

Fundamentals of Systems Engineering

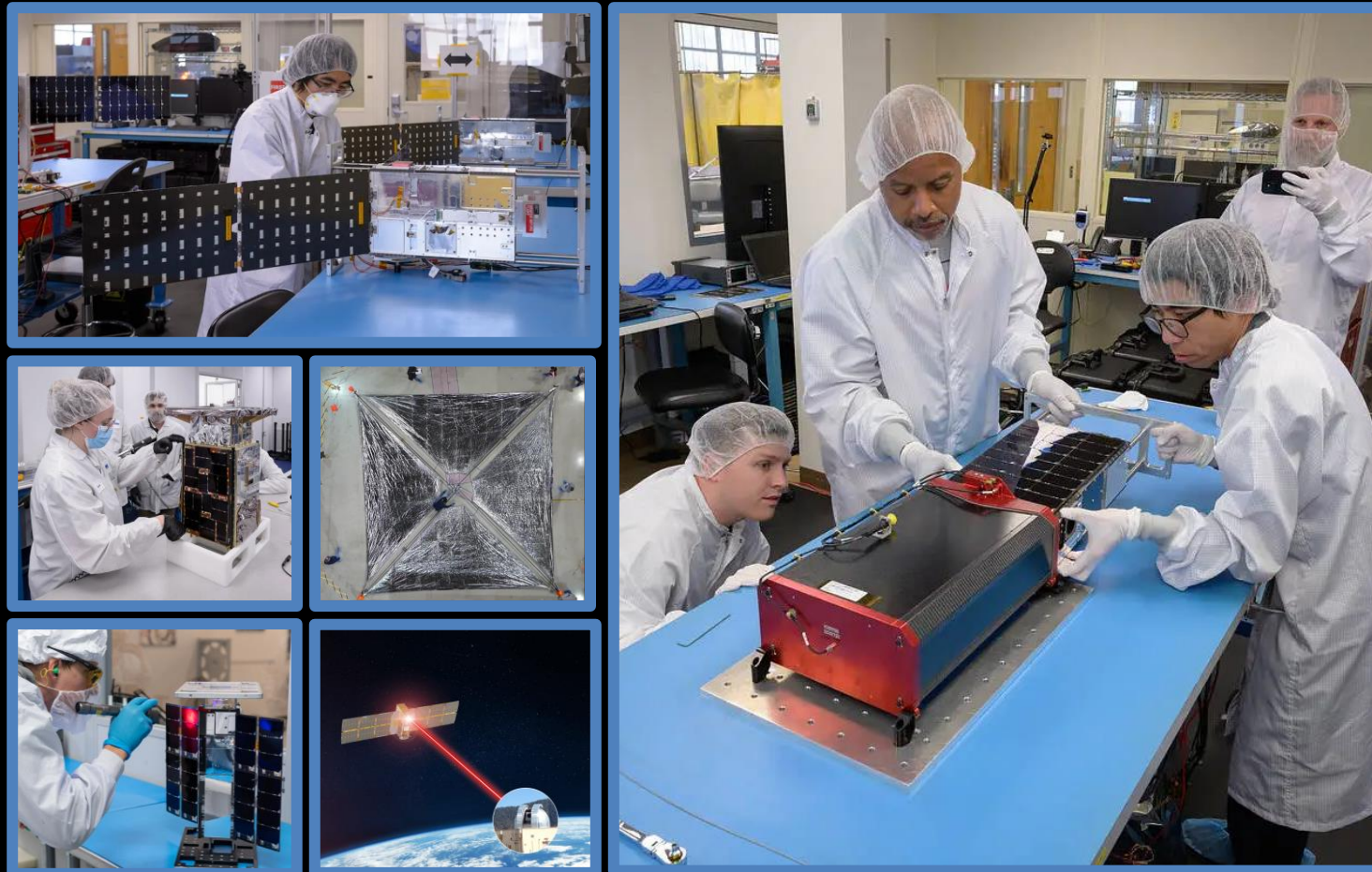
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Access to Space for All
Systems Engineering Webinar Series

United Nations Office for
Outer Space Affairs

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Webinar Overview

This webinar offers an overview of the fundamentals of systems engineering and project management as they relate to small spacecraft projects. This overview includes a discussion of the following:

- What is Systems Engineering?
- What does a Systems Engineer do?
- What are the Elements of Managing a Small Spacecraft Project?
- What are the Elements of a Project's Life Cycle Phases?
- What are the Roles and Responsibilities of a Systems Engineer?
- Why does NASA use Systems Engineering?



What is Systems Engineering?



