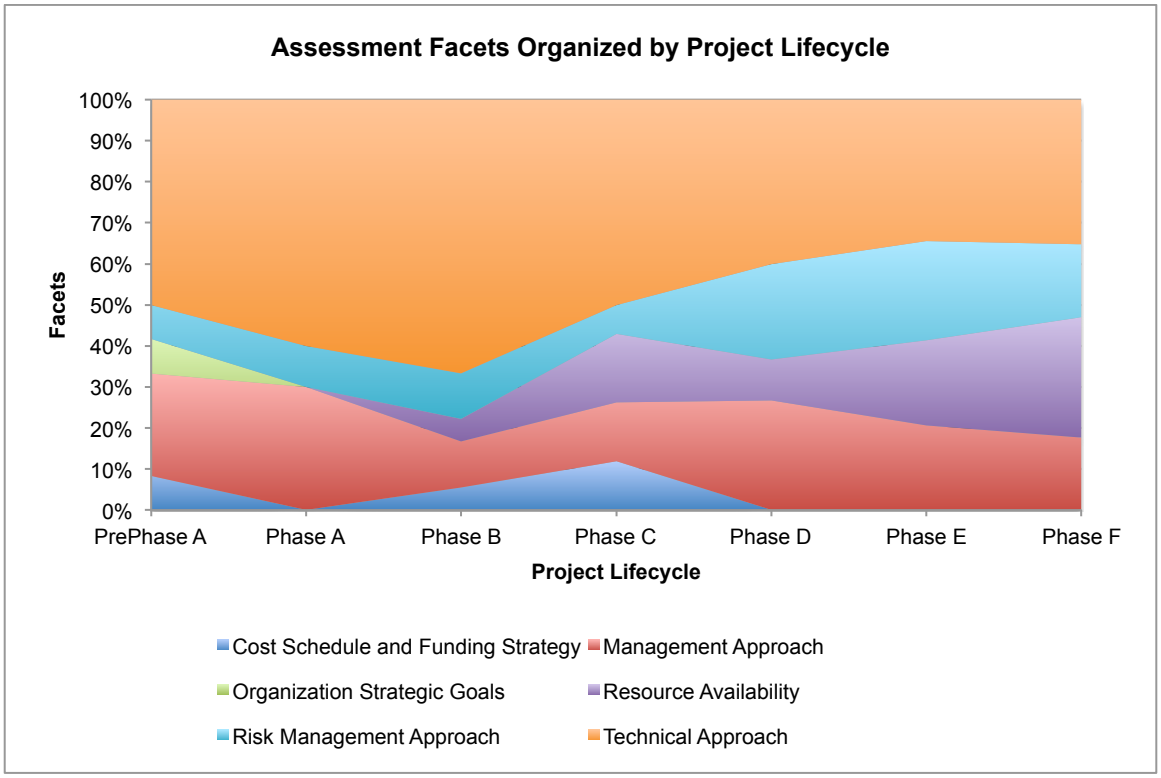



**Figure 10: Assessment Facets Organized by Project Lifecycle**

**Table 4: Count of Assessment Facets Organized by Project Lifecycle**

| Assessment Facet | Pre-Phase A | Phase A | Phase B | Phase C | Phase D | Phase E | Phase F |
|---|---|---|---|---|---|---|---|
| **Cost Schedule and Funding Strategy** | 1 | 0 | 1 | 5 | 0 | 0 | 0 |
| **Management Approach** | 3 | 6 | 2 | 6 | 8 | 6 | 3 |
| **Organization Strategic Goals** | 1 | 0 | 0 | 0 | 0 | 0 | 0 |
| **Resource Availability** | 0 | 0 | 1 | 7 | 3 | 6 | 5 |
| **Risk Management Approach** | 1 | 2 | 2 | 3 | 7 | 7 | 3 |
| **Technical Approach** | 6 | 12 | 12 | 21 | 12 | 10 | 6 |
| **Total** | **12** | **20** | **18** | **42** | **30** | **29** | **17** |

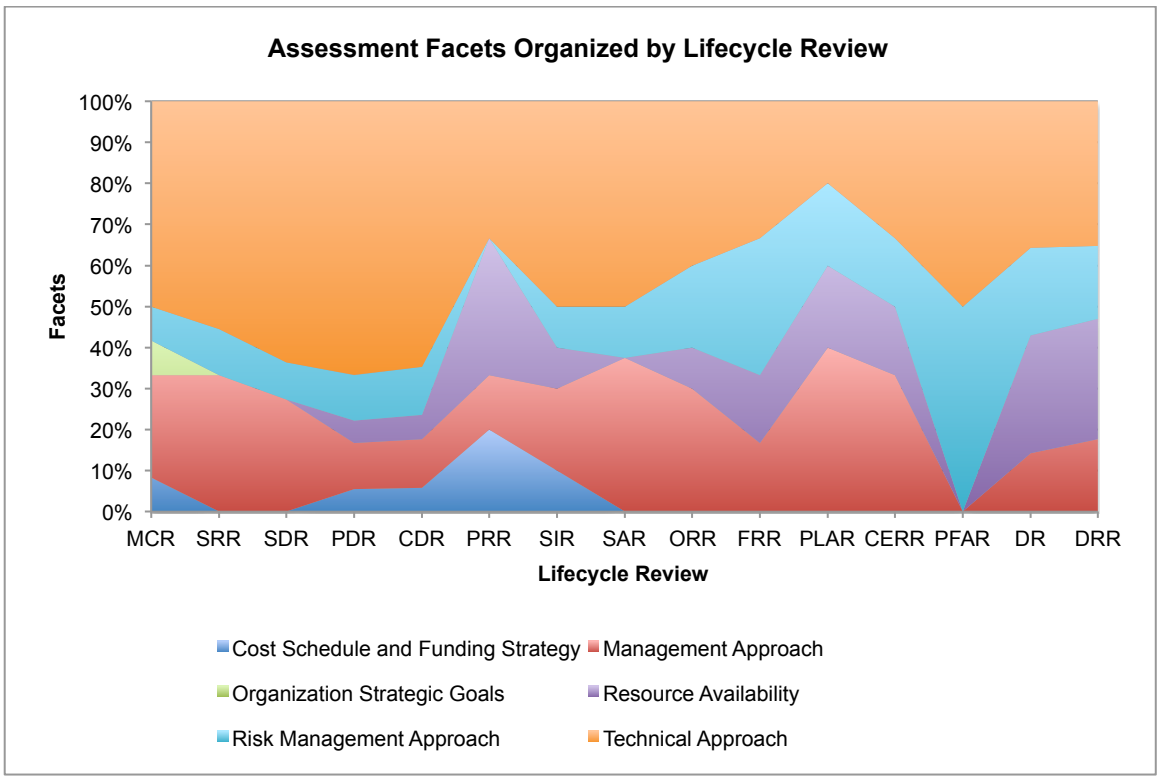


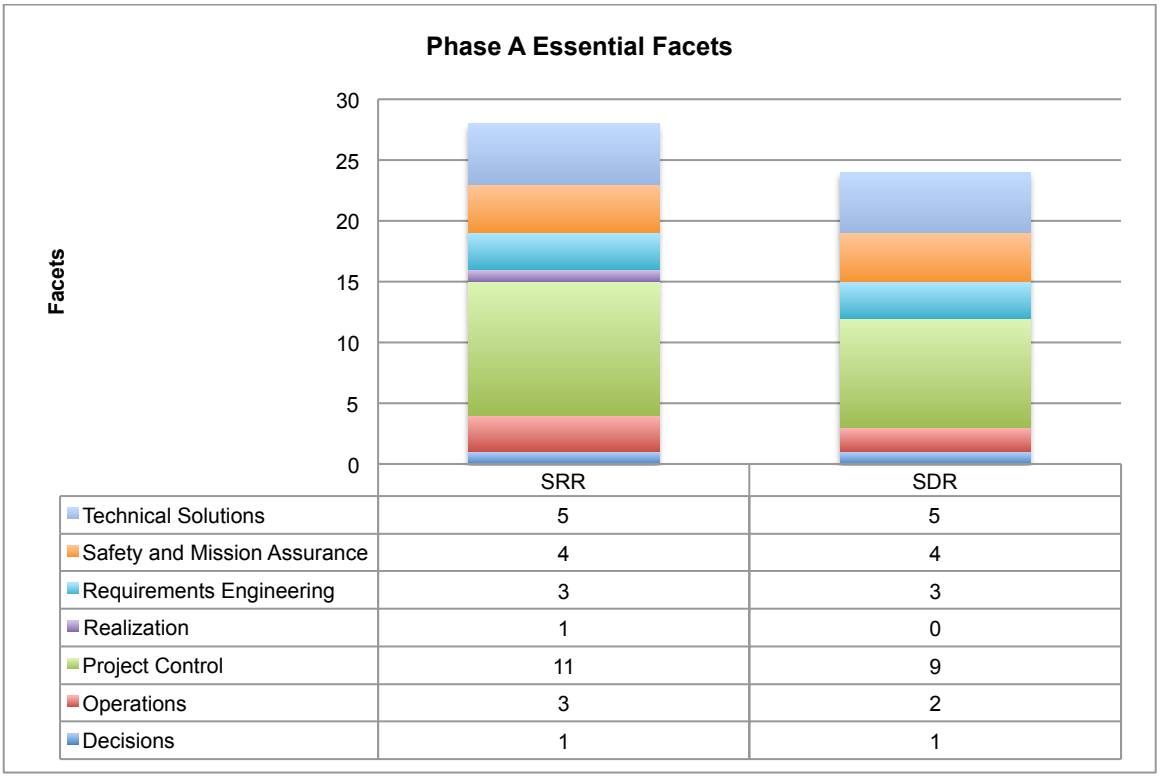

**Figure 11: Assessment Facets Organized by Lifecycle Reviews**

**Table 5: Count of Assessment Facets Organized by Lifecycle Reviews**

| Assessment Facet | MCR | SRR | SDR | PDR | CDR | PRR | SIR | SAR | ORR | FRR | PLAR | CERR | PFAR | DR | DRR |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| **Cost Schedule and Funding Strategy** | 1 | 0 | 0 | 1 | 1 | 3 | 1 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| **Management Approach** | 3 | 3 | 3 | 2 | 2 | 2 | 2 | 3 | 3 | 2 | 2 | 2 | 0 | 2 | 3 |
| **Organization Strategic Goals** | 1 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| **Resource Availability** | 0 | 0 | 0 | 1 | 1 | 5 | 1 | 0 | 1 | 2 | 1 | 1 | 0 | 4 | 5 |
| **Risk Management Approach** | 1 | 1 | 1 | 2 | 2 | 0 | 1 | 1 | 2 | 4 | 1 | 1 | 2 | 3 | 3 |
| **Technical Approach** | 6 | 5 | 7 | 12 | 11 | 5 | 5 | 4 | 4 | 4 | 1 | 2 | 2 | 5 | 6 |
| **Total** | **12** | **9** | **11** | **18** | **17** | **15** | **10** | **8** | **10** | **12** | **5** | **6** | **4** | **14** | **17** |

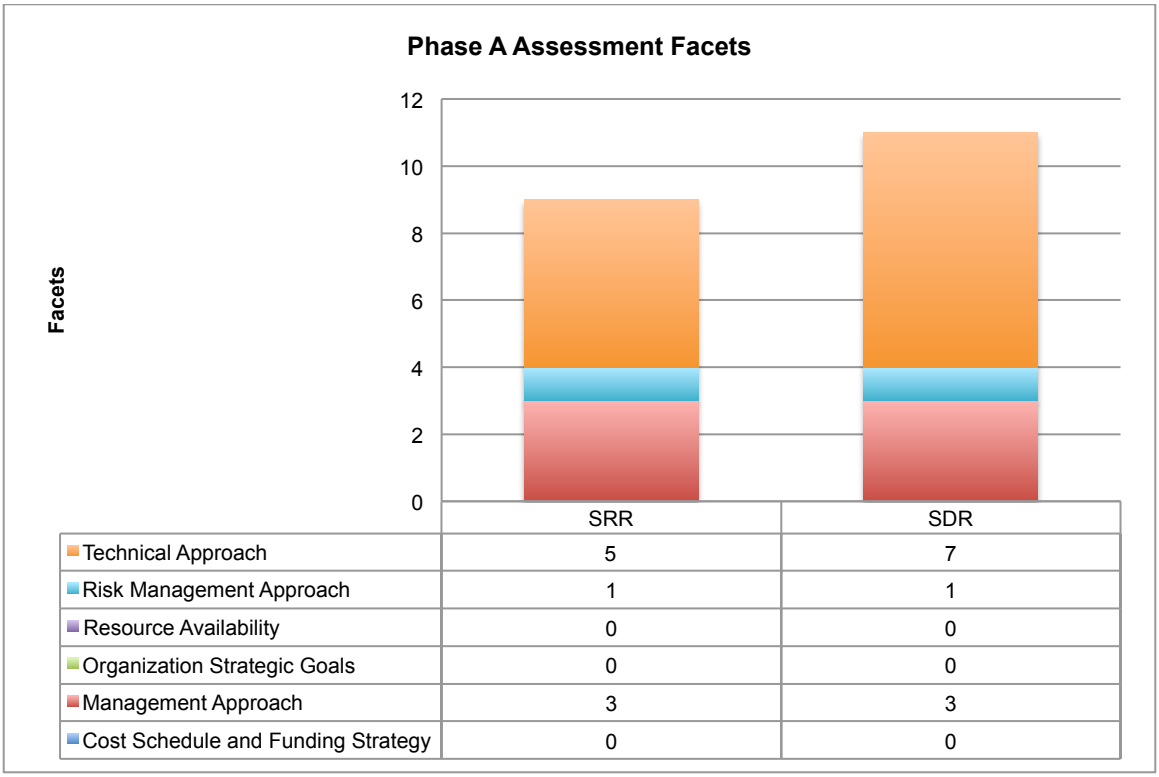
### 5.2.2 Phase A Results

The analysis identified 72 unique essentials for Phase A. There are a total of 52 essential facets and 20 assessment facets spread across two lifecycle reviews. Figure 12 provides a summary of the Phase A Essential Facets. Figure 13 provides a summary of the Phase A Assessment Facets.




| | SRR | SDR |
|---|---|---|
| Technical Solutions | 5 | 5 |
| Safety and Mission Assurance | 4 | 4 |
| Requirements Engineering | 3 | 3 |
| Realization | 1 | 0 |
| Project Control | 11 | 9 |
| Operations | 3 | 2 |
| Decisions | 1 | 1 |

**Figure 12: Phase A Essentials Facets**




| | SRR | SDR |
|---|---|---|
| Technical Approach | 5 | 7 |
| Risk Management Approach | 1 | 1 |
| Resource Availability | 0 | 0 |
| Organization Strategic Goals | 0 | 0 |
| Management Approach | 3 | 3 |
| Cost Schedule and Funding Strategy | 0 | 0 |

**Figure 13: Phase A Assessment Facets**

# 6 Application

## 6.1 Systems Engineering Lifecycle Template

This research introduces a new modeling tool called a Systems Engineering Lifecycle Template (SELT). The purpose of the Systems Engineering Lifecycle Template is to combine the project lifecycle and organization of essentials by facets in a single location, and to provide a comprehensive "road map" to the system model. Model-based systems engineering enables systems engineers to capture each essential as one or more entities in a MBSE tool. Collections of entities define the essentials and ultimately define the project. The MBSE tool maintains the collection of entities without any knowledge of the project lifecycle or organization by facets. The Systems Engineering Lifecycle Template provides a structure to link the entities in the system model to the project lifecycle, maintain the organization by facets, and present the entities in a manner that is easy to use and understand by the project team.

For the scope of this research, the Systems Engineering Lifecycle Template is described for use in the MBSE tool Innoslate and assumes the use of the NASA Procedural Requirements. The Systems Engineering Lifecycle Template is a virtual document located within the CONOPS[2] section of the system model. A virtual document was chosen as the tool because project team members are accustomed to using documents to convey information. Viewing information in a database can be difficult and an uncommon skill. A virtual document is a middle ground to keep a familiar method while taking advantage of the virtual document features of Innoslate.

### 6.1.1 Virtual Document

A virtual document is similar to other electronic documents but it includes additional features unique to Innoslate. A virtual document in Innoslate is a collection of statements, which are a type of entity. Recall from section 3.1.3, that an entity is something that can exist by itself and is uniquely identifiable by its attributes and relationships. Attributes are characteristics of an entity that include a name, number and description. For a statement, the name is the same as the heading in a document. The number is the hierarchical numbering to identify and locate the entity within the document. The description is any information describing the entity including text, images and tables. The relationships are the connections entities have to other entities within the system model. Relationships allow statements in the virtual document to be linked to the evidence in the system model. Innoslate allows a user to view the statements together like a virtual document organized by number, or as individual statements in their entity form. This ability to seamlessly switch between the views makes virtual documents in Innoslate a very powerful tool.

### 6.1.2 Organization

The Systems Engineering Lifecycle Template is a hierarchical representation of the project lifecycle and essentials. At the top level is the project lifecycle, followed by the lifecycle reviews and at the lowest levels are the essentials. The project lifecycle and

[2] Innoslate version 3.4 does not support general documents. It was necessary to locate the template in the CONOPS section to take advantage of the virtual document features of Innoslate.

lifecycle reviews are in chronological order. This level of organization provides the link between the system model and the project lifecycle. Using the approach presented earlier in this research, facets are used to organize the essentials. Each essential represented in the template is a statement and as described earlier has its own set of attributes and relationships. This organizes the essentials within the system model and provides a link between the essentials and the evidence. Figure 14 illustrates the organization, showing the Phase A SRR lifecycle review from the NASA Project Lifecycle, as it would appear in Innoslate. A completed template is available at the links provided in Appendix B. The contents of the Systems Engineering Lifecycle Template are described in more detail in the following sections.