Systems Engineering, is a “robust approach to the design, creation, and operation of systems. In simple terms, the approach consists of identification of system goals, creation of alternative system design concepts, performance of design trades, selection and implementation of the best design, verification that the design is properly built and integrated, and post-implementation assessment of how well the system meets (or met) the goals.”

NASA Systems Engineering Handbook, 1995

National Aeronautics and Space Administration

National Aeronautics and
Space Administration



www.nasa.gov

Systems Engineering Knowledge Base



Knowledge Base

System Level
Thinking and Basic
Analytical Skills

Domain Specific
Knowledge

- Customer
- Product
- Technology
- Organization

System
Engineering Roles

- Process
- Tools
- Role
- Product Line
Functions
 - Manufacturing
 - Quality
 - Test
 - H/W & S/W
Development

Professional
Effectiveness Skills

- Meeting Focus
- Questioning Skills
- Conflict Resolution
- Creativity
- Closure

What Does a Systems Engineer Do?

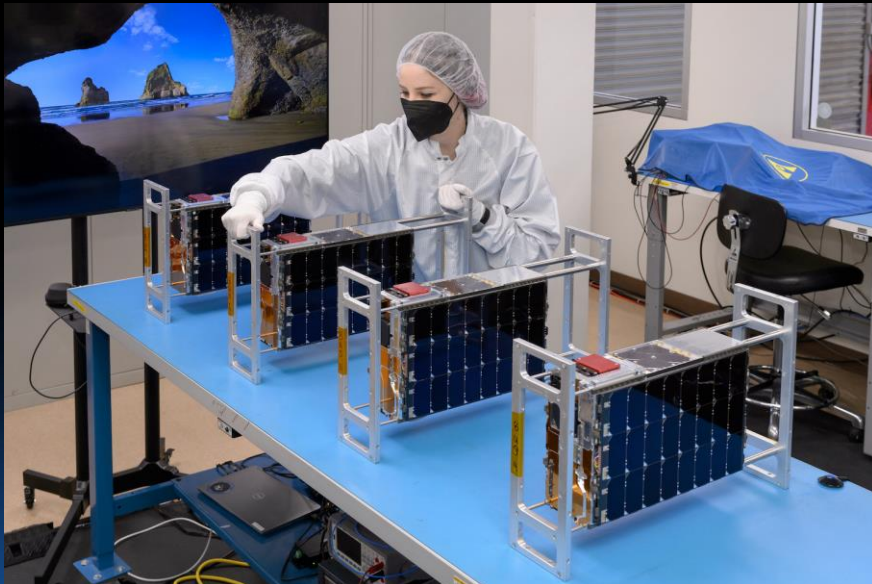


- Lead requirements analysis efforts:
 - Top level requirements
 - Derived requirements
 - Detailed design requirements
 - Allocate requirements to segment/subsystem level
 - Validate requirements with customers, users, authorities
- Develop specification inputs
- Establish functional baseline
- Ensure technical integrity
- Integrate specialty inputs
- Develop interface definitions
- Lead architecture identification
- Develop system concept
- Synthesize potential system solutions
- Partition the system into elements
- Lead feasibility studies
- Identify/lead/perform trade studies and analyses
- Support design solutions
- Approve test plans
- Coordinate verification activities
- Coordinate failure analyses

Attributes of a Good Systems Engineer



- Possesses Intellectual Curiosity
- Sees the Big Picture
- Understands Connections
- Comfortable with Change
- Comfortable with Uncertainty

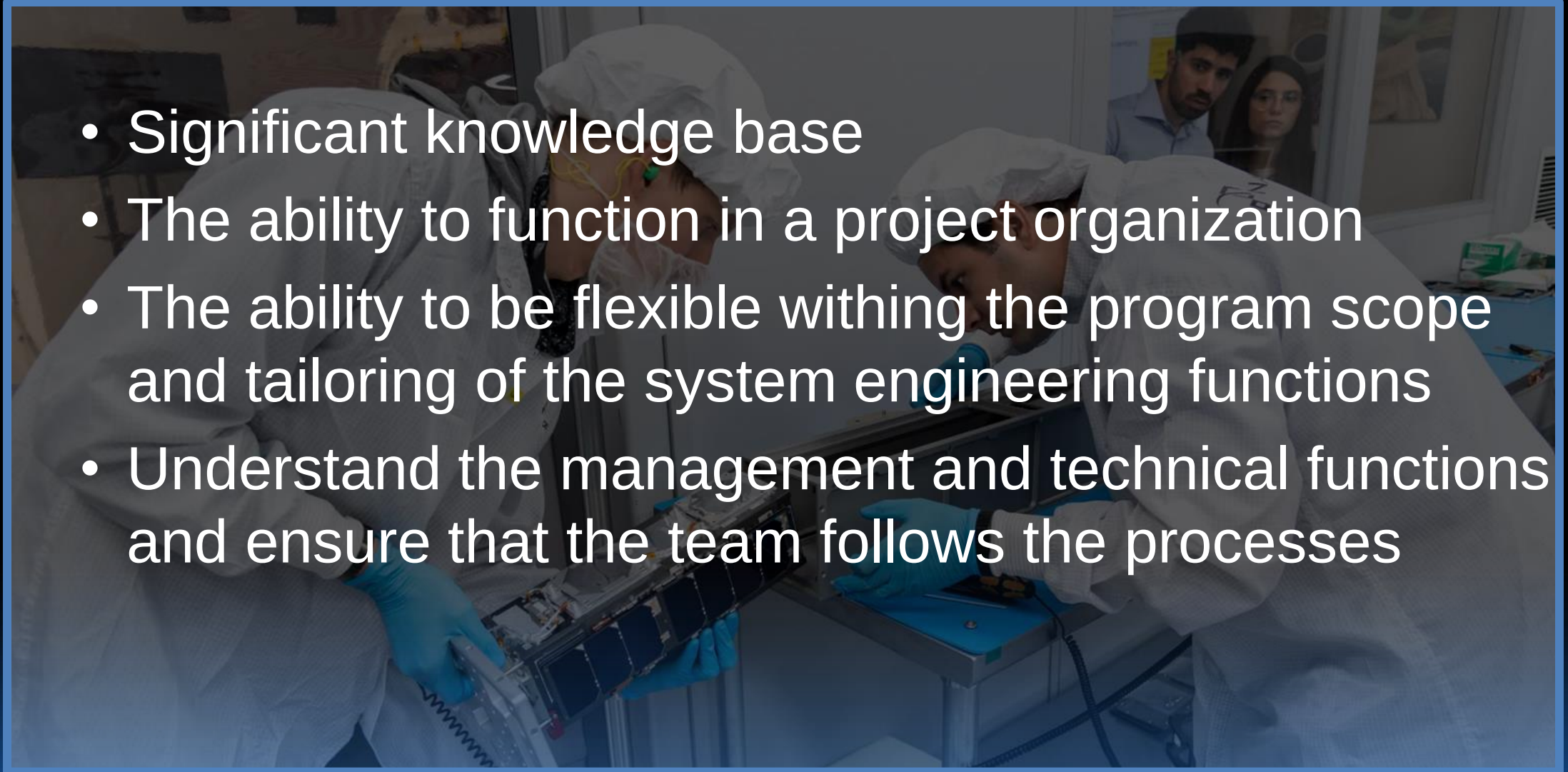


- Processes “Proper Paranoia”
- Manages Resources and Margins
- Good Communication Skills
- Self-Confident and Energy
- Has an Appreciation for Process