**Figure 14: Example Organization in Innoslate**

#### 6.1.2.1 Lifecycle Statements

In the template, the lifecycle statements are at the top of the organizational hierarchy and in chronological order. Each phase of the lifecycle has its own entry. The lifecycle attributes are described in detail below.

##### 6.1.2.1.1 Number Attribute

The number attribute is an incremental hierarchical numbering to identify the lifecycle within the template. This is the same as the list numbers found in word processing applications. Innoslate is capable of maintaining and updating this numbering as the template is created.

##### 6.1.2.1.2 Name Attribute

The name attribute is the name of the lifecycle. For example, the names of the NASA lifecycles are Pre-Phase A, Phase A thru Phase F.

##### 6.1.2.1.3 Description Attribute

The description attributes is a short description of the lifecycle phase including the purpose, inputs and outputs. For example, NASA provides descriptions for each of the phases in the NASA Space Flight Program and Project Management Handbook. The Phase A description is:

> *"The purpose of Phase A is to develop a proposed mission/system architecture that is credible and responsive to program requirements and constraints on the project, including resources. The Phase A work products need to demonstrate that the maturity of the project's mission/system definition and associated plans are sufficient to begin Phase B, and the mission can probably be achieved within available resources with acceptable risk"* (NASA, NASA/SP-2014-3705, 2014, p. 153).

#### 6.1.2.2 Lifecycle Review Statements

The lifecycle review statements are below the lifecycle statements and are also in chronological order. Each lifecycle review has its own entry. The attributes are described in detail below.

##### 6.1.2.2.1 Number

The number attribute is a continuation of the hierarchical numbering established at the higher level.

##### 6.1.2.2.2 Name

The name attribute is the name of the lifecycle review. For example, the names of the Phase A reviews are Systems Requirements Review and Systems Definition Review.

##### 6.1.2.2.3 Description

The description attribute is a short description of the lifecycle review describing its purpose and goals. For examples, the SRR description is:

> *"The purpose of the SRR is to evaluate whether the functional and performance requirements defined for the system are responsive to the program's requirements on the project and represent achievable capabilities."* (NASA, NASA/SP-2014-3705, 2014, p. 155).

#### 6.1.2.3 Facets

The facets are the two broad types of facets described in section 4, Essential Facets and Assessment Facets. This level of the hierarchy is for separating and organizing the two facet types. The only content at this level are two statements, one for Essential Facets and a second for Assessment Facets.

##### 6.1.2.3.1 Number

The number attribute is a continuation of the hierarchical numbering established at the higher level.

##### 6.1.2.3.2 Name

The name attribute is either Essential Facets or Assessment Facets

##### 6.1.2.3.3 Description

The description attribute is not required for this level.

#### 6.1.2.4 Essential Facets

The essential facets are the facets described in section 4.2 and are organized alphabetically. Each of the seven essential facets has an entry. An essential facet may be omitted at this level if there is no evidence associated with a particular lifecycle review.

##### 6.1.2.4.1 Number

The number attribute is a continuation of the hierarchical numbering established at the higher level.

##### 6.1.2.4.2 Name

The name attribute is the name of the facet. These are defined in section 4.2.

##### 6.1.2.4.3 Description

The description attribute is a short description of the facet. These are defined in sections 4.2.1 thru 4.2.7.

#### 6.1.2.5 Assessment Facets

The assessment facets are the facets described in section 4.3 and are organized alphabetically. Each of the six assessment facets has an entry. An assessment facet may be omitted at this level if there is no success criteria associated with a particular lifecycle review.

##### 6.1.2.5.1 Number

The number attribute is a continuation of the hierarchical numbering established at the higher level.

##### 6.1.2.5.2 Name

The name attribute is the name of the facet. These are defined in section 4.3.

##### 6.1.2.5.3 Description

The description attribute is a short description of the facet. These are defined in sections 4.3.1 thru 4.3.6.

#### 6.1.2.6 Evidence Statements

The evidence statements are below the facet statements and are organized as determined by the project team. Each piece of evidence has an entry. There are two types of evidence statements. Evidence associated with essential facets and evidence associated with assessment facets. Both evidence statements share similar attributes and the only difference between them is the assessment evidence statement contains additional information in the description attribute as described in the following sections.

##### 6.1.2.6.1 Number

The number attribute is a continuation of the hierarchical numbering established at the higher level.

##### 6.1.2.6.2 Name

The name attribute is the name of the evidence. The name can be anything that the project team understands. A good starting point is to use the name form the project process if it's available. For example, the names of evidence statements for the Phase A Systems Requirement Review can be found in Table 7, in the column Evidence Name and a few of them are listed below:

- Essential Facets
  - Mission Concept
  - Mission Operations
  - Parent Requirements
  - Risk Management Plan
  - Risk Assessment and Mitigation
  - Configuration Management Plan
  - Safety Analysis
- Assessment Facets
  - Functional Allocation
  - SEMP
  - Risk Management Plan
  - Risk Assessment and Mitigation
  - Technology Development Plan

##### 6.1.2.6.3 Description

The description attribute consists of two parts. The first part is a table containing the following information:

- Reference to the source defining the evidence
- Description of the evidence
- Assessment of the evidence (Assessment evidence statements only)
- Location of the evidence within the model.

The purpose of the table is to provide the project team with quick summary of the evidence statement. Following the table is an open area where additional information can be provided by the project team as necessary. The contents of the description attribute are described in more detail in the following sections.

#### 6.1.2.6.3.1 Reference
The reference to the source can be anything to allow the project team to locate the source of the evidence within the project processes. For example SRR.EC.06.A is reference to one of the items listed in table G-4 of NPR 7123.1B. In this example, the evidence is an entrance criterion for the Systems Requirement Review (See Table 7).

#### 6.1.2.6.3.2 Description
The description is anything to allow the project team to understand what they must produce. The description of evidence can come from the source process. Continuing from the previous example, SRR.EC.06.A is an "Updated concept definition" (See Table 7).

#### 6.1.2.6.3.3 Assessment
The assessment is only for evidence statements associated with assessment facets. The purpose of this field is for the project team to perform a self-assessment of how well the project meets the given success criteria evidence. This can be as simple as "meets requirement", "needs work" or any other agreed upon terminology to convey the assessment.

#### 6.1.2.6.3.4 Location
The location is a placeholder for a reference to the evidence within the model. Using Innoslate, one of two methods is possible. One method is to include a hyperlink to the evidence in the model. Another method is to assign a relationship to one or more entities in the model that define the evidence. In this case, the location field can be left empty or direct the project team to view the statement's relationships.

#### 6.1.2.6.4 Open Area
The open area after the summary table is a free space that can be used by the project team as necessary to include additional information about the evidence statement.

### 6.1.3 Usage
The Systems Engineering Lifecycle Template is used throughout the project lifecycle. The template needs to be setup like any other tool and this occurs at the beginning of a project. The setup is accomplished by analyzing the project processes to identify the project lifecycle, lifecycle reviews and essentials. This information is recorded in the template, organized as described earlier. Even in this initial state the template is a powerful tool. It outlines the project lifecycle and identifies the systems engineering essentials organized by facets. The management team can use the initial template to develop the work breakdown structure, develop staffing profiles and develop the budget. As the project progresses, the project team updates the information for each systems engineering essential and provides a location within the model using one of the methods described earlier. In parallel, the management team can assess the status of the project by tracking completion of essentials by lifecycle phase or review. This process of updating and maintaining the template continues for the duration of the project. The template becomes a living document the project team maintains throughout the project.

## 6.2 NanoMet Academic Case Study

The motivation for this research is the Nanosatellite Applications for Meteorological Support (NanoMet). The NanoMet project is an academic case study to teach space systems engineering, project management, and to provide a complete mission lifecycle experience. The hypothetical NanoMet mission is to provide a low-cost, rapid response gap-filler capability for low-resolution meteorological data for the United States government. The mission is based around the design, development, deployment and operation of nanosatellites based on the 3U CubeSat standard. Once deployed the system consists of an uncontrolled constellation to provide meteorological data including low-resolution imagery to its users. The baseline mission consists of 5 satellites deployed to an initial altitude of 400km, 52 degree inclined orbit. Once operational, the nanosatellites provide supplemental coverage to existing systems. The expected lifecycle for a nanosatellite is approximately 6 months. The NanoMet project utilizes a model-based systems engineering methodology to model the representative artifacts a team would produce on a space mission using the MBSE tool Innoslate. In addition to teaching space systems engineering, the NanoMet project also provides an opportunity to introduce and develop the skills necessary to use model-based systems engineering methodologies.

### 6.2.1 MBSE Skills Development

Systems engineers need to develop new skills to effectively utilize MBSE methodologies. In MBSE, instead of writing documents consisting of requirement statements and textual descriptions to describe the system, the system is described by a collection of models. As discussed in section 3.1, a model is an abstracted representation of a system characteristic, behavior or quality. The models have intrinsic attributes and relationships as defined by the modeling language LML. A system model, such as the NanoMet model, may contain hundreds or thousands of models and systems engineers interact with the system model using the MBSE tool Innoslate. MBSE enables systems engineers to think about the system in a more natural way but the difficulty is learning the skills necessary to organize, interact and use the information. These new skills must be developed over time and requires practice to become proficient. Since systems engineers are accustomed to documents to communicate information and Innoslate includes the ability to use virtual documents, it made sense to leverage this feature to help transition to MBSE, while developing the skills necessary to effectively utilize MBSE.

# 7 Conclusions

## 7.1 Research Results

The Systems Engineering Lifecycle Template is the answer this research developed to define essential systems engineering and to simplify the implementation of model-based systems engineering. The Systems Engineering Lifecycle Template is a powerful modeling tool that can be used by an entire project team throughout the project lifecycle. This is accomplished by using a virtual document to combine the project lifecycle and organization of systems engineering essentials in a single location within the system model. The virtual document allows systems engineers to link the entities in the system model to the project lifecycle, organize them according to systems engineering facets, and present the information in a manner that is easy to use and understand. The Systems Engineering Lifecycle Template allows systems engineers to interact with the system model in a structured format. It provides a framework for organizing and communicating a system model using a combination of document centric and model-based systems engineering methodologies.

The framework for the Systems Engineering Lifecycle Template consists of two main parts, the project processes and systems engineering facets. The project processes define several characteristics of a project that must be incorporated into the system model. These characteristics include defining the lifecycle, identifying the lifecycle reviews, specifying the evidence a project must produce, and determining how a project is assessed throughout its lifecycle. The lifecycle information is relatively simple to identify and organize, and therefore it forms the core structure of the Systems Engineering Lifecycle Template. The systems engineering facets were developed in response to the quantity and types of evidence a project must produce, and how a project is assessed throughout its lifecycle. The facets provide a method for identifying and organizing the systems engineering essentials in a format that is easy to use and understand. This information forms the bulk of the Systems Engineering Lifecycle Template and is the most frequently accessed information about the project.

In essence, the Systems Engineering Lifecycle Template tells the story of a project from start to finish. In the beginning, it outlines the project lifecycle and the systems engineering essentials the project team must produce. As the SELT is used, it provides traceability to the project processes, progress towards milestones, assesses the health of a project, and introduces MBSE methodologies to the project team. It guides the project team and its stakeholders through the system model by providing a simple and familiar method to locate the essentials within the system model. The SELT can be used as an effective tool to transition from document centric systems engineering to model-based systems engineering. Most importantly the Systems Engineering Lifecycle Template serves as a communications tool for the entire project team.

## 7.2 Future Work

The future work is to apply this research and the new approach to systems engineering to the NanoMet project. The process for applying this research to NanoMet is described in the following sections. This research completed several of the tasks and can be directly applied. The supporting documents generated by this research are available in Innoslate in the locations specified in Appendix B.

### 7.2.1 Analyze Processes

The processes need to be analyzed to identify the project lifecycle and lifecycle reviews. This research conducted a detailed analysis of the NanoMet processes in section 5 and identified the NanoMet lifecycle and lifecycle reviews.

### 7.2.2 Identify Key Evidence and Success Criteria

The key evidence and success criteria need to be identified by reviewing the project processes. This research identified the key evidence and success criteria and the results are available in Appendix C.

### 7.2.3 Create the Systems Engineering Lifecycle Template

The Systems Engineering Lifecycle Template is created from the project lifecycle, lifecycle reviews and key essentials. The data to create the Systems Engineering Lifecycle Template is provided in tabular format in Appendix C. Instructions are provided in Appendix D to export the Systems Engineering Lifecycle Template from this data. Appendix E contains instructions on how to import the document into the NanoMet model.

### 7.2.4 Map Essentials

Mapping the essentials can only be performed once the Systems Engineering Lifecycle Template is added to the NanoMet model. It is recommended to begin mapping the essentials for Phase A only. Examples are provided in Appendix F on how to map essentials to the Systems Engineering Lifecycle Template.

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# Appendix B SYS 800 Deliverables

Copies of the SYS 800 deliverables that are part of this research are available in Innoslate. Access to the project will need to be granted in order to view the project and associated deliverables. Contact the author or advisor for permission.

- SYS 800 Essential SE
  - Location
    - https://app.innoslate.com/project/p2747V1/dashboard
  - Research Paper
    - https://app.innoslate.com/project/p2747V1/database/entity/e3
  - Analysis Results and SELT Export Tool
    - SELT_Data_20151127.xlsm
    - https://app.innoslate.com/project/p2747V1/database/entity/e1
  - Systems Engineering Lifecycle Template
    - Systems Engineering Lifecycle Template 20151125.docx
    - https://app.innoslate.com/project/p2747V1/database/entity/e2
  - Systems Engineering Lifecycle Template
    - Innoslate Virtual Document
    - https://app.innoslate.com/project/p2747V1/document/conops
- Author Contact Info
  - steven.orosz@gmail.com

# Appendix C NASA Procedural Requirements Analysis Data

This appendix contains the results of analyzing Appendix G of NR 7123.1B. The following tables are in this appendix:

- Pre-Phase A Facets
- Phase A Facets
- Phase B Facets
- Phase C Facets
- Phase D Facets
- Phase E Facets
- Phase F Facets

Table 6: Pre-Phase A Facets

| Number | Review | Evidence Name | Description | Facet Type | Facet |
|---|---|---|---|---|---|
| MCR.EC.00 | MCR | MCR Entrance Criteria | These are Entrance Criteria for MCR. | Essentials | |
| MCR.EC.01 | MCR | Agenda | An agenda for the MCR, success criteria, and instructions to the review board have been agreed to by the technical team, the project manager, and the review chair prior to the review. | Essentials | Project Control |
| MCR.EC.02 | MCR | Reviews | All planned higher level MCRs and peer reviews have been successfully conducted and RID/RFA/Action Items have been addressed with the concurrence of the originators. | Essentials | Project Control |
| MCR.EC.03 | MCR | Primary Products | The following primary products are ready for review: | Essentials | |
| MCR.EC.03.A | MCR | Stakeholders and Expectations | Stakeholders have been identified and stakeholder expectations have been defined and are ready to be baselined after review comments are incorporated. | Essentials | Requirements Engineering |
| MCR.EC.03.B | MCR | Mission Concept | The concept has been developed to a sufficient level of detail to demonstrate a technically feasible solution to the mission/project needs and is ready to be baselined after review comments are incorporated. | Essentials | Decisions |
| MCR.EC.03.C | MCR | Key Performance Parameters | MOEs and any other mission success criteria have been defined and are ready to be approved. | Essentials | Requirements Engineering |
| MCR.EC.04 | MCR | Programmatic Products | Programmatic products are ready for review at the maturity levels stated in the governing program/project management NPR. | Essentials | Project Control |
| MCR.EC.05 | MCR | Technical Products | Other technical products (as applicable) for hardware, software, and human system elements have been made available to the cognizant participants prior to the review: | Essentials | |
| MCR.EC.05.A | MCR | Goals and Objectives | Mission/project goals and objectives that are ready to be baselined after review comments are incorporated. | Essentials | Requirements Engineering |
| MCR.EC.05.B | MCR | Alternative Concepts | Alternative concepts that have been analyzed and are ready to be reviewed. | Essentials | Decisions |
| MCR.EC.05.C | MCR | Cost and Schedule Estimates | Initial risk-informed cost and schedule estimates for implementation. | Essentials | Project Control |
| MCR.EC.05.D | MCR | Descope Options | Preliminary mission descope options. | Essentials | Decisions |
| MCR.EC.05.E | MCR | Risk Assessment and Mitigation | A preliminary assessment performed by the team of top technical, cost, schedule, and safety risks with developed associated risk management and mitigation strategies and options. | Essentials | Safety and Mission Assurance |
| MCR.EC.05.F | MCR | V and V Approach | Preliminary approach to verification and validation for the selected concept(s). | Essentials | Realization |
| MCR.EC.05.G | MCR | SEMP | A preliminary SEMP, including technical plans. | Essentials | Project Control |
| MCR.EC.05.H | MCR | Technology Development Plan | Technology Development Plan that is ready to be baselined after review comments are incorporated. | Essentials | Project Control |
| MCR.EC.05.I | MCR | TRL Assessment | Initial technology readiness that has been assessed and documented with technology assets, heritage products, and gaps identified. | Essentials | Technical Solutions |