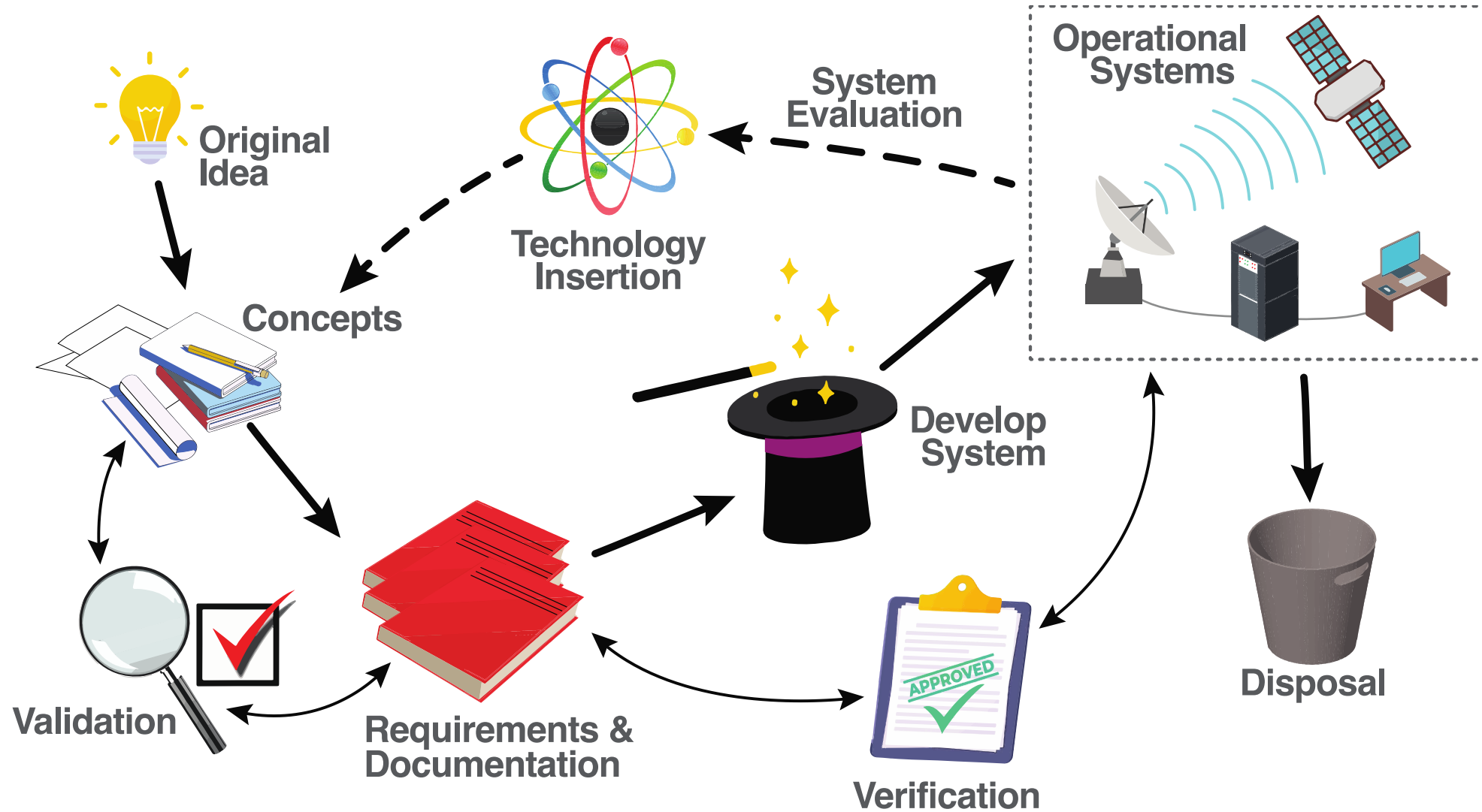
What Does It Take to be a Systems Engineer?



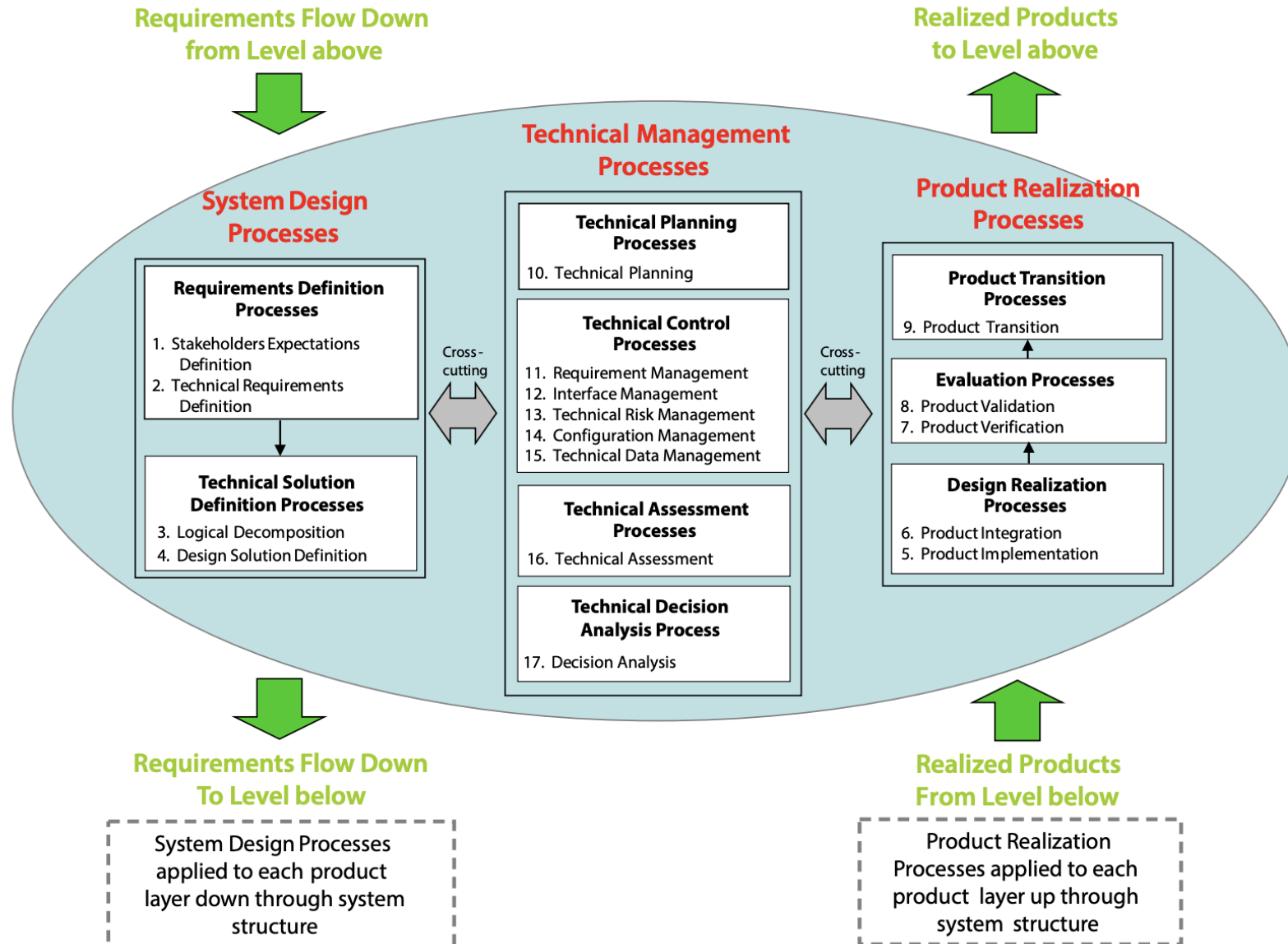
- Significant knowledge base
- The ability to function in a project organization
- The ability to be flexible withing the program scope and tailoring of the system engineering functions
- Understand the management and technical functions and ensure that the team follows the processes