Table 6: Pre-Phase A Facets

| Number | Review | Evidence Name | Description | Facet Type | Facet |
|---|---|---|---|---|---|
| MCR.EC.05.J | MCR | Engineering Development Assessment | Preliminary engineering development assessment and technical plans to achieve what needs to be accomplished in the next phase. | Essentials | Technical Solutions |
| MCR.EC.05.K | MCR | Support Strategy | Conceptual life-cycle support strategies (logistics, manufacturing, and operation). | Essentials | Operations |
| MCR.EC.05.L | MCR | Software Products | Software criteria and products, per NASA-HDBK-2203, NASA Software Engineering Handbook. | Essentials | Technical Solutions |
| MCR.SC.00 | MCR | MCR Success Criteria | These are Success Criteria for MCR | Assessments | |
| MCR.SC.01 | MCR | Mission Objectives | Mission objectives are clearly defined and stated and are unambiguous and internally consistent. | Assessments | Technical Approach |
| MCR.SC.02 | MCR | Concept Meets Expectations | The selected concept(s) satisfactorily meets the stakeholder expectations. | Assessments | Technical Approach |
| MCR.SC.03 | MCR | Feasibility | The mission is feasible. A concept has been identified that is technically feasible. A rough cost estimate is within an acceptable cost range. | Assessments | Technical Approach |
| MCR.SC.04 | MCR | Evaluation Criteria | The concept evaluation criteria to be used in candidate systems evaluation have been identified and prioritized. | Assessments | Management Approach |
| MCR.SC.05 | MCR | Need | The need for the mission has been clearly identified. | Assessments | Organization Strategic Goals |
| MCR.SC.06 | MCR | Cost and Schedule Estimates | The cost and schedule estimates are credible and sufficient resources are available for project formulation. | Assessments | Cost Schedule and Funding Strategy |
| MCR.SC.07 | MCR | Compliance with Guidance | The program/project has demonstrated compliance with applicable NASA and implementing Center requirements, standards, processes, and procedures. | Assessments | Management Approach |
| MCR.SC.08 | MCR | TBD/TBR Disposition | TBD and TBR items are clearly identified with acceptable plans and schedule for their disposition. | Assessments | Management Approach |
| MCR.SC.09 | MCR | Alternative Concepts | Alternative concepts have adequately considered the use of existing assets or products that could satisfy the mission or parts of the mission. | Assessments | Technical Approach |
| MCR.SC.10 | MCR | Technical Planning | Technical planning is sufficient to proceed to the next phase. | Assessments | Technical Approach |
| MCR.SC.11 | MCR | Risk Assessment and Mitigation | Risk and mitigation strategies have been identified and are acceptable based on technical risk assessments. | Assessments | Risk Management Approach |
| MCR.SC.12 | MCR | Software | Software components meet the exit criteria defined in the NASA-HDBK-2203, NASA Software Engineering Handbook. | Assessments | Technical Approach |

Table 7: Phase A Facets

| Number | Review | Evidence Name | Description | Facet Type | Facet |
|---|---|---|---|---|---|
| SRR.EC.00 | SRR | SRR Entrance Criteria | These are Entrance Criteria for SRR. | Essentials | |
| SRR.EC.01 | SRR | Milestones | The project has successfully completed the previously planned milestone reviews and responses have been made to all RFAs and RIDs, or a timely closure plan exists for those items remaining open. | Essentials | Project Control |
| SRR.EC.02 | SRR | Agenda | A preliminary SRR agenda, success criteria, and instructions to the review board have been agreed to by the technical team, project manager, and review chair prior to the SRR. | Essentials | Project Control |
| SRR.EC.03 | SRR | Reviews | All planned higher level SRR and peer reviews have been successfully conducted and RID/RFA/Action Items have been addressed with the concurrence of the originators. | Essentials | Project Control |
| SRR.EC.04 | SRR | Programmatic Products | Programmatic products are ready for review at the maturity levels stated in the governing program/project management NPR. | Essentials | Project Control |
| SRR.EC.05 | SRR | Primary Products | The following primary technical products for hardware and software system elements are available to the cognizant participants prior to the review: | Essentials | |
| SRR.EC.05.A | SRR | System Requirements | Requirements for system being reviewed are ready to be baselined after the review and preliminary allocation to the next lower level system has been performed. | Essentials | Requirements Engineering |
| SRR.EC.05.B | SRR | SEMP | For projects and single-project programs, the SEMP is ready to be baselined after review comments are incorporated. | Essentials | Project Control |
| SRR.EC.06 | SRR | Technical Products | Other SRR work products (as applicable) for hardware, software, and human system elements have been made available to the cognizant participants. | Essentials | |
| SRR.EC.06.A | SRR | Mission Concept | Updated concept definition. | Essentials | Decisions |
| SRR.EC.06.B | SRR | Mission Operations | Updated concept of operations. | Essentials | Operations |
| SRR.EC.06.C | SRR | Parent Requirements | Updated parent requirements. | Essentials | Requirements Engineering |
| SRR.EC.06.D | SRR | Risk Management Plan | Risk management plan ready to be baselined after review comments are incorporated. | Essentials | Project Control |
| SRR.EC.06.E | SRR | Risk Assessment and Mitigation | Updated risk assessment and mitigations. | Essentials | Safety and Mission Assurance |
| SRR.EC.06.F | SRR | Configuration Management Plan | Configuration management plan ready to be baselined after review comments are incorporated. | Essentials | Project Control |
| SRR.EC.06.G | SRR | Document Tree | Initial document tree or model structure. | Essentials | Technical Solutions |
| SRR.EC.06.H | SRR | V and V Approach | Preliminary verification and validation method identified for each requirement. | Essentials | Realization |
| SRR.EC.06.I | SRR | Safety Analysis | Preliminary system safety analysis. | Essentials | Safety and Mission Assurance |
| SRR.EC.06.J | SRR | Key Performance Parameters | Preliminary MOPS and TPM and other key driving requirements. | Essentials | Requirements Engineering |

Table 7: Phase A Facets

| Number | Review | Evidence Name | Description | Facet Type | Facet |
|---|---|---|---|---|---|
| SRR.EC.06.K | SRR | Specialty Disciplines | Other specialty discipline analyses, as required. | Essentials | Technical Solutions |
| SRR.EC.06.L | SRR | Cost and Schedule Estimates | Updated cost and schedule estimates for the project implementation. | Essentials | Project Control |
| SRR.EC.06.M | SRR | Basis of Estimate | Updated documentation of Basis of Estimate (cost and schedule). | Essentials | Project Control |
| SRR.EC.06.N | SRR | Technology Development Plan | Updated Technology Development Plan. | Essentials | Project Control |
| SRR.EC.06.O | SRR | TRL Assessment | Updated technology readiness that has been assessed and documented with technology assets, heritage products, and gaps identified. | Essentials | Technical Solutions |
| SRR.EC.06.P | SRR | Support Strategy | Logistics documentation (e.g., preliminary maintenance plan). | Essentials | Operations |
| SRR.EC.06.Q | SRR | Human Rating Certification | Initial Human Rating Certification Package. | Essentials | Safety and Mission Assurance |
| SRR.EC.06.R | SRR | Human Systems Integration Plan | Human Systems Integration Plan (HSIP) ready to be baselined after review comments are incorporated. | Essentials | Project Control |
| SRR.EC.06.S | SRR | SMA Plan | System safety and mission assurance plan ready to be baselined after review comments are incorporated. | Essentials | Safety and Mission Assurance |
| SRR.EC.06.T | SRR | Mission Operations | Preliminary operations concept. | Essentials | Operations |
| SRR.EC.06.U | SRR | Engineering Development Assessment | Preliminary engineering development assessment and technical plans to achieve what needs to be accomplished in the next phase. | Essentials | Technical Solutions |
| SRR.EC.06.V | SRR | Software Products | Software criteria and products, per the NASA-HDBK-2203, NASA Software Engineering Handbook. | Essentials | Technical Solutions |
| SRR.SC.00 | SRR | SRR Success Criteria | These are Success Criteria for SRR | Assessments | |
| SRR.SC.01 | SRR | System Requirements | The functional and performance requirements defined for the system are responsive to the parent requirements and represent achievable capabilities. | Assessments | Technical Approach |
| SRR.SC.02 | SRR | Requirement Maturity | The maturity of the requirements definition and associated plans is sufficient to begin Phase B. | Assessments | Technical Approach |
| SRR.SC.03 | SRR | Requirement Allocation | The project utilizes a sound process for the allocation and control of requirements throughout all levels, and a plan has been defined to complete the requirements definition at lower levels within schedule constraints. | Assessments | Management Approach |
| SRR.SC.04 | SRR | Interfaces | Interfaces with external entities and between major internal elements have been identified. | Assessments | Technical Approach |
| SRR.SC.05 | SRR | V and V Approach | Preliminary approaches have been determined for how requirements will be verified and validated. | Assessments | Technical Approach |

Table 7: Phase A Facets

| Number | Review | Evidence Name | Description | Facet Type | Facet |
|---|---|---|---|---|---|
| SRR.SC.06 | SRR | Risk Assessment and Mitigation | Major risks have been identified and technically assessed, and viable mitigation strategies have been defined. | Assessments | Risk Management Approach |
| SRR.SC.07 | SRR | Compliance with Guidance | The program/project has demonstrated compliance with applicable NASA and implementing Center requirements, standards, processes, and procedures. | Assessments | Management Approach |
| SRR.SC.08 | SRR | TBD/TBR Disposition | TBD and TBR items are clearly identified with acceptable plans and schedule for their disposition. | Assessments | Management Approach |
| SRR.SC.09 | SRR | Software | Software components meet the exit criteria defined in NASA-HDBK-2203, NASA Software Engineering Handbook. | Assessments | Technical Approach |
| SDR.EC.00 | SDR | SDR Entrance Criteria | These are Entrance Criteria for SDR. | Essentials | |
| SDR.EC.01 | SDR | Milestones | The project has successfully completed the previously planned milestone reviews and responses have been made to all RFAs and RIDs, or a timely closure plan exists for those items remaining open. | Essentials | Project Control |
| SDR.EC.02 | SDR | Agenda | A preliminary MDR/SDR agenda, success criteria, and instructions to the review board have been agreed to by the technical team, project manager, and review chair prior to the MDR/SDR. | Essentials | Project Control |
| SDR.EC.03 | SDR | Reviews | All planned higher level MDR/SDR and peer reviews have been successfully conducted and RID/RFA/Action Items have been addressed with the concurrence of the originators. | Essentials | Project Control |
| SDR.EC.04 | SDR | Programmatic Products | Programmatic products are ready for review at the maturity levels stated in the governing program/project management NPR. | Essentials | Project Control |
| SDR.EC.05 | SDR | Primary Products | The following primary technical products for hardware, software, and human system elements are available to the cognizant participants prior to the review: | Essentials | |
| SDR.EC.05.A | SDR | Architecture | Defined architecture, including major tradeoffs and options ready to be baselined after review comments are incorporated. | Essentials | Decisions |
| SDR.EC.05.B | SDR | Requirement Allocation | Allocation of requirements to next lower level ready to be baselined after review comments is incorporated. | Essentials | Requirements Engineering |
| SDR.EC.05.C | SDR | Key Performance Parameters | MOPs, TPM, and other key driving requirement ready to be approved. | Essentials | Requirements Engineering |
| SDR.EC.05.D | SDR | Trends | Initial trending information on the mass margins (for projects involving hardware), power margins (for projects that are powered) and closure of review actions (RFA, RID, and/or Action Items). | Essentials | Technical Solutions |
| SDR.EC.06 | SDR | Technical Products | Other MDR/SDR technical products listed below for both hardware and software system elements have been made available to the cognizant participants prior to the review: | Essentials | |
| SDR.EC.06.A | SDR | Functional Allocation | Supporting analyses, functional/timing descriptions, and allocations of functions to architecture elements. | Essentials | Technical Solutions |
| SDR.EC.06.B | SDR | SEMP | Updated SEMP. | Essentials | Project Control |
| SDR.EC.06.C | SDR | Risk Management Plan | Updated risk management plan. | Essentials | Project Control |

Table 7: Phase A Facets

| Number | Review | Evidence Name | Description | Facet Type | Facet |
|---|---|---|---|---|---|
| SDR.EC.06.D | SDR | Risk Assessment and Mitigation | Updated risk assessment and mitigations (if required by the governing PM NPR, including PRA). | Essentials | Safety and Mission Assurance |
| SDR.EC.06.E | SDR | Technology Development Plan | Updated Technology Development Plan. | Essentials | Project Control |
| SDR.EC.06.F | SDR | TRL Assessment | Updated technology readiness that has been assessed and documented with technology assets, heritage products, and gaps identified. | Essentials | Technical Solutions |
| SDR.EC.06.G | SDR | Basis of Estimate | Updated cost and schedule data with ranges and a basis of the estimates. | Essentials | Project Control |
| SDR.EC.06.H | SDR | Support Strategy | Preliminary Integrated Logistics Support Plan (ILSP). | Essentials | Operations |
| SDR.EC.06.I | SDR | Human Rating Certification | Updated Human Rating Certification Package. | Essentials | Safety and Mission Assurance |
| SDR.EC.06.J | SDR | Interfaces | Preliminary interface definitions. | Essentials | Requirements Engineering |
| SDR.EC.06.K | SDR | Margins | Initial technical resource utilization estimates and margins. | Essentials | Technical Solutions |
| SDR.EC.06.L | SDR | SMA Plan | Updated safety and mission assurance (SandMA) plan. | Essentials | Safety and Mission Assurance |
| SDR.EC.06.M | SDR | Human Systems Integration Plan | Updated HSIP. | Essentials | Project Control |
| SDR.EC.06.N | SDR | Mission Operations | Preliminary operations concept. | Essentials | Operations |
| SDR.EC.06.O | SDR | Safety Analysis | Preliminary system safety analysis. | Essentials | Safety and Mission Assurance |
| SDR.EC.06.P | SDR | Software Products | Software criteria and products, per NASA-HDBK-2203, NASA Software Engineering Handbook. | Essentials | Technical Solutions |
| SDR.SC.00 | SDR | SDR Success Criteria | These are Success Criteria for SDR. | Assessments | |
| SDR.SC.01 | SDR | Credible | The proposed mission/system architecture is credible and responsive to program requirements and constraints, including resources. | Assessments | Technical Approach |
| SDR.SC.02 | SDR | Feasibility | The mission can likely be achieved within available resources with acceptable risk. | Assessments | Technical Approach |
| SDR.SC.03 | SDR | Project Maturity | The project's mission/system definition and associated plans are sufficiently mature to begin Phase B. | Assessments | Technical Approach |
| SDR.SC.04 | SDR | Requirement Allocation | All technical requirements are allocated to the architectural elements. | Assessments | Technical Approach |
| SDR.SC.05 | SDR | Architecture Trades | The architecture tradeoffs are completed, and those planned for Phase B adequately address the option space. | Assessments | Technical Approach |

Table 7: Phase A Facets

| Number | Review | Evidence Name | Description | Facet Type | Facet |
|---|---|---|---|---|---|
| SDR.SC.06 | SDR | Risk Assessment and Mitigation | Significant development, mission, and health and safety risks are identified and technically assessed, and a process and resources exist to manage the risks. | Assessments | Risk Management Approach |
| SDR.SC.07 | SDR | Technology Development Plan | Adequate planning exists for the development of any enabling new technology. | Assessments | Management Approach |
| SDR.SC.08 | SDR | Mission Operations | The operations concept is consistent with proposed design concept(s) and is in alignment with the mission requirements. | Assessments | Technical Approach |
| SDR.SC.09 | SDR | Compliance with Guidance | The program/project has demonstrated compliance with applicable NASA and implementing Center requirements, standards, processes, and procedures. | Assessments | Management Approach |
| SDR.SC.10 | SDR | TBD/TBR Disposition | TBD and TBR items are clearly identified with acceptable plans and schedule for their disposition. | Assessments | Management Approach |
| SDR.SC.11 | SDR | Software | Software components meet the exit criteria defined in NASA-HDBK-2203, NASA Software Engineering Handbook. | Assessments | Technical Approach |

Table 8: Phase B Facets

| Number | Review | Evidence Name | Description | Facet Type | Facet |
|---|---|---|---|---|---|
| PDR.EC.00 | PDR | PDR Entrance Criteria | These are Entrance Criteria for PDR. | Essentials | |
| PDR.EC.01 | PDR | Milestones | The Project has successfully completed the previous planned milestone reviews, and responses have been made to all RFAs and RIDs, or a timely closure plan exists for those remaining open. | Essentials | Project Control |
| PDR.EC.02 | PDR | Agenda | A preliminary PDR agenda, success criteria, and instructions to the review board have been agreed to by the technical team, project manager, and review chair prior to the PDR. | Essentials | Project Control |
| PDR.EC.03 | PDR | Reviews | All planned lower level PDRs and peer reviews have been successfully conducted and RID/RFA/Action Items have been addressed with the concurrence of the originators. | Essentials | Project Control |
| PDR.EC.04 | PDR | Programmatic Products | Programmatic products are ready for review at the maturity levels stated in the governing program/project management NPR. | Essentials | Project Control |
| PDR.EC.05 | PDR | Primary Products | The following primary products are ready for review: | Essentials | |
| PDR.EC.05.A | PDR | Preliminary Design | A preliminary design that can be shown to meet requirements and key technical performance measures. | Essentials | Technical Solutions |
| PDR.EC.05.B | PDR | Trends | Updated trending information on the mass margins (for projects involving hardware), power margins (for projects that are powered), and closure of review actions (RFA, RID, and/or Action Items). | Essentials | Technical Solutions |
| PDR.EC.06 | PDR | Technical Products | Other PDR technical products (as applicable) for hardware, software, and human system elements have been made available to the cognizant participants prior to the review: | Essentials | |
| PDR.EC.06.A | PDR | Specifications | Subsystem design specifications (hardware and software), with supporting trade-off analyses and data, as required, that are ready to be baselined after review comments are incorporated. | Essentials | Technical Solutions |
| PDR.EC.06.B | PDR | TRL Assessment | Updated technology readiness assessment. | Essentials | Technical Solutions |
| PDR.EC.06.C | PDR | Technology Development Plan | Updated Technology Development Plan. | Essentials | Project Control |
| PDR.EC.06.D | PDR | Risk Assessment and Mitigation | Updated risk assessment and mitigation. | Essentials | Safety and Mission Assurance |
| PDR.EC.06.E | PDR | Cost and Schedule | Life-Cycle Cost and Integrated Master Schedule (IMS) that are ready to be baselined after review comments are incorporated. When required, the Joint Confidence Level (JCL) analysis. | Essentials | Project Control |
| PDR.EC.06.F | PDR | Support Strategy | Baseline ILSP. | Essentials | Operations |
| PDR.EC.06.G | PDR | Technical Planning | Applicable technical plans that are ready to be baselined after review comments are incorporated (e.g., technical performance measurement plan, contamination control plan, parts management plan, environments control plan, Electromagnetic Interference/ Electromagnetic Compatibility (EMI/EMC) control plan, payload-to-carrier integration plan, producibility/manufacturability program plan, reliability program plan, quality assurance plan). | Essentials | Project Control |
| PDR.EC.06.H | PDR | Standards | Applicable standards that have been identified and incorporated. | Essentials | Project Control |
| PDR.EC.06.I | PDR | Safety Analysis | Updated safety analyses and plans. | Essentials | Safety and Mission Assurance |

Table 8: Phase B Facets

| Number | Review | Evidence Name | Description | Facet Type | Facet |
|---|---|---|---|---|---|
| PDR.EC.06.J | PDR | Document Tree | Preliminary engineering drawing tree. | Essentials | Technical Solutions |
| PDR.EC.06.K | PDR | Interfaces | Interface control documents that are ready to be baselined after review comments are incorporated. | Essentials | Requirements Engineering |
| PDR.EC.06.L | PDR | V and V Plan | Verification/validation plan that is ready to be baselined after review comments are incorporated. | Essentials | Project Control |
| PDR.EC.06.M | PDR | Regulatory Plans | Plans to respond to regulatory requirements (e.g., Environmental Impact Statement), as required, that are ready to be baselined after review comments are incorporated. | Essentials | Project Control |
| PDR.EC.06.N | PDR | Disposal Plan | Preliminary Disposal Plan. | Essentials | Project Control |
| PDR.EC.06.O | PDR | Margins | Updated technical resource utilization estimates and margins. | Essentials | Technical Solutions |
| PDR.EC.06.P | PDR | Mission Operations | Baseline operations concept. | Essentials | Operations |
| PDR.EC.06.Q | PDR | Human Systems Integration Plan | Updated Human Systems Integration Plan. | Essentials | Project Control |
| PDR.EC.06.R | PDR | Human Rating Certification | Updated Human Rating Certification Package. | Essentials | Safety and Mission Assurance |
| PDR.EC.06.S | PDR | Software Products | Software criteria and products, per NASA-HDBK-2203, NASA Software Engineering Handbook. | Essentials | Technical Solutions |
| PDR.SC.00 | PDR | PDR Success Criteria | These are Success Criteria for PDR. | Assessments | |
| PDR.SC.01 | PDR | System Requirements | The top-level requirements including mission success criteria, TPMs, and any sponsor-imposed constraints are agreed upon, finalized, stated clearly, and consistent with the preliminary design. | Assessments | Technical Approach |
| PDR.SC.02 | PDR | Requirement Allocation | The flow down of verifiable requirements is complete and proper or, if not, an adequate plan exists for timely resolution of open items. Requirements are traceable to mission goals and objectives. | Assessments | Technical Approach |
| PDR.SC.03 | PDR | Cost and Schedule | The program cost, schedule, and JCL analysis (when required) are credible and within program constraints and ready for NASA commitment. | Assessments | Cost Schedule and Funding Strategy |
| PDR.SC.04 | PDR | Preliminary Design | The preliminary design is expected to meet the requirements at an acceptable level of risk. | Assessments | Technical Approach |
| PDR.SC.05 | PDR | Interfaces | Definition of the technical interfaces (both external entities and between internal elements) is consistent with the overall technical maturity and provides an acceptable level of risk. | Assessments | Technical Approach |
| PDR.SC.06 | PDR | Technology Development Plan | Any required new technology has been developed to an adequate state of readiness, or backup options exist and are supported to make them viable alternatives. | Assessments | Technical Approach |
| PDR.SC.07 | PDR | Risk Assessment and Mitigation | The project risks are understood and have been credibly assessed, and plans, a process, and resources exist to effectively manage them. | Assessments | Risk Management Approach |

Table 8: Phase B Facets

| Number | Review | Evidence Name | Description | Facet Type | Facet |
|---|---|---|---|---|---|
| PDR.SC.08 | PDR | SMA Products | Safety and mission assurance (e.g., safety, reliability, maintainability, quality, and Electrical, Electronic, and Electromechanical (EEE) parts) have been adequately addressed in preliminary designs and any applicable SandMA products (e.g., PRA, system safety analysis, and failure modes and effects analysis) meet requirements, are at the appropriate maturity level for this phase of the program's life cycle, and indicate that the program safety/reliability residual risks will be at an acceptable level. | Assessments | Risk Management Approach |
| PDR.SC.09 | PDR | Margins | Adequate technical and programmatic margins (e.g., mass, power, memory) and resources exist to complete the development within budget, schedule, and known risks. | Assessments | Resource Availability |
| PDR.SC.10 | PDR | Mission Operations | The operational concept is technically sound, includes (where appropriate) human systems, and includes the flow down of requirements for its execution. | Assessments | Technical Approach |
| PDR.SC.11 | PDR | Technical Trade Studies | Technical trade studies are mostly complete to sufficient detail and remaining trade studies are identified, plans exist for their closure, and potential impacts are understood. | Assessments | Technical Approach |
| PDR.SC.12 | PDR | Compliance with Guidance | The program/project has demonstrated compliance with applicable NASA and implementing Center requirements, standards, processes, and procedures. | Assessments | Management Approach |
| PDR.SC.13 | PDR | TBD/TBR Disposition | TBD and TBR items are clearly identified with acceptable plans and schedule for their disposition. | Assessments | Management Approach |
| PDR.SC.14 | PDR | Specifications | Preliminary analysis of the primary subsystems has been completed and summarized, highlighting performance and design margin challenges. | Assessments | Technical Approach |
| PDR.SC.15 | PDR | Modeling | Appropriate modeling and analytical results are available and have been considered in the design. | Assessments | Technical Approach |
| PDR.SC.16 | PDR | Heritage Designs | Heritage designs have been suitably assessed for applicability and appropriateness. | Assessments | Technical Approach |
| PDR.SC.17 | PDR | Manufacturability | Manufacturability has been adequately included in design. | Assessments | Technical Approach |
| PDR.SC.18 | PDR | Software | Software components meet the exit criteria defined in NASA-HDBK-2203, NASA Software Engineering Handbook. | Assessments | Technical Approach |

Table 9: Phase C Facets

| Number | Review | Evidence Name | Description | Facet Type | Facet |
|---|---|---|---|---|---|
| CDR.EC.00 | CDR | CDR Entrance Criteria | These are Entrance Criteria for CDR. | Essentials | |
| CDR.EC.01 | CDR | Milestones | The project has successfully completed the previous planned milestone reviews, and responses have been made to all RFAs and RIDs or a timely closure plan exists for those remaining open. | Essentials | Project Control |
| CDR.EC.02 | CDR | Agenda | A preliminary CDR agenda, success criteria, and instructions to the review board have been agreed to by the technical team, project manager, and review chair prior to the CDR. | Essentials | Project Control |
| CDR.EC.03 | CDR | Reviews | All planned lower level CDRs and peer reviews have been successfully conducted, and RID/RFA/Action Items have been addressed with the concurrence of the originators. | Essentials | Project Control |
| CDR.EC.04 | CDR | Programmatic Products | Programmatic products are ready for review at the maturity levels stated in the governing program/project management NPR. | Essentials | Project Control |
| CDR.EC.05 | CDR | Primary Products | The following primary products are ready for review: | Essentials | |
| CDR.EC.05.A | CDR | Detailed Design | A baselined detailed design that can be shown to meet requirements and key technical performance measures. | Essentials | Technical Solutions |
| CDR.EC.05.B | CDR | Trends | Updated trending information on the mass margins (for projects involving hardware), power margins (for projects that are powered), and closure of review actions (RFA, RID and/or Action Items). | Essentials | Technical Solutions |
| CDR.EC.06 | CDR | Technical Products | Other CDR technical work products (as applicable) for hardware, software, and human system elements have been made available to the cognizant participants prior to the review: | Essentials | |
| CDR.EC.06.A | CDR | Specifications | Product build-to specifications along with supporting trade-off analyses and data that are ready to be baselined after review comments are incorporated. | Essentials | Technical Solutions |
| CDR.EC.06.B | CDR | AI&T Plans | Fabrication, assembly, integration, and test plans and procedures are being developed and are ready to be baselined after review comments are incorporated. | Essentials | Realization |
| CDR.EC.06.C | CDR | Document and Drawings | Technical data package (e.g., integrated schematics, spares provisioning list, interface control documents, engineering analyses, and specifications). | Essentials | Technical Solutions |
| CDR.EC.06.D | CDR | Mission Operations | Defined operational limits and constraints. | Essentials | Technical Solutions |
| CDR.EC.06.E | CDR | Margins | Updated technical resource utilization estimates and margins. | Essentials | Technical Solutions |
| CDR.EC.06.F | CDR | Acceptance Plans | Acceptance plans that are ready to be baselined after review comments are incorporated. | Essentials | Project Control |
| CDR.EC.06.G | CDR | Command and Telemetry Lists | Command and telemetry list. | Essentials | Technical Solutions |
| CDR.EC.06.H | CDR | V and V Plan | Updated verification plan. | Essentials | Project Control |
| CDR.EC.06.I | CDR | V and V Plan | Updated validation plan. | Essentials | Project Control |
| CDR.EC.06.J | CDR | Launch Site Operations Plan | Preliminary launch site operations plan. | Essentials | Project Control |
| CDR.EC.06.K | CDR | Checkout and Activation Plan | Preliminary checkout and activation plan. | Essentials | Project Control |
| CDR.EC.06.L | CDR | Disposal Plan | Preliminary disposal plan (including decommissioning or termination). | Essentials | Project Control |

Table 9: Phase C Facets

| Number | Review | Evidence Name | Description | Facet Type | Facet |
|---|---|---|---|---|---|
| CDR.EC.06.M | CDR | TRL Assessment | Updated technology readiness assessment. | Essentials | Technical Solutions |
| CDR.EC.06.N | CDR | Technology Development Plan | Updated Technology Development Plan. | Essentials | Project Control |
| CDR.EC.06.O | CDR | Risk Assessment and Mitigation | Updated risk assessment and mitigation. | Essentials | Safety and Mission Assurance |
| CDR.EC.06.P | CDR | Human Systems Integration Plan | Updated Human Systems Integration Plan (HSIP). | Essentials | Project Control |
| CDR.EC.06.Q | CDR | Human Rating Certification | Updated Human Rating Certification Package. | Essentials | Safety and Mission Assurance |
| CDR.EC.06.R | CDR | SMA Products | Updated reliability analyses and assessments. | Essentials | Safety and Mission Assurance |
| CDR.EC.06.S | CDR | Cost and Schedule | Updated Life-Cycle Costs and IMS. | Essentials | Project Control |
| CDR.EC.06.T | CDR | Support Strategy | Updated ILSP. | Essentials | Operations |
| CDR.EC.06.U | CDR | Safety Analysis | Subsystem-level and preliminary operations safety analyses that are ready to be baselined after review comments are incorporated. | Essentials | Safety and Mission Assurance |
| CDR.EC.06.V | CDR | Certification Plans | Systems and subsystem certification plans and requirements (as needed) that are ready to be baselined after review comments are incorporated. | Essentials | Safety and Mission Assurance |
| CDR.EC.06.W | CDR | Safety Analysis | System safety analysis with associated verifications that is ready to be baselined after review comments are incorporated. | Essentials | Safety and Mission Assurance |
| CDR.EC.06.X | CDR | Software Products | Software criteria and products, per NASA-HDBK-2203, NASA Software Engineering Handbook. | Essentials | Technical Solutions |
| CDR.SC.00 | CDR | CDR Success Criteria | These are Success Criteria for CDR. | Assessments | |
| CDR.SC.01 | CDR | Detailed Design | The detailed design is expected to meet the requirements with adequate margins. | Assessments | Technical Approach |
| CDR.SC.02 | CDR | Interfaces | Interface control documents are sufficiently mature to proceed with fabrication, assembly, integration, and test, and plans are in place to manage any open items. | Assessments | Technical Approach |
| CDR.SC.03 | CDR | Cost and Schedule | The program cost and schedule estimates are credible and within program constraints. | Assessments | Cost Schedule and Funding Strategy |
| CDR.SC.04 | CDR | Project Maturity | High confidence exists in the product baseline, and adequate documentation exists or will exist in a timely manner to allow proceeding with fabrication, assembly, integration, and test. | Assessments | Technical Approach |
| CDR.SC.05 | CDR | V and V Approach | The product verification and product validation requirements and plans are complete. | Assessments | Technical Approach |

Table 9: Phase C Facets

| Number | Review | Evidence Name | Description | Facet Type | Facet |
|---|---|---|---|---|---|
| CDR.SC.06 | CDR | AI&T Plans | The testing approach is comprehensive, and the planning for system assembly, integration, test, and launch site and mission operations is sufficient to progress into the next phase. | Assessments | Technical Approach |
| CDR.SC.07 | CDR | Margins | Adequate technical and programmatic margins (e.g., mass, power, memory) and resources exist to complete the development within budget, schedule, and known risks. | Assessments | Resource Availability |
| CDR.SC.08 | CDR | Risk Assessment and Mitigation | Risks to mission success are understood and credibly assessed, and plans and resources exist to effectively manage them. | Assessments | Risk Management Approach |
| CDR.SC.09 | CDR | SMA Products | Safety and mission assurance (e.g., safety, reliability, maintainability, quality, and EEE parts) have been adequately addressed in system and operational designs, and any applicable SandMA products (e.g., PRA, system safety analysis, and failure modes and effects analysis) meet requirements, are at the appropriate maturity level for this phase of the program's life cycle, and indicate that the program safety/reliability residual risks will be at an acceptable level. | Assessments | Risk Management Approach |
| CDR.SC.10 | CDR | Compliance with Guidance | The program/project has demonstrated compliance with applicable NASA and implementing Center requirements, standards, processes, and procedures. | Assessments | Management Approach |
| CDR.SC.11 | CDR | TBD/TBR Disposition | TBD and TBR items are clearly identified with acceptable plans and schedule for their disposition. | Assessments | Management Approach |
| CDR.SC.12 | CDR | Testing | Engineering test units, life test units, and/or modeling and simulations have been developed and tested per plan. | Assessments | Technical Approach |
| CDR.SC.13 | CDR | Material Properties | Material properties tests are completed along with analyses of loads, stress, fracture control, contamination generation, etc. | Assessments | Technical Approach |
| CDR.SC.14 | CDR | SMA Products | EEE parts have been selected, and planned testing and delivery will support build schedules. | Assessments | Technical Approach |
| CDR.SC.15 | CDR | Mission Operations | The operational concept has matured, is at a CDR level of detail, and has been considered in test planning. | Assessments | Technical Approach |
| CDR.SC.16 | CDR | Manufacturability | Manufacturability has been adequately included in design. | Assessments | Technical Approach |
| CDR.SC.17 | CDR | Software | Software components meet the exit criteria defined in NASA-HDBK-2203, NASA Software Engineering Handbook. | Assessments | Technical Approach |
| PRR.EC.00 | PRR | PPR Entrance Criteria | These are Entrance Criteria for PPR. | Essentials | |
| PRR.EC.01 | PRR | Production Engineering | The significant production engineering problems and nonconformances encountered during development are resolved. | Essentials | Realization |
| PRR.EC.02 | PRR | Design Documentation | The design documentation needed to support production is available. | Essentials | Technical Solutions |
| PRR.EC.03 | PRR | Production Plans | The production plans and preparation to begin fabrication are developed. | Essentials | Project Control |
| PRR.EC.04 | PRR | MGSE and EGSE | The production-enabling products are ready. | Essentials | Realization |
| PRR.EC.05 | PRR | Resources | Resources are available, have been allocated, and are ready to support end product production. | Essentials | Realization |
| PRR.EC.06 | PRR | Cost and Schedule | Updated costs and schedules. | Essentials | Project Control |