Idea to Operational System



The Systems Engineer Engine

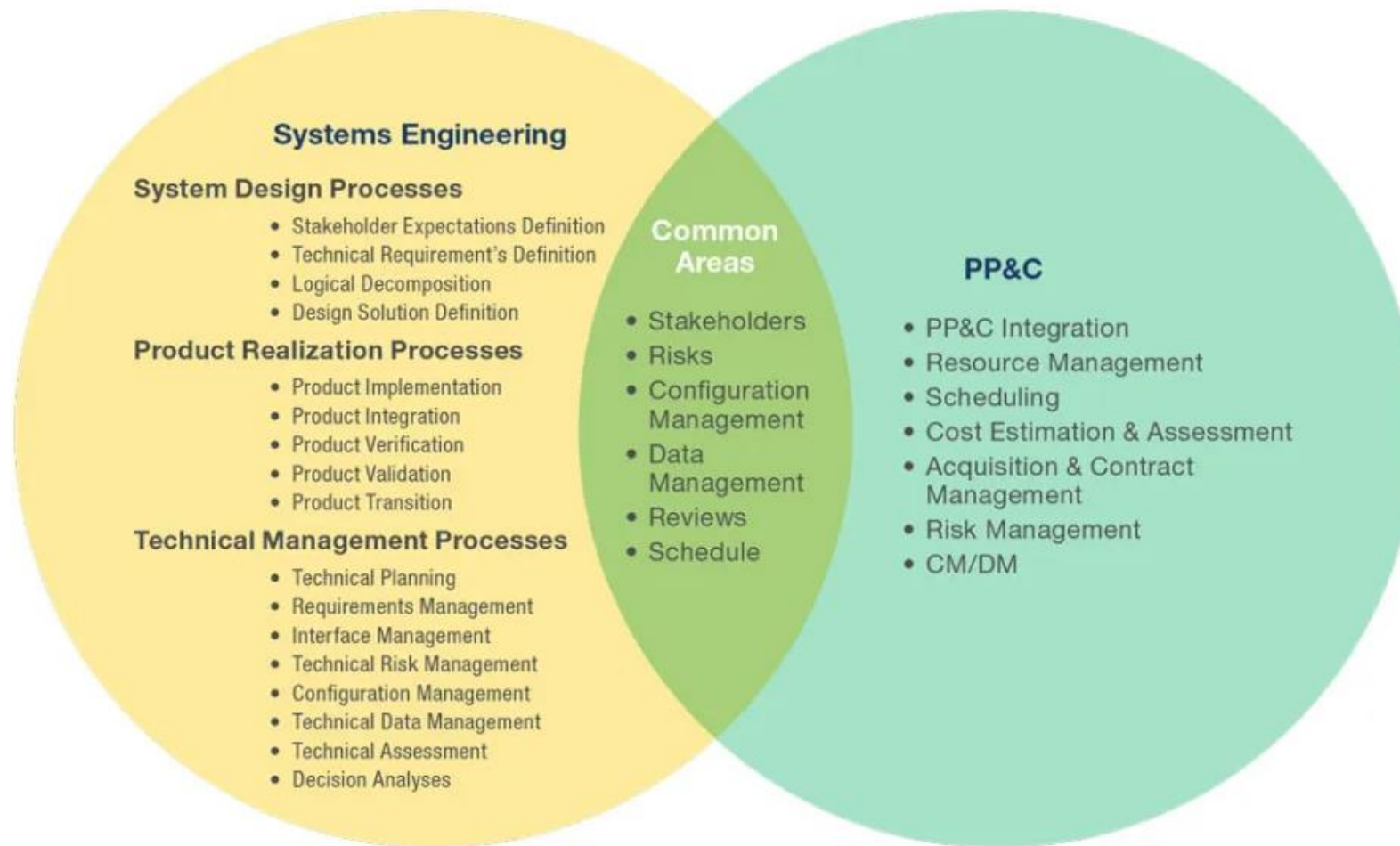


Systems Engineering in Context of Overall Project Management



PROJECT MANAGEMENT ACTIVITIES

- Setting up Project Team
- Programmatic Stakeholders (non-technical, non-business)
- Programmatic Planning (non-technical, non-business)
- Identifying Programmatic (non-technical) requirements
- Identifying Programmatic Risks
- Technology Transfer and Commercialization
- Integration of technical and non-technical activities
- Overall Approver/Decider

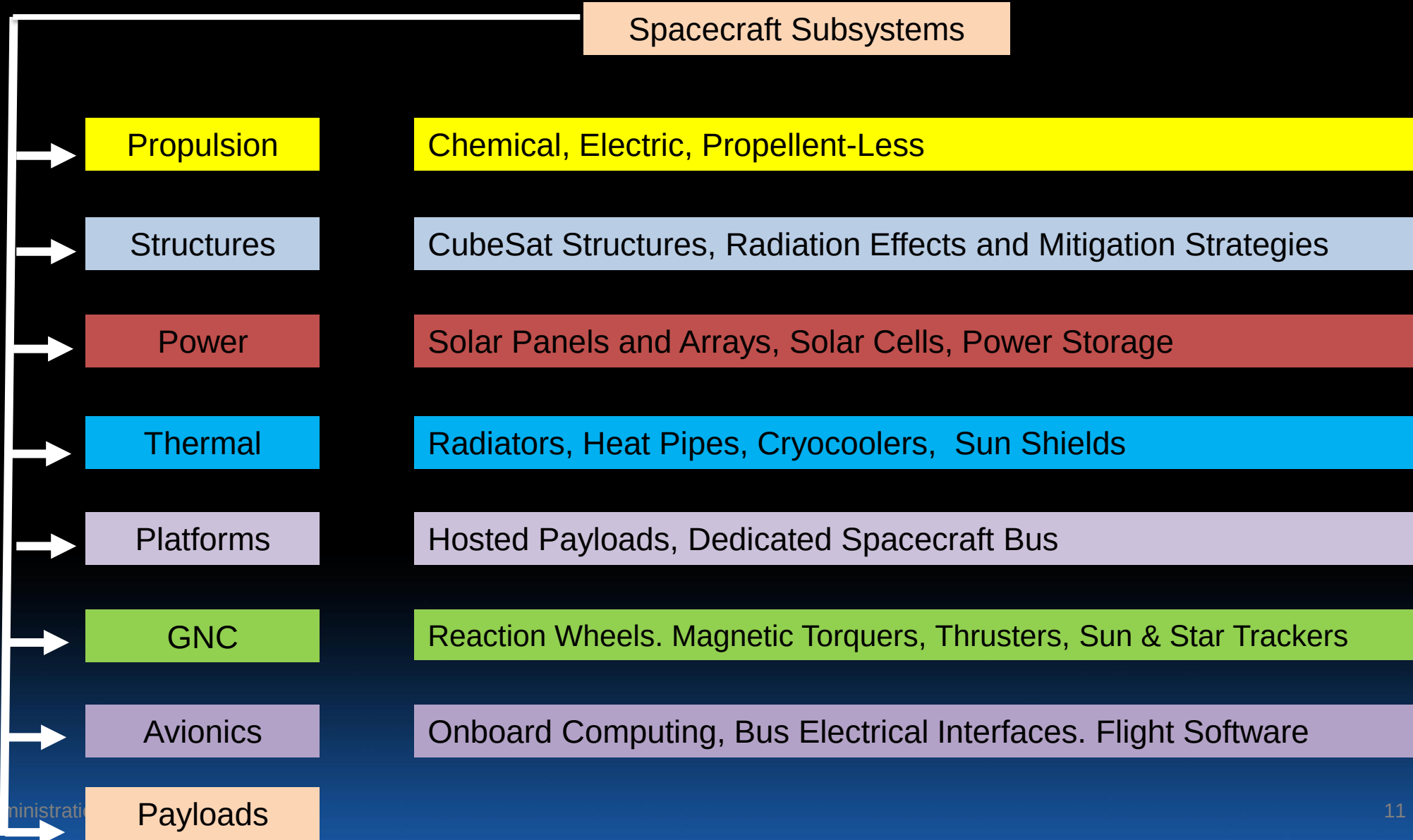


What are the Elements of Managing a Small Spacecraft Project?