Table 9: Phase C Facets

| Number | Review | Evidence Name | Description | Facet Type | Facet |
|---|---|---|---|---|---|
| PRR.EC.07 | PRR | Risk Assessment and Mitigation | Risks have been identified, credibly assessed, and characterized, and mitigation efforts have been defined. | Essentials | Safety and Mission Assurance |
| PRR.EC.08 | PRR | Bill of Materials | The bill of materials is available and critical parts identified. | Essentials | Realization |
| PRR.EC.09 | PRR | Delivery Schedules | Delivery schedules are available. | Essentials | Realization |
| PRR.EC.10 | PRR | Inspections | In-process inspections have been identified and planned. | Essentials | Safety and Mission Assurance |
| PRR.EC.11 | PRR | Software Products | Software criteria and products, per NASA-HDBK-2203, NASA Software Engineering Handbook. | Essentials | Technical Solutions |
| PRR.SC.00 | PRR | PPR Success Criteria | These are Success Criteria for PPR. | Assessments | |
| PRR.SC.01 | PRR | Project Maturity | High confidence exists that the system requirements will be met in the final production configuration. | Assessments | Technical Approach |
| PRR.SC.02 | PRR | Margins | Adequate resources are in place to support production. | Assessments | Resource Availability |
| PRR.SC.03 | PRR | Cost and Schedule | The program cost and schedule estimates are credible and within program constraints. | Assessments | Cost Schedule and Funding Strategy |
| PRR.SC.04 | PRR | Manufacturability | Design-for-manufacturing considerations have been incorporated to ensure ease and efficiency of production and assembly. | Assessments | Technical Approach |
| PRR.SC.05 | PRR | Compliance with Guidance | The product is deemed manufacturable. Evidence is provided that the program/project is compliant with NASA and Implementing Center requirements, standards, processes, and procedures. | Assessments | Technical Approach |
| PRR.SC.06 | PRR | TBD/TBR Disposition | TBD and TBR items are clearly identified, with acceptable plans and schedule for their disposition. Alternate sources for resources have been identified for key items. | Assessments | Management Approach |
| PRR.SC.07 | PRR | Support Strategy | Adequate spares have been planned and budgeted. | Assessments | Cost Schedule and Funding Strategy |
| PRR.SC.08 | PRR | Facilities | Required facilities and tools are sufficient for end product production. | Assessments | Resource Availability |
| PRR.SC.09 | PRR | MGSE and EGSE | Specified special tools and test equipment are available in proper quantities. | Assessments | Resource Availability |
| PRR.SC.10 | PRR | Training | Production and support staff are qualified. | Assessments | Resource Availability |
| PRR.SC.11 | PRR | Certification | Drawings and/or production models are approved/certified. | Assessments | Technical Approach |
| PRR.SC.12 | PRR | Production Engineering | Production engineering and planning are sufficiently mature for cost-effective production. | Assessments | Cost Schedule and Funding Strategy |
| PRR.SC.13 | PRR | SMA Products | Production processes and methods are consistent with quality requirements and compliant with occupational health and safety, environmental, and energy conservation regulations. | Assessments | Management Approach |

Table 9: Phase C Facets

| Number | Review | Evidence Name | Description | Facet Type | Facet |
|---|---|---|---|---|---|
| PRR.SC.14 | PRR | Qualified Suppliers | Qualified suppliers are available for materials that are to be procured. | Assessments | Resource Availability |
| PRR.SC.15 | PRR | Software | Software components meet the exit criteria defined in NASA-HDBK-2203, NASA Software Engineering Handbook. | Assessments | Technical Approach |
| SIR.EC.00 | SIR | SIR Entrance Criteria | These are Entrance Criteria for SIR. | Essentials | |
| SIR.EC.01 | SIR | Milestones | The project has successfully completed the previous planned milestone reviews, and responses have been made to all RFAs and RIDs or a timely closure plan exists for those remaining open. | Essentials | Project Control |
| SIR.EC.02 | SIR | Agenda | A preliminary SIR agenda, success criteria, and instructions to the review board have been agreed to by the technical team, project manager, and review chair prior to the SIR. | Essentials | Project Control |
| SIR.EC.03 | SIR | Primary Products | The following primary products are ready for review: | Essentials | |
| SIR.EC.03.A | SIR | Technical Planning | Integration plans baselined at PDR that have been updated and approved. | Essentials | Project Control |
| SIR.EC.03.B | SIR | Trends | Updated trending information on the mass margins (for projects involving hardware), power margins (for projects that are powered), and closure of review actions (RFA, RID, and/or Action Items). | Essentials | Technical Solutions |
| SIR.EC.03.C | SIR | V and V Results | Preliminary VandV results from any lower tier products that have been verified. | Essentials | Realization |
| SIR.EC.04 | SIR | Programmatic Products | Programmatic products are ready for review at the maturity levels stated in the governing program/project management NPR. | Essentials | Project Control |
| SIR.EC.05 | SIR | Procedures | Integration procedures have been identified and are scheduled for completion prior to their need dates. | Essentials | Realization |
| SIR.EC.06 | SIR | | Segments and/or components are on schedule to be available for integration. | Essentials | Realization |
| SIR.EC.07 | SIR | Interfaces | Mechanical and electrical interfaces for hardware necessary to start system integration have been verified against the interface control documentation and plans for verification of remaining hardware exist. | Essentials | Realization |
| SIR.EC.08 | SIR | Qualification Tests | All functional, unit-level, subsystem, and qualification testing has been conducted successfully or is on track to be conducted prior to scheduled integration. | Essentials | Realization |
| SIR.EC.09 | SIR | Facilities | Integration facilities, including clean rooms, ground support equipment, handling fixtures, overhead cranes, and electrical test equipment, are ready or will be available when required. | Essentials | Realization |
| SIR.EC.10 | SIR | Training | Support personnel have been trained. | Essentials | Safety and Mission Assurance |
| SIR.EC.11 | SIR | SMA Products | Handling and safety requirements have been documented. | Essentials | Safety and Mission Assurance |
| SIR.EC.12 | SIR | Discrepancies | All known system discrepancies have been identified, dispositioned, and are on schedule for closure. | Essentials | Safety and Mission Assurance |

Table 9: Phase C Facets

| Number | Review | Evidence Name | Description | Facet Type | Facet |
|---|---|---|---|---|---|
| SIR.EC.13 | SIR | Quality Control | The quality control organization is ready to support the integration effort. | Essentials | Safety and Mission Assurance |
| SIR.EC.14 | SIR | Technical Products | Other SIR technical products (as applicable) for hardware, software, and human system elements have been made available to the cognizant participants prior to the review: | Essentials | |
| SIR.EC.14.A | SIR | Cost and Schedule | Updated Life-Cycle Costs and IMS. | Essentials | Project Control |
| SIR.EC.14.B | SIR | Design | Updated design solution definition. | Essentials | Technical Solutions |
| SIR.EC.14.C | SIR | Interfaces | Updated interface definition(s). | Essentials | Requirements Engineering |
| SIR.EC.14.D | SIR | V and V Approach | Updated verification and validation plans. | Essentials | Project Control |
| SIR.EC.14.E | SIR | Transportation | Final transportation criteria and instructions. | Essentials | Realization |
| SIR.EC.14.F | SIR | Mission Operations | Preliminary mission operations plans. | Essentials | Operations |
| SIR.EC.14.G | SIR | Decommissioning Plans | Preliminary decommissioning plans. | Essentials | Project Control |
| SIR.EC.14.H | SIR | Disposal Plan | Preliminary disposal plans. | Essentials | Project Control |
| SIR.EC.14.I | SIR | Software Products | Software criteria and products, per NASA-HDBK-2203, NASA Software Engineering Handbook. | Essentials | Technical Solutions |
| SIR.SC.00 | SIR | SIR Success Criteria | These are Success Criteria for SIR. | Assessments | |
| SIR.SC.01 | SIR | AI&T Plans | Integration plans and procedures are on track for completion and approval to support system integration. | Assessments | Technical Approach |
| SIR.SC.02 | SIR | Test Results | Previous component, subsystem, and system test results form a satisfactory basis for proceeding to integration. | Assessments | Technical Approach |
| SIR.SC.03 | SIR | Cost and Schedule | The program cost and schedule estimates are credible and within program constraints. | Assessments | Cost Schedule and Funding Strategy |
| SIR.SC.04 | SIR | Risk Assessment and Mitigation | Risks are identified and accepted by program/project leadership, as required. | Assessments | Risk Management Approach |
| SIR.SC.05 | SIR | Compliance with Guidance | The program/project has demonstrated compliance with applicable NASA and implementing Center requirements, standards, processes, and procedures. | Assessments | Management Approach |
| SIR.SC.06 | SIR | TBD/TBR Disposition | TBD and TBR items are clearly identified with acceptable plans and schedule for their dispositions. | Assessments | Management Approach |
| SIR.SC.07 | SIR | AI&T Plans | The integration procedures and work flow have been clearly defined and documented or are on schedule to be clearly defined and documented prior to their need date. | Assessments | Technical Approach |
| SIR.SC.08 | SIR | AI&T Plans | The review of the integration plans, as well as the procedures, environment, and configuration of the items to be integrated, provides a reasonable expectation that the integration will proceed successfully. | Assessments | Technical Approach |

Table 9: Phase C Facets

| Number | Review | Evidence Name | Description | Facet Type | Facet |
|---|---|---|---|---|---|
| SIR.SC.09 | SIR | Training | Integration personnel have received appropriate training in the integration and health and safety procedures. | Assessments | Resource Availability |
| SIR.SC.10 | SIR | Software Products | Software components meet the exit criteria defined in NASA-HDBK-2203, NASA Software Engineering Handbook. | Assessments | Technical Approach |

Table 10: Phase D Facets

| Number | Review | Evidence Name | Description | Facet Type | Facet |
|---|---|---|---|---|---|
| SAR.EC.00 | SAR | SAR Entrance Criteria | These are Entrance Criteria for SAR. | Essentials | |
| SAR.EC.01 | SAR | Milestones | The project has successfully completed the previous planned milestone reviews, RFA/RIDs have been closed, and plans to complete open work are defined. | Essentials | Project Control |
| SAR.EC.02 | SAR | Agenda | A preliminary SAR agenda, success criteria, and instructions to the review team have been agreed to by the technical team, project manager, and review chair prior to the review. | Essentials | Project Control |
| SAR.EC.03 | SAR | Technical Products | The following SAR technical products have been made available to the cognizant participants prior to the review: | Essentials | |
| SAR.EC.03.A | SAR | Supplier SAR Results | Results of the SARs conducted at the major suppliers. | Essentials | Project Control |
| SAR.EC.03.B | SAR | V and V Results | Product verification results. | Essentials | Realization |
| SAR.EC.03.C | SAR | V and V Results | Product validation results. | Essentials | Realization |
| SAR.EC.03.D | SAR | Acceptance Criteria | Documentation that the delivered system complies with the established acceptance criteria. | Essentials | Realization |
| SAR.EC.03.E | SAR | Performance Documentation | Documentation that the system will perform properly in the expected operational environment. | Essentials | Realization |
| SAR.EC.03.F | SAR | Test Results | Technical data package that has been updated to include all test results. | Essentials | Realization |
| SAR.EC.03.G | SAR | Certification | Final Certification Package. | Essentials | Safety and Mission Assurance |
| SAR.EC.03.H | SAR | Technical Products | Baselined as-built hardware and software documentation. | Essentials | Technical Solutions |
| SAR.EC.03.I | SAR | Risk Assessment and Mitigation | Updated risk assessment and mitigation. | Essentials | Safety and Mission Assurance |
| SAR.EC.03.J | SAR | Transfer Documentation | Required safe shipping, handling, checkout, and operational plans and procedures. | Essentials | Project Control |
| SAR.EC.03.K | SAR | Software Products | Software criteria and products, per NASA-HDBK-2203, NASA Software Engineering Handbook. | Essentials | Technical Solutions |
| SAR.SC.00 | SAR | SAR Success Criteria | These are Success Criteria for SAR. | Assessments | |

Table 10: Phase D Facets

| Number | Review | Evidence Name | Description | Facet Type | Facet |
|---|---|---|---|---|---|
| SAR.SC.01 | SAR | | Required tests and analyses are complete and indicate that the system will perform properly in the expected operational environment. | Assessments | Technical Approach |
| SAR.SC.02 | SAR | Risk Assessment and Mitigation | Risks are known and manageable. | Assessments | Risk Management Approach |
| SAR.SC.03 | SAR | Acceptance Criteria | System meets the established acceptance criteria. | Assessments | Technical Approach |
| SAR.SC.04 | SAR | Compliance with Guidance | The program/project has demonstrated compliance with applicable NASA and implementing Center requirements, standards, processes, and procedures. | Assessments | Management Approach |
| SAR.SC.05 | SAR | TBD/TBR Disposition | TBD and TBR items are resolved. | Assessments | Management Approach |
| SAR.SC.06 | SAR | Technical Products | Technical data package is complete and reflects the delivered system. | Assessments | Technical Approach |
| SAR.SC.07 | SAR | Lessons Learned | All applicable lessons learned for organizational improvement and system operations are captured. | Assessments | Management Approach |
| SAR.SC.08 | SAR | Software | Software components meet the exit criteria defined in NASA-HDBK-2203, NASA Software Engineering Handbook. | Assessments | Technical Approach |
| ORR.EC.00 | ORR | ORR Entrance Criteria | These are Entrance Criteria for ORR. | Essentials | |
| ORR.EC.01 | ORR | | All planned ground-based testing has been completed. | Essentials | Realization |
| ORR.EC.02 | ORR | Anomaly Resolution | Test failures and anomalies from verification and validation testing have been resolved, and the results/mitigations/work-arounds have been incorporated into supporting and enabling operational products. | Essentials | Safety and Mission Assurance |
| ORR.EC.03 | ORR | Resources | All operational supporting and enabling products (e.g., facilities, equipment, documents, software tools, databases) that are necessary for nominal and contingency operations have been tested and delivered/installed at the site(s) necessary to support operations. | Essentials | Operations |
| ORR.EC.04 | ORR | Programmatic Products | Programmatic products are ready for review at the maturity levels stated in the governing program/project management NPR. | Essentials | Project Control |
| ORR.EC.05 | ORR | Operations Documents | Operations documentation (handbook, procedures, etc.) has been written, verified, and approved. | Essentials | Operations |
| ORR.EC.06 | ORR | Training | Users/operators have been trained on the correct operation of the system. | Essentials | Safety and Mission Assurance |
| ORR.EC.07 | ORR | Contingency Plans | Operational contingency planning has been completed, and operations personnel have been trained on their use. | Essentials | Operations |
| ORR.EC.08 | ORR | Primary Products | The following primary products are ready for review: | Essentials | |
| ORR.EC.08.A | ORR | Mission Operations | Updated operations plans. | Essentials | Operations |
| ORR.EC.08.B | ORR | Operations Documents | Updated operational procedures. | Essentials | Operations |
| ORR.EC.08.C | ORR | Decommissioning Plans | Preliminary decommissioning plan. | Essentials | Project Control |

Table 10: Phase D Facets

| Number | Review | Evidence Name | Description | Facet Type | Facet |
|---|---|---|---|---|---|
| ORR.EC.09 | ORR | | Other ORR technical products have been made available to the cognizant participants prior to the review: | Essentials | |
| ORR.EC.09.A | ORR | Cost and Schedule | Updated cost and schedule. | Essentials | Project Control |
| ORR.EC.09.B | ORR | Technical Products | Updated as-built hardware and software documentation. | Essentials | Technical Solutions |
| ORR.EC.09.C | ORR | V and V Results | Preliminary VandV results. | Essentials | Realization |
| ORR.EC.09.D | ORR | Disposal Plan | Preliminary disposal plan. | Essentials | Project Control |
| ORR.EC.09.E | ORR | Certification | Preliminary certification for flight/use. | Essentials | Safety and Mission Assurance |
| ORR.EC.09.F | ORR | Human Rating Certification | Updated Human Rating Certification Package. | Essentials | Safety and Mission Assurance |
| ORR.EC.09.G | ORR | Software Products | Software criteria and products, per NASA-HDBK-2203, NASA Software Engineering Handbook. | Essentials | Technical Solutions |
| ORR.SC.00 | ORR | ORR Success Criteria | These are Success Criteria for ORR. | Assessments | |
| ORR.SC.01 | ORR | Operational Status | The system, including all enabling products, is determined to be ready to be placed in an operational status. | Assessments | Technical Approach |
| ORR.SC.02 | ORR | Lessons Learned | All applicable lessons learned for organizational improvement and systems operations have been captured. | Assessments | Management Approach |
| ORR.SC.03 | ORR | Anomaly Resolution | All waivers and anomalies have been closed. | Assessments | Risk Management Approach |
| ORR.SC.04 | ORR | Training | Systems hardware, software, personnel, and procedures are in place to support operations. | Assessments | Resource Availability |
| ORR.SC.05 | ORR | Operations Documents | Operations plans and schedules are consistent with mission objectives. | Assessments | Technical Approach |
| ORR.SC.06 | ORR | Risk Assessment and Mitigation | Mission risks have been identified, planned mitigations are adequate, and residual risks are accepted by the program/project manager. | Assessments | Risk Management Approach |
| ORR.SC.07 | ORR | Test Results | Testing is consistent with the expected operational environment. | Assessments | Technical Approach |
| ORR.SC.08 | ORR | Compliance with Guidance | The program/project has demonstrated compliance with applicable NASA and implementing Center requirements, standards, processes, and procedures. | Assessments | Management Approach |
| ORR.SC.09 | ORR | TBD/TBR Disposition | TBD and TBR items are resolved. | Assessments | Management Approach |
| ORR.SC.10 | ORR | Software | Software components meet the exit criteria defined in NASA-HDBK-2203, NASA Software Engineering Handbook. | Assessments | Technical Approach |
| FRR.EC.00 | FRR | FRR Entrance Criteria | These are Entrance Criteria for FRR. | Essentials | |