Managing a project consists of three main objectives:

- Managing the technical aspects of the project
- Managing the project team
- Managing the cost and schedule.

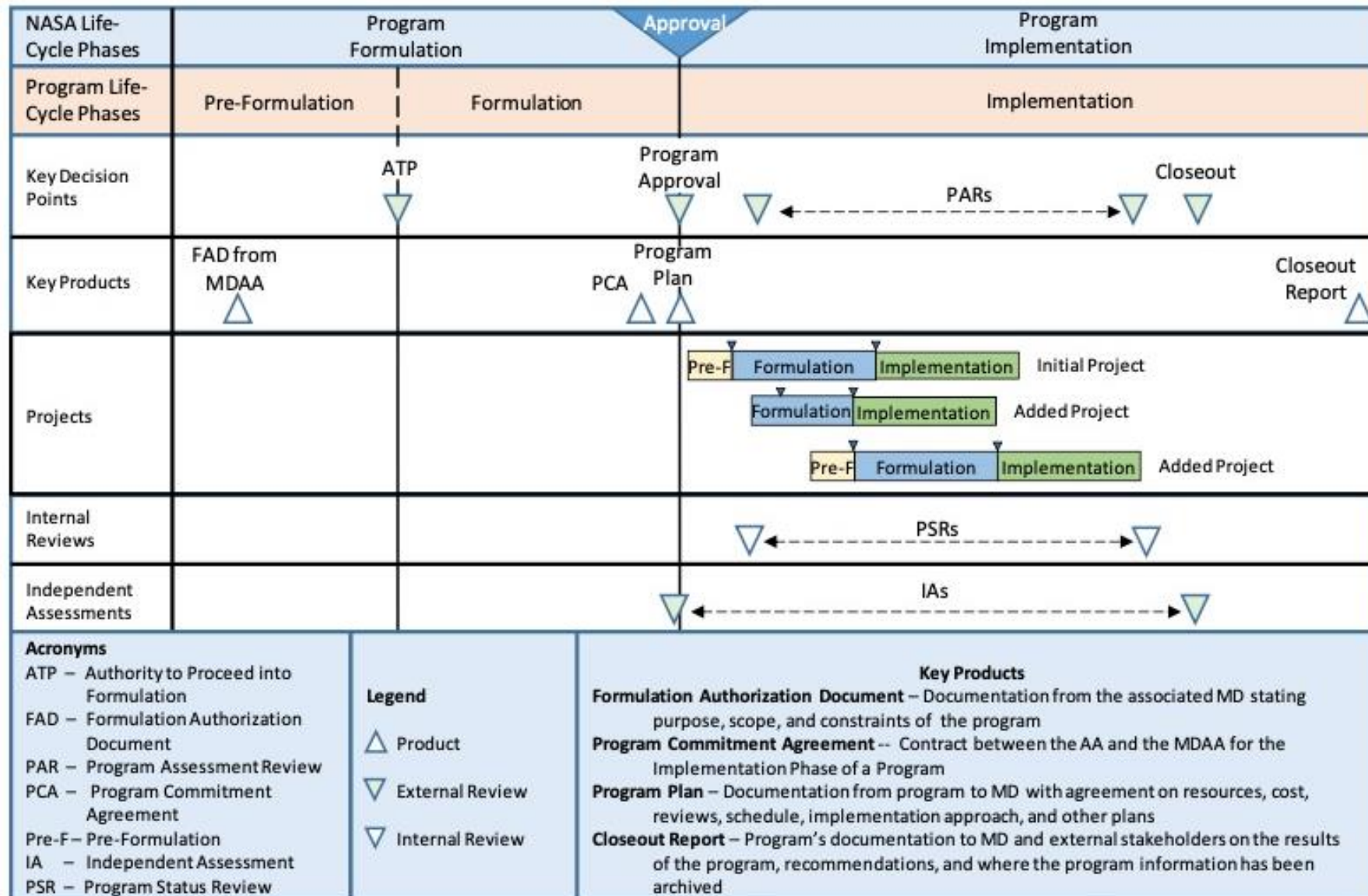


What are the Elements of a Project's Life Cycle Phases?