Table 10: Phase D Facets

| Number | Review | Evidence Name | Description | Facet Type | Facet |
|---|---|---|---|---|---|
| FRR.EC.01 | FRR | Project Maturity | The system and support elements are ready and have been properly configured for flight. | Essentials | Operations |
| FRR.EC.02 | FRR | Interfaces | System and support element interfaces have been demonstrated to function as expected. | Essentials | Operations |
| FRR.EC.03 | FRR | System State | The system state supports a launch "go" decision based on the established go/no-go criteria. | Essentials | Operations |
| FRR.EC.04 | FRR | Programmatic Products | Programmatic products are ready for review at the maturity levels stated in the governing program/project management NPR. | Essentials | Project Control |
| FRR.EC.05 | FRR | Anomaly Resolution | Flight failures and anomalies from previously completed flights and reviews have been resolved, and the results/mitigations/work-arounds have been incorporated into supporting and enabling operational products. | Essentials | Safety and Mission Assurance |
| FRR.EC.06 | FRR | | The following primary products are ready for review: | Essentials | |
| FRR.EC.06.A | FRR | Certification | Final certification for flight/use. | Essentials | Safety and Mission Assurance |
| FRR.EC.06.B | FRR | V and V Results | Baselined VandV results. | Essentials | Realization |
| FRR.EC.06.C | FRR | Disposal Plan | Disposal plan that is ready to be baselined after review comments are incorporated. | Essentials | Project Control |
| FRR.EC.06.D | FRR | Technical Products | Other FRR technical products have been made available to the cognizant participants prior to the review: | Essentials | Technical Solutions |
| FRR.EC.06.E | FRR | Cost and Schedule | Updated cost. | Essentials | Project Control |
| FRR.EC.06.F | FRR | Cost and Schedule | Updated schedule. | Essentials | Project Control |
| FRR.EC.06.G | FRR | Technical Products | Updated as-built hardware and software documentation. | Essentials | Technical Solutions |
| FRR.EC.06.H | FRR | Operations Documents | Updated operations procedures. | Essentials | Operations |
| FRR.EC.06.I | FRR | Decommissioning Plans | Preliminary decommissioning plan. | Essentials | Project Control |
| FRR.EC.06.J | FRR | Software Products | Software criteria and products, per NASA-HDBK-2203, NASA Software Engineering Handbook. | Essentials | Technical Solutions |
| FRR.SC.00 | FRR | FRR Success Criteria | These are Success Criteria for FRR. | Assessments | |
| FRR.SC.01 | FRR | System State | The flight vehicle is ready for flight. | Assessments | Technical Approach |
| FRR.SC.02 | FRR | System Safety | The hardware is deemed acceptably safe for flight. | Assessments | Risk Management Approach |
| FRR.SC.03 | FRR | Certification | Certification that flight operations can safely proceed with acceptable risk has been achieved. | Assessments | Risk Management Approach |
| FRR.SC.04 | FRR | Software Readiness | Flight and ground software elements are ready to support flight and flight operations. | Assessments | Resource Availability |

Table 10: Phase D Facets

| Number | Review | Evidence Name | Description | Facet Type | Facet |
|---|---|---|---|---|---|
| FRR.SC.05 | FRR | Interfaces | Interfaces have been checked and demonstrated to be functional. | Assessments | Technical Approach |
| FRR.SC.06 | FRR | Compliance with Guidance | The program/project has demonstrated compliance with applicable NASA and implementing Center requirements, standards, processes, and procedures. | Assessments | Management Approach |
| FRR.SC.07 | FRR | TBD/TBR Disposition | TBD and TBR items are resolved. | Assessments | Management Approach |
| FRR.SC.08 | FRR | Anomaly Resolution | Open items and waivers have been examined and residual risk from these is deemed to be acceptable. | Assessments | Risk Management Approach |
| FRR.SC.09 | FRR | Environmental Factors | The flight and recovery environmental factors are within constraints. | Assessments | Technical Approach |
| FRR.SC.10 | FRR | Risk Assessment and Mitigation | All open safety and mission risk items have been addressed, and the residual risk is deemed acceptable. | Assessments | Risk Management Approach |
| FRR.SC.11 | FRR | Supporting Organizations | Supporting organizations are ready to support flight. | Assessments | Resource Availability |
| FRR.SC.12 | FRR | Software | Software components meet the exit criteria defined in NASA-HDBK-2203, NASA Software Engineering Handbook. | Assessments | Technical Approach |

Table 11: Phase E Facets

| Number | Review | Evidence Name | Description | Facet Type | Facet |
|---|---|---|---|---|---|
| PLAR.EC.00 | PLAR | PLAR Entrance Criteria | These are Entrance Criteria for PLAR. | Essentials | |
| PLAR.EC.01 | PLAR | Initial Operations Results | The launch and early operations performance, including (when appropriate) the early propulsive maneuver results, are available. | Essentials | Operations |
| PLAR.EC.02 | PLAR | Spacecraft Performance | The observed spacecraft and science instrument performance, including instrument calibration plans and status, are available. | Essentials | Operations |
| PLAR.EC.03 | PLAR | Launch Vehicle Performance | The launch vehicle performance assessment and mission implications, including launch sequence assessment and launch operations experience with lessons learned, are completed. | Essentials | Operations |
| PLAR.EC.04 | PLAR | Programmatic Products | Programmatic products are ready for review at the maturity levels stated in the governing program/project management NPR. | Essentials | Project Control |
| PLAR.EC.05 | PLAR | Mission Operations | The mission operations and ground data system experience, including tracking and data acquisition support and spacecraft telemetry data analysis is available. | Essentials | Operations |
| PLAR.EC.06 | PLAR | Resources | The mission operations organization, including status of staffing, facilities, tools, and mission software (e.g., spacecraft analysis and sequencing), is available. | Essentials | Operations |
| PLAR.EC.07 | PLAR | Anomaly Resolution | In-flight anomalies and the responsive actions taken, including any autonomous fault protection actions taken by the spacecraft or any unexplained spacecraft telemetry, including alarms, are documented. | Essentials | Safety and Mission Assurance |
| PLAR.EC.08 | PLAR | System Changes | The need for significant changes to procedures, interface agreements, software, and staffing has been documented. | Essentials | Requirements Engineering |
| PLAR.EC.09 | PLAR | Operations Documents | Documentation is updated, including any updates originating from the early operations experience. | Essentials | Operations |
| PLAR.EC.10 | PLAR | Post Launch Development | Plans for post-launch development have been addressed. | Essentials | Project Control |
| PLAR.SC.00 | PLAR | PLAR Success Criteria | These are Success Criteria for PLAR. | Assessments | |
| PLAR.SC.01 | PLAR | Spacecraft Performance | The observed spacecraft and science payload performance agrees with prediction, or if not, is adequately understood so that future behavior can be predicted with confidence. | Assessments | Technical Approach |
| PLAR.SC.02 | PLAR | Anomaly Resolution | All anomalies have been adequately documented and their impact on operations assessed. Further, anomalies impacting spacecraft health and safety or critical flight operations have been properly dispositioned. | Assessments | Risk Management Approach |
| PLAR.SC.03 | PLAR | Resources | The mission operations capabilities, including staffing and plans, are adequate to accommodate the actual flight performance. | Assessments | Resource Availability |
| PLAR.SC.04 | PLAR | Compliance with Guidance | The program/project has demonstrated compliance with applicable NASA and implementing Center requirements, standards, processes, and procedures. | Assessments | Management Approach |
| PLAR.SC.05 | PLAR | Open Items | Open items, if any, on operations identified as part of the ORR have been satisfactorily dispositioned. | Assessments | Management Approach |
| CERR.EC.00 | CERR | CERR Entrance Criteria | These are Entrance Criteria for CERR. | Essentials | |
| CERR.EC.01 | CERR | Event Requirements | Critical event/activity requirements and constraints have been identified. | Essentials | Requirements Engineering |
| CERR.EC.02 | CERR | Event Implementation | Critical event/activity design and implementation are complete. | Essentials | Operations |

Table 11: Phase E Facets

| Number | Review | Evidence Name | Description | Facet Type | Facet |
|---|---|---|---|---|---|
| CERR.EC.03 | CERR | Event Testing | Critical event/activity testing is complete. | Essentials | Operations |
| CERR.EC.04 | CERR | Programmatic Products | Programmatic products are ready for review at the maturity levels stated in the governing program/project management NPR. | Essentials | Project Control |
| CERR.EC.05 | CERR | Event Planning | Critical event/activity operations planning, including contingencies, is complete. | Essentials | Operations |
| CERR.EC.06 | CERR | Training | Operations personnel training for the critical event/activity has been conducted. | Essentials | Operations |
| CERR.EC.07 | CERR | Event V and V | Critical event/activity sequence verification and validation is complete. | Essentials | Operations |
| CERR.EC.08 | CERR | Spacecraft Performance | Flight system is healthy and capable of performing the critical event/activity. | Essentials | Operations |
| CERR.EC.09 | CERR | Anomaly Resolution | Flight failures and anomalies from critical event/activity testing have been resolved, and the results/mitigations/work-arounds have been incorporated into supporting and enabling operational products. | Essentials | Safety and Mission Assurance |
| CERR.EC.10 | CERR | | The following technical products have been made available to the cognizant participants prior to the review: | Essentials | |
| CERR.EC.10.A | CERR | Certification | Final certification for critical event readiness. | Essentials | Safety and Mission Assurance |
| CERR.EC.10.B | CERR | | Updated operations procedures. | Essentials | Operations |
| CERR.SC.00 | CERR | CERR Success Criteria | These are Success Criteria for CERR. | Assessments | |
| CERR.SC.01 | CERR | Event Design | The critical activity design complies with requirements. The preparation for the critical activity, including the verification and validation, is thorough. | Assessments | Technical Approach |
| CERR.SC.02 | CERR | Resources | The project (including all the systems, supporting services, and documentation) is ready to support the activity. | Assessments | Resource Availability |
| CERR.SC.03 | CERR | Event Requirements | The requirements for the successful execution of the critical event(s) are complete and understood and have flowed down to the appropriate levels for implementation. | Assessments | Technical Approach |
| CERR.SC.04 | CERR | Compliance with Guidance | The program/project is compliant with NASA and Implementing Center requirements, standards, processes, and procedures. | Assessments | Management Approach |
| CERR.SC.05 | CERR | TBD/TBR Disposition | Any TBD and TBR items have been resolved. | Assessments | Management Approach |
| CERR.SC.06 | CERR | Risk Assessment and Mitigation | All open risk items have been addressed and the residual risk is deemed acceptable. | Assessments | Risk Management Approach |
| PFAR.EC.00 | PFAR | PFAR Entrance Criteria | These are Entrance Criteria for PFAR. | Essentials | |
| PFAR.EC.01 | PFAR | Anomaly Disposition | All anomalies that occurred during the mission, as well as during preflight testing, countdown, and ascent, are dispositioned. | Essentials | Safety and Mission Assurance |
| PFAR.EC.02 | PFAR | Technical Products | All flight and post-flight documentation applicable to future flights of the spacecraft or the design is available. | Essentials | Operations |
| PFAR.EC.03 | PFAR | Planned Activities | All planned activities to be performed post-flight have been completed. | Essentials | Operations |

Table 11: Phase E Facets

| Number | Review | Evidence Name | Description | Facet Type | Facet |
|---|---|---|---|---|---|
| PFAR.EC.04 | PFAR | Programmatic Products | Programmatic products are ready for review at the maturity levels stated in the governing program/project management NPR. | Essentials | Project Control |
| PFAR.EC.05 | PFAR | Anomaly Resolution | Problem reports, corrective action requests, and post-flight anomaly records are completed. | Essentials | Safety and Mission Assurance |
| PFAR.EC.06 | PFAR | Post Flight Reports | All post-flight hardware and flight performance data evaluation reports are completed. | Essentials | Operations |
| PFAR.EC.07 | PFAR | Operations Documents | Plans for retaining assessment documentation and imaging have been made. | Essentials | Operations |
| PFAR.SC.00 | PFAR | PFAR Success Criteria | These are Success Criteria for PFAR. | Assessments | |
| PFAR.SC.01 | PFAR | Flight Report | Formal final report documenting flight performance and recommendations for future missions is complete and adequate. | Assessments | Technical Approach |
| PFAR.SC.02 | PFAR | Anomaly Disposition | All anomalies have been adequately documented and dispositioned. | Assessments | Risk Management Approach |
| PFAR.SC.03 | PFAR | Anomaly Assessment | The impact of anomalies on future flight operations has been assessed and documented. | Assessments | Risk Management Approach |
| PFAR.SC.04 | PFAR | Operations Documents | Reports and other documentation have been retained for performance comparison and trending. | Assessments | Technical Approach |
| DR.EC.00 | DR | DR Entrance Criteria | These are Entrance Criteria for DR. | Essentials | |
| DR.EC.01 | DR | System Requirements | The requirements associated with decommissioning are defined. | Essentials | Requirements Engineering |
| DR.EC.02 | DR | Decommissioning Plans | Plans are in place for decommissioning and any other removal from service activities. | Essentials | Project Control |
| DR.EC.03 | DR | Resources | Resources are in place to support and implement decommissioning. | Essentials | Operations |
| DR.EC.04 | DR | Programmatic Products | Programmatic products are ready for review at the maturity levels stated in the governing program/project management NPR. | Essentials | Project Control |
| DR.EC.05 | DR | System Safety | Health and safety, environmental, and any other constraints have been identified. | Essentials | Safety and Mission Assurance |
| DR.EC.06 | DR | System Capabilities | Current system capabilities relating to decommissioning are understood. | Essentials | Operations |
| DR.EC.07 | DR | Off-Nominal Operations | Off-nominal operations, all contributing events, conditions, and changes to the originally expected baseline have been considered and assessed. | Essentials | Operations |
| DR.EC.08 | DR | Technical Products | The following primary product is ready for review: | Essentials | |
| DR.EC.08.A | DR | Decommissioning Plans | Decommissioning plan that is ready to be baselined after review comments are incorporated. | Essentials | Project Control |
| DR.EC.09 | DR | Technical Products | Other DR technical products have been made available to the cognizant participants prior to the review: | Essentials | Technical Solutions |

Table 11: Phase E Facets

| Number | Review | Evidence Name | Description | Facet Type | Facet |
|---|---|---|---|---|---|
| DR.EC.09.A | DR | Cost and Schedule | Updated cost | Essentials | Project Control |
| DR.EC.09.B | DR | Cost and Schedule | Updated schedule. | Essentials | Project Control |
| DR.EC.09.C | DR | Disposal Plan | Updated disposal plan. | Essentials | Project Control |
| DR.SC.00 | DR | DR Success Criteria | These are Success Criteria for DR. | Assessments | |
| DR.SC.01 | DR | Decommissioning Rationale | The rationale for decommissioning is documented. | Assessments | Technical Approach |
| DR.SC.02 | DR | Decommissioning Plans | The decommissioning plan is complete, meets requirements, is approved by appropriate management, and is compliant with applicable Agency safety, environmental, and health regulations. | Assessments | Technical Approach |
| DR.SC.03 | DR | Operations Documents | Operations plans for decommissioning, including contingencies, are complete and approved. | Assessments | Technical Approach |
| DR.SC.04 | DR | Resources | Adequate resources (schedule, budget, and staffing) have been identified and are available to successfully complete all decommissioning activities. | Assessments | Resource Availability |
| DR.SC.05 | DR | Support Systems | All required support systems for decommissioning are available. | Assessments | Resource Availability |
| DR.SC.06 | DR | Training | All personnel have been properly trained for the nominal and contingency decommissioning procedures. | Assessments | Resource Availability |
| DR.SC.07 | DR | System Safety | Safety, health, and environmental hazards have been identified, and controls have been verified. | Assessments | Risk Management Approach |
| DR.SC.08 | DR | Risk Assessment and Mitigation | Risks associated with the decommissioning have been identified, and adequately mitigated. | Assessments | Risk Management Approach |
| DR.SC.09 | DR | Residual Risks | Residual risks have been accepted by the required management. | Assessments | Risk Management Approach |
| DR.SC.10 | DR | Compliance with Guidance | The program/project is compliant with NASA and Implementing Center requirements, standards, processes, and procedures. | Assessments | Management Approach |
| DR.SC.11 | DR | TBD/TBR Disposition | Any TBD and TBR items are clearly identified with acceptable plans and schedule for their disposition. | Assessments | Management Approach |
| DR.SC.12 | DR | Operations Documents | Plans for archival and subsequent analysis of mission data have been defined and approved, and arrangements have been finalized for the execution of such plans. | Assessments | Technical Approach |
| DR.SC.13 | DR | Lessons Learned | Plans for the capture and dissemination of appropriate lessons learned during the project life cycle have been defined and approved. | Assessments | Technical Approach |
| DR.SC.14 | DR | Transition Plans | Plans for transition of personnel have been defined and approved. | Assessments | Resource Availability |

Table 12: Phase F Facets

| Number | Review | Evidence Name | Description | Facet Type | Facet |
|---|---|---|---|---|---|
| DRR.EC.00 | DRR | DRR Entrance Criteria | These are Entrance Criteria for DRR. | Essentials | |
| DRR.EC.01 | DRR | System Requirements | Requirements associated with disposal are defined. | Essentials | Requirements Engineering |
| DRR.EC.02 | DRR | Disposal Plan | Plans are in place for disposal and any other removal from service activities. | Essentials | Project Control |
| DRR.EC.03 | DRR | Resources | Resources are in place to support disposal. | Essentials | Operations |
| DRR.EC.04 | DRR | Programmatic Products | Programmatic products are ready for review at the maturity levels stated in the governing program/project management NPR. | Essentials | Project Control |
| DRR.EC.05 | DRR | System Safety | Safety, environmental, health, and any other constraints are described. | Essentials | Safety and Mission Assurance |
| DRR.EC.06 | DRR | System Capabilities | Current system capabilities related to disposal are described and understood. | Essentials | Operations |
| DRR.EC.07 | DRR | Off-Nominal Operations | Off-nominal operations, all contributing events, conditions, and changes to the originally expected baseline have been considered and assessed. | Essentials | Operations |
| DRR.EC.08 | DRR | Cost and Schedule | Updated cost. | Essentials | Project Control |
| DRR.EC.09 | DRR | Cost and Schedule | Updated schedule. | Essentials | Project Control |
| DRR.EC.10 | DRR | Primary Products | The following primary product is ready for review: | Essentials | |
| DRR.EC.10.A | DRR | Disposal Plan | Updated disposal plan. | Essentials | Project Control |
| DRR.SC.00 | DRR | DRR Success Criteria | These are Success Criteria for DRR. | Assessments | |
| DRR.SC.01 | DRR | Disposal Rationale | The rationale for disposal is documented. | Assessments | Technical Approach |
| DRR.SC.02 | DRR | Disposal Plan | The disposal plan is complete, meets requirements, is approved by appropriate management, and is compliant with applicable Agency safety, environmental, and health regulations. | Assessments | Technical Approach |
| DRR.SC.03 | DRR | Operations Documents | Operations plans for disposal, including contingencies, are complete and approved. | Assessments | Technical Approach |
| DRR.SC.04 | DRR | Support Systems | All required support systems for disposal are available. | Assessments | Resource Availability |
| DRR.SC.05 | DRR | Training | All personnel have been properly trained for the nominal and contingency disposal procedures. | Assessments | Resource Availability |
| DRR.SC.06 | DRR | System Safety | Safety, health, and environmental hazards have been identified, and controls have been verified. | Assessments | Risk Management Approach |
| DRR.SC.07 | DRR | Risk Assessment and Mitigation | Risks associated with the disposal have been identified and adequately mitigated. | Assessments | Risk Management Approach |

Table 12: Phase F Facets

| Number | Review | Evidence Name | Description | Facet Type | Facet |
|---|---|---|---|---|---|
| DRR.SC.08 | DRR | Residual Risks | Residual risks have been accepted by the required management. | Assessments | Risk Management Approach |
| DRR.SC.09 | DRR | Hardware Recovery | If hardware is to be recovered from orbit: | Assessments | |
| DRR.SC.09.A | DRR | Recovery Plans | Return site activity plans have been defined and approved. | Assessments | Technical Approach |
| DRR.SC.09.B | DRR | Support Systems | Required facilities are available and meet requirements, including those for contamination control, if needed. | Assessments | Resource Availability |
| DRR.SC.09.C | DRR | Transportation Plans | Transportation plans are defined and approved. | Assessments | Technical Approach |
| DRR.SC.09.D | DRR | Shipping Containers | Shipping containers and handling equipment, as well as contamination and environmental control and monitoring devices, are available. | Assessments | Resource Availability |
| DRR.SC.10 | DRR | Asset Disposition | Plans for disposition of mission-owned assets (i.e., hardware, software, and facilities) have been defined and approved. | Assessments | Management Approach |
| DRR.SC.11 | DRR | Resources | Adequate resources (schedule, budget, and staffing) have been identified and are available to successfully complete all disposal activities. | Assessments | Resource Availability |
| DRR.SC.12 | DRR | Archival | All mission and project data and documentation has been archived per disposal plan. | Assessments | Technical Approach |
| DRR.SC.13 | DRR | Compliance with Guidance | The program/project is compliant with NASA and Implementing Center requirements, standards, processes, and procedures. | Assessments | Management Approach |
| DRR.SC.14 | DRR | TBD/TBR Disposition | TBD and TBR items have all been dispositioned. | Assessments | Management Approach |

# Appendix D Exporting Systems Engineering Lifecycle Template

This appendix contains the instructions to export a Systems Engineering Lifecycle Template using the Excel file containing the Analysis Results and SELT Export tool.

1. Download Excel file containing *Analysis Results and SELT Export Tool* from location specified in Appendix B.

2. Create a new blank Microsoft Word document, and then minimize the window.

3. Open Excel file and go to sheet *Export_Setup*. Sheet is divided into 3 areas: Organization, Essential Table and Assessment Table as shown in Figure 15.
   - Organization Area controls how data is exported from Excel into Word and establishes the hierarchical organization of exported document. This feature relies on using Styles and Heading levels in Word.
   - Essential Table defines column headers and data (if any) to include in Essential Table.
   - Assessment Table defines column headers and data (if any) to include in Assessment Table.
   - **NOTE:** Only edit cells in yellow. Do not delete any of the white cells because the macros performing the exporting rely on the values in those cells.

| | A | B | C | D | E | F | G | H | I |
|---|---|---|---|---|---|---|---|---|---|
| 1 | | | | | | | | | |
| 2 | | Export To Word | | | | | | | |
| 3 | | | | | | | | | |
| 4 | | | | | | | | | |
| 5 | **Organization** | | | | | | | | |
| 6 | **Heading Level** | **Field** | **Values** | | | | | | |
| 7 | 1 | Phase | PrePhase A | Phase A | Phase B | Phase C | Phase D | Phase E | Phase F |
| 8 | 2 | Review | | | | | | | |
| 9 | 3 | Facet Type | Essentials | Assessments | | | | | |
| 10 | 4 | Facet | | | | | | | |
| 11 | 5 | Name | | | | | | | |
| 12 | 6 | | | | | | | | |
| 13 | 7 | | | | | | | | |
| 14 | 8 | | | | | | | | |
| 15 | 9 | | | | | | | | |
| 16 | | | | | | | | | |
| 17 | **Essential Table** | | | | | | | | |
| 18 | **Column** | NPR | Description | Evidence | | | | | |
| 19 | **Field** | Number | Description | | | | | | |
| 20 | | | | | | | | | |
| 21 | **Assessment Table** | | | | | | | | |
| 22 | **Column** | NPR | Description | Assessment | Evidence | | | | |
| 23 | **Field** | Number | Description | | | | | | |

**Figure 15: Export Setup**

4. In Fields column, enter fields to export. Field names correspond to column headers from sheet *Review_Criteria*.

   For example: Using Figure 15, following fields are exported: Phase, Review, Facet Type, Facet, Name.

5. In Values column, enter data to export. Field values correspond to data contained in rows on sheet *Review_Criteria*. Values are exported in the order entered. If no field values are entered then all data associated with field will be exported.

   For example: Using Figure 15, following field values are exported:

   | | |
   |---|---|
   | Phase: | Pre-Phase A, Phase A, Phase B, Phase C, Phase D, Phase E, Phase F |
   | Review: | All Reviews are exported |
   | Facet Type: | Essentials, Assessments |
   | Facet: | All facets are exported |
   | Name: | All names are exported |

6. In Essential Table, specify column headers and associated data to export. Column headers can be any value. Field names correspond to column headers from sheet *Review_Criteria*. A blank field name can be used so no data is exported for that field.

   For example: Using Figure 15, essential table will have 3 columns and 2 rows. Column headers are NPR, Description, and Evidence. Exported data includes number and description. No data will be exported for Evidence column and will be blank.

7. In Assessment Table, specify column headers and associated data to export. Column headers can be any value. Field names correspond to column headers from sheet *Review_Criteria*. A blank field name can be used so no data is exported for that field.

   For example: Using Figure 15, assessment table will have 4 columns and 2 rows. Column headers are NPR, Description, Assessment, and Evidence. Exported data includes number and description. No data will be exported for Assessment and Evidence columns.

8. Click *Export to Word*. During this process both Word and Excel will be visible. When export is complete a Save Dialog Box will appear.

   NOTE:
   During export do not interact with Word or Excel, as that will interrupt the export. It is best to not perform any other tasks while exporting.

# Appendix E Importing Systems Engineering Lifecycle Template

This appendix contains the instructions to import a Systems Engineering Lifecycle Template into an Innoslate project.

1. Create Systems Engineering Lifecycle Template outside of Innoslate. See Appendix D for instructions.

2. Open Innoslate project and choose *Import Analyzer* from Main Menu.

3. Configure *Import Analyzer* as follows, then click Next

   File Type: Microsoft Word (.docx)
   Configure Settings: Statement

4. Choose file to upload. Innoslate will upload the file, and then perform an analysis. After *Import Analyzer* completes its analysis, click Next. Innoslate will provide a preview and list any errors. Click Save.

   NOTE: Innoslate assumes uploaded document is a requirements document and will place it in the Requirements section of the database, as shown in Figure 16. It will be necessary to manually change the document from a requirements document to a CONOPS document.

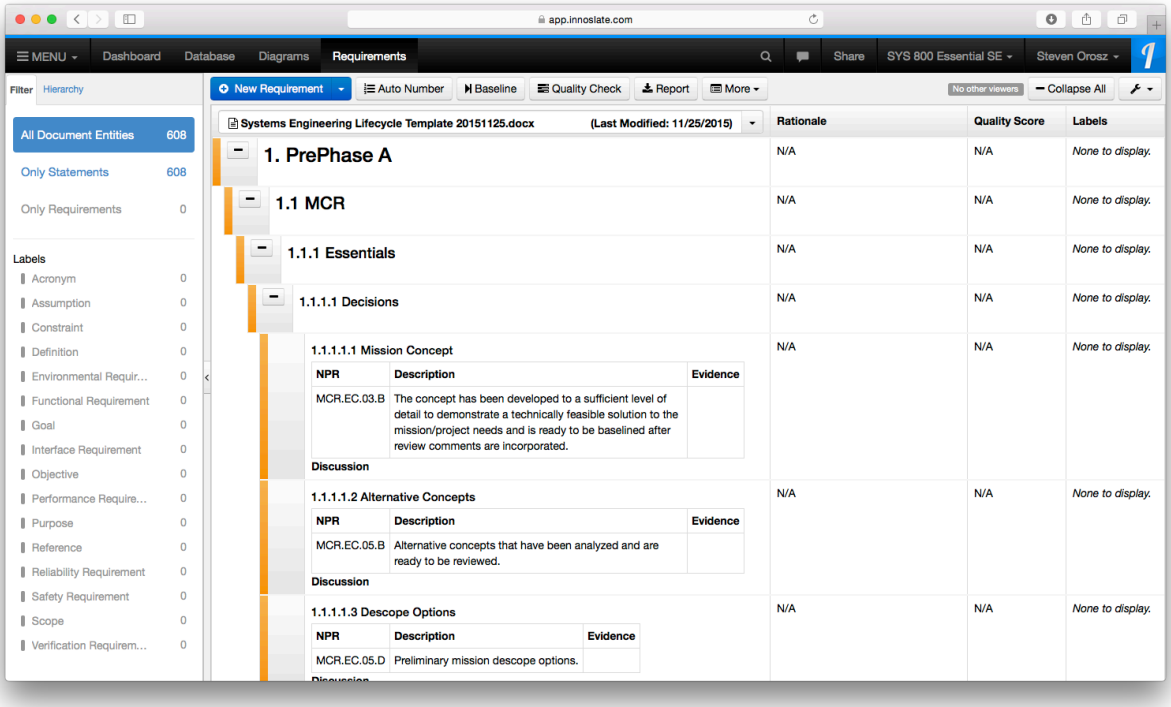


**Figure 16: Initially Upload Systems Engineering Lifecycle Template**

5. From Main Menu, choose *Database*.

6. Locate uploaded document in Artifacts section of database. Click on document to open its Entity view.

7. On left side of Entity view, locate *Requirements Document* label. It will be highlighted in blue, as shown in Figure 17. Click the X to remove it. Locate *Concept of Operations Document* label and click it. It will be highlighted blue, as shown in Figure 18. Click the Save button at top of Entity view.

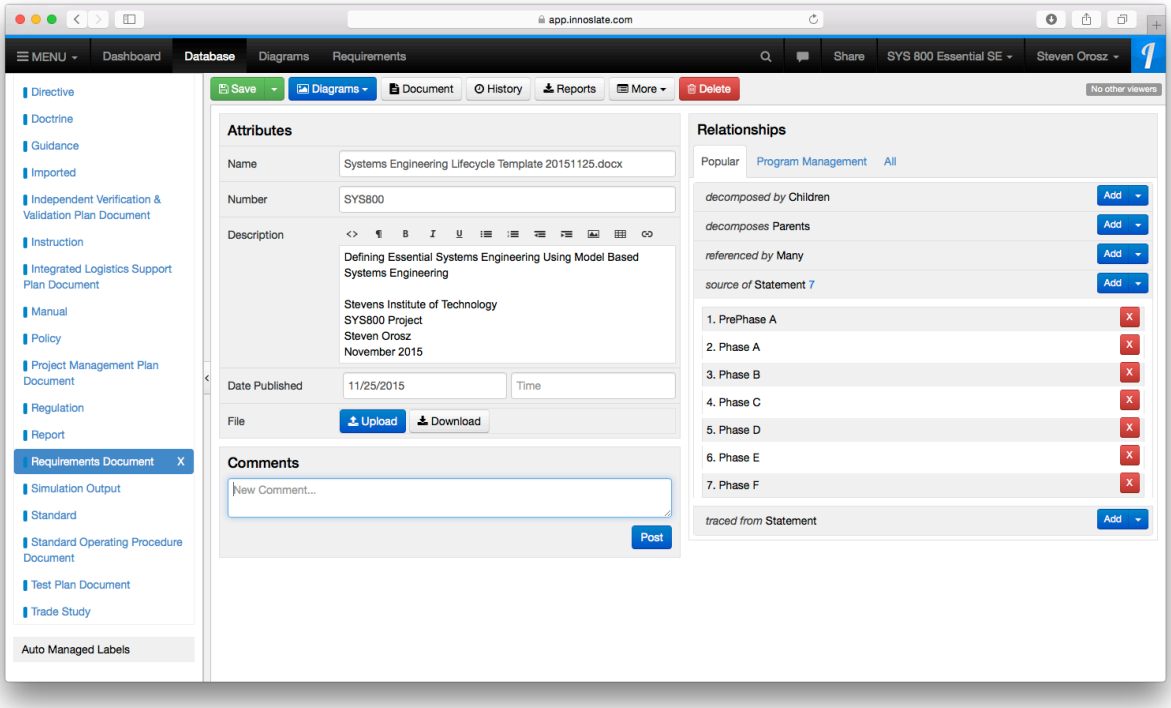


**Figure 17: SELT with Requirements Document Label**

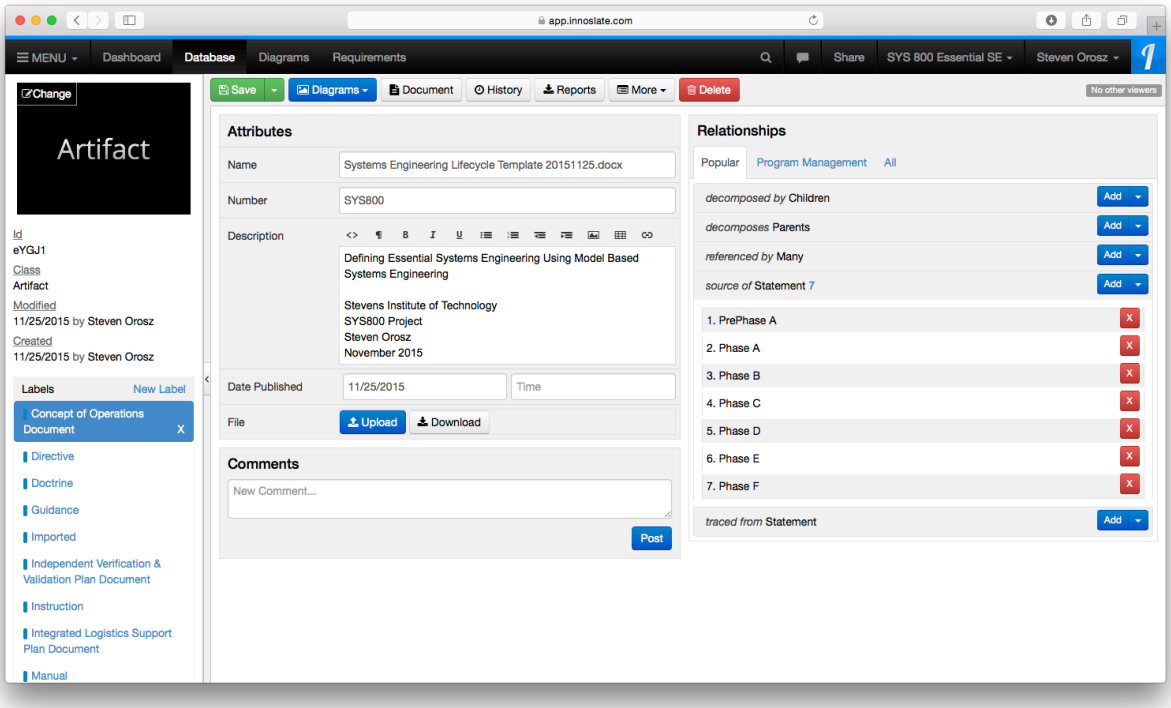


**Figure 18: SELT with Concept of Operations Document Label**

8. From Main Menu, choose CONOPS. A view similar to Figure 19 will appear. Verify correct document is chosen in the pull down menu at top of screen.

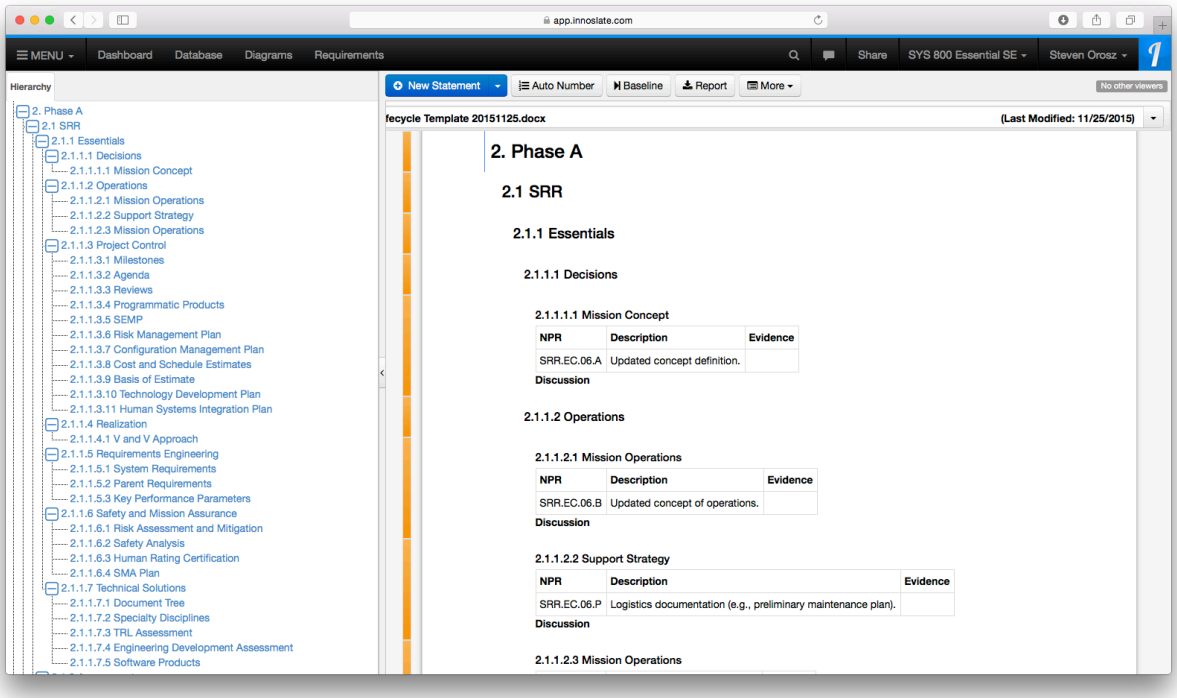


**Figure 19: Imported Systems Engineering Lifecycle Template**

# Appendix F Systems Engineering Lifecycle Template Examples

This appendix provides examples for linking facets in the Systems Engineering Lifecycle Template to entities in the model database. Two examples are provided.

- Linking by hyperlink
- Linking by entity relationships

**Example 1: Linking by Hyperlink**

One method for linking is to use a hyperlink. For this example, a placeholder entity was created in the model database to represent the key evidence *Updated Concept Definition* and is shown in Figure 20. This key evidence satisfies the Phase A, SRR Decision Essential Facet, SRR.EC.06.A in section 2.1.1.1.1 of the Systems Engineering Lifecycle Template.

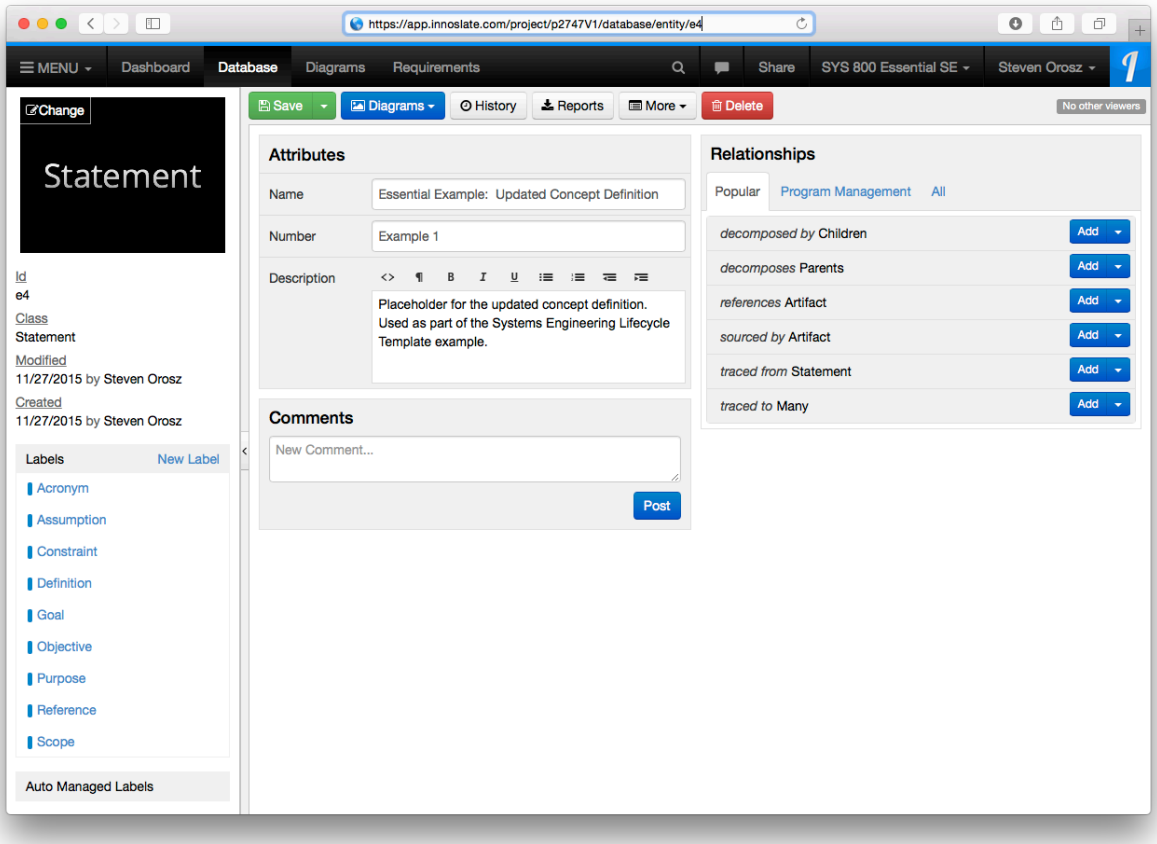


**Figure 20: Placeholder Entity for Updated Concept Definition**

1. Locate entity to link using the Database view or Search tool in Innoslate.

2. Copy the hyperlink at the top of web browser, as shown in Figure 20. In this example the hyperlink is:
   - https://app.innoslate.com/project/p2747V1/database/entity/e4

3. Next go to the Systems Engineering Lifecycle Template using the CONOPS view and navigate to section 2.1.1.1.1.

4. Click on the Statement Entity so it can be edited. Then in the Essential Table, paste the hyperlink into the cell below *Evidence*. The view will look similar to Figure 21. After pasting in the hyperlink, click the green checkmark on the left side of the view.

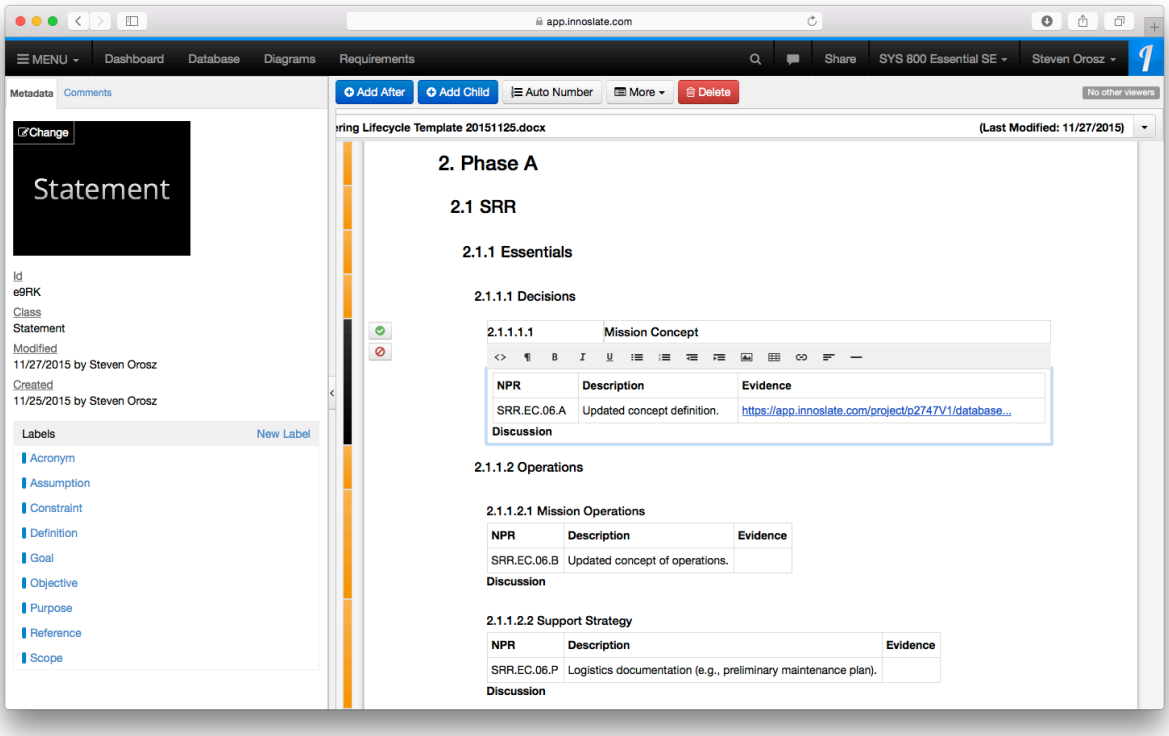


**Figure 21: Linking by Hyperlink**

## Example 2: Linking by Entity Relationships

The preferred method for linking is to define a relationship between the facet and the key evidence in the model database. This example will use the placeholder key evidence created in Example 1.

1. Go to the Systems Engineering Lifecycle Template using the CONOPS view and navigate to section 2.1.1.1.1.

2. Click on the Statement Entity so it can be edited. At the top of the screen click the *More* button and choose *Go to Entity View*. The view will be similar to Figure 22.

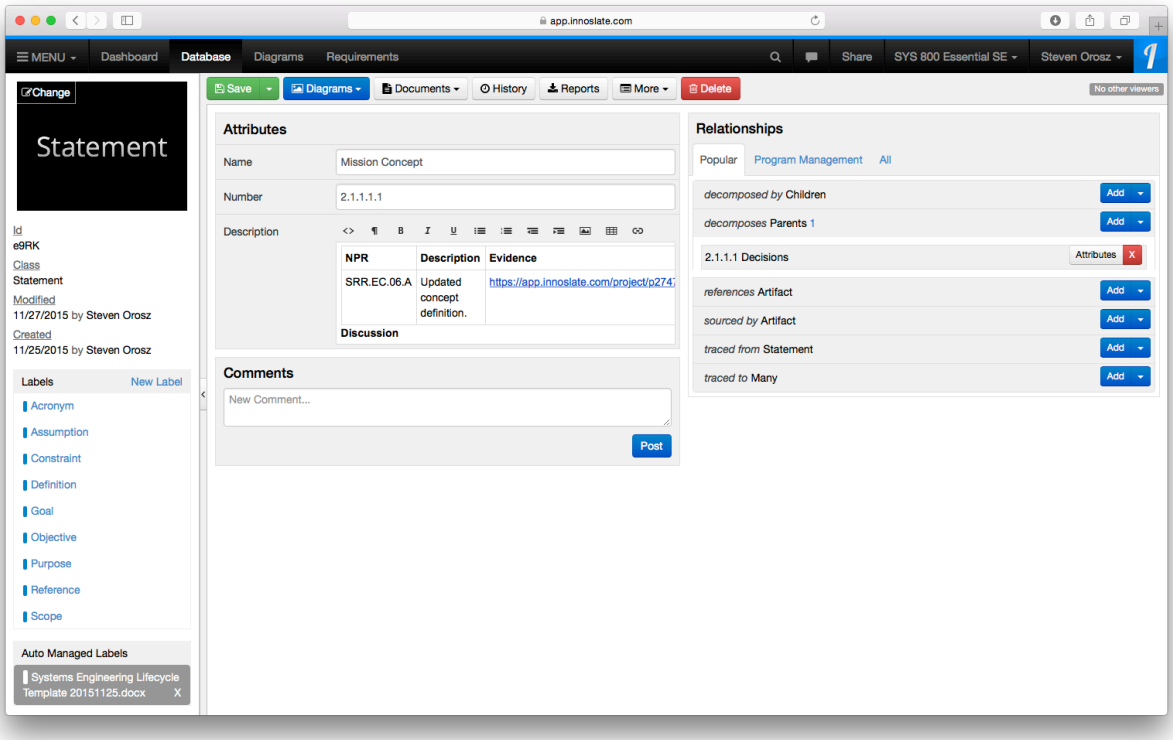


**Figure 22: Entity View of Facet**

3. Create new relationship under *Traced To* by clicking the blue *Add* button and choose *Add Existing*. Search for the evidence and when it is found, click the green *Add* button. Then click the green *Save* button at the top of the Statement Entity view. When completed, the facet view for the will be similar to Figure 23.

4. Click on the newly created relationship to open the key evidence entity. It will now show a *Traced From* relationship, similar to Figure 24.

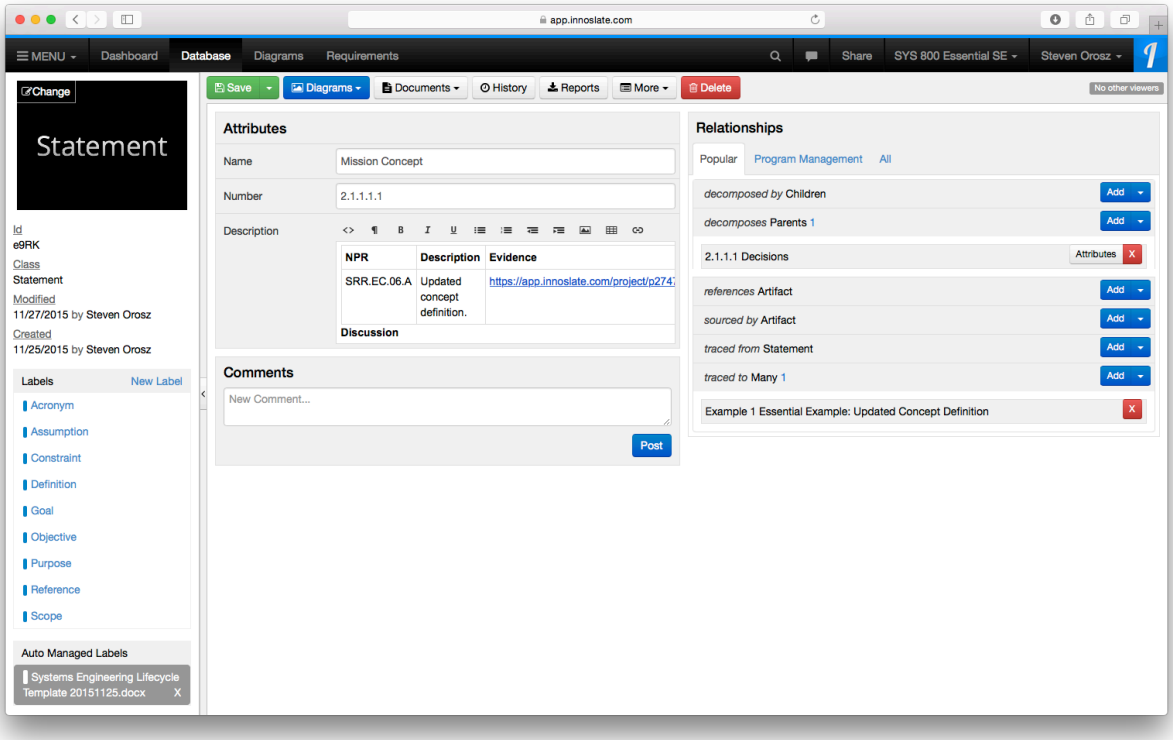


**Figure 23: Linking by Entity Relationships, Facet View**

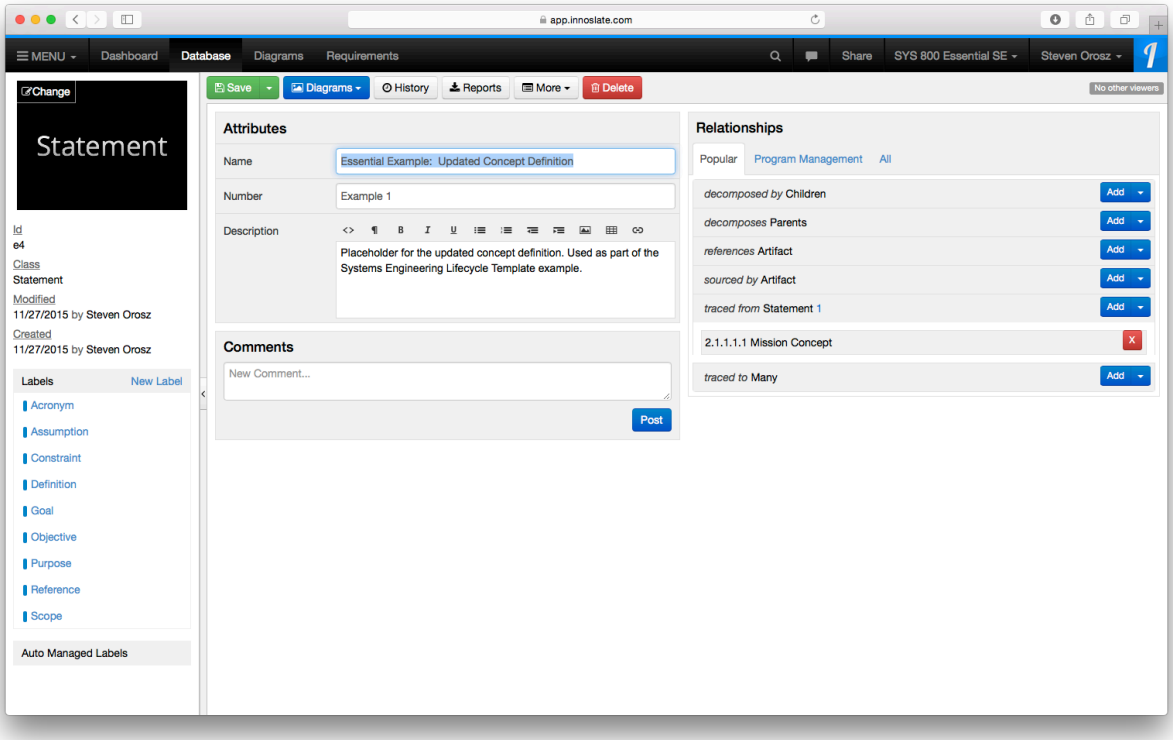


**Figure 24: Linking by Entity Relationships, Key Evidence View**