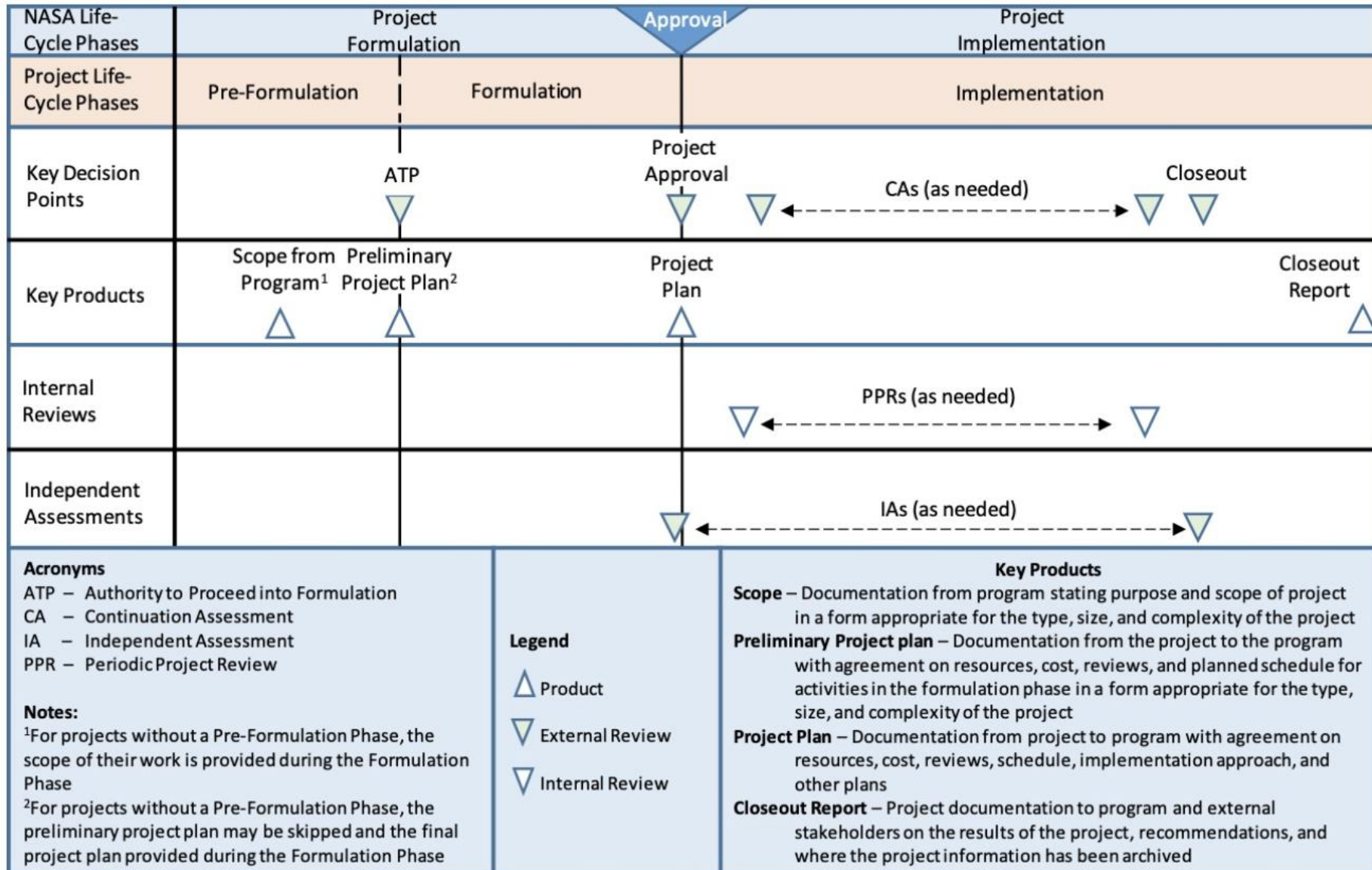
- Program Formulation
- Program Implementation
- Project Pre-Phase A: Concept Studies
- Project Phase A: Concept and Technology Development
- Project Phase B: Preliminary Design and Technology Completion
- Project Phase C: Final Design and Fabrication
- Project Phase D: System Assembly, Integration and Test, Launch
- Project Phase E: Operations and Sustainment
- Project Phase F: Closeout
- Funding: The Budget Cycle

Program Life Cycle per NPR 7120.8A: NASA Research and Technology Program and Project Management Requirements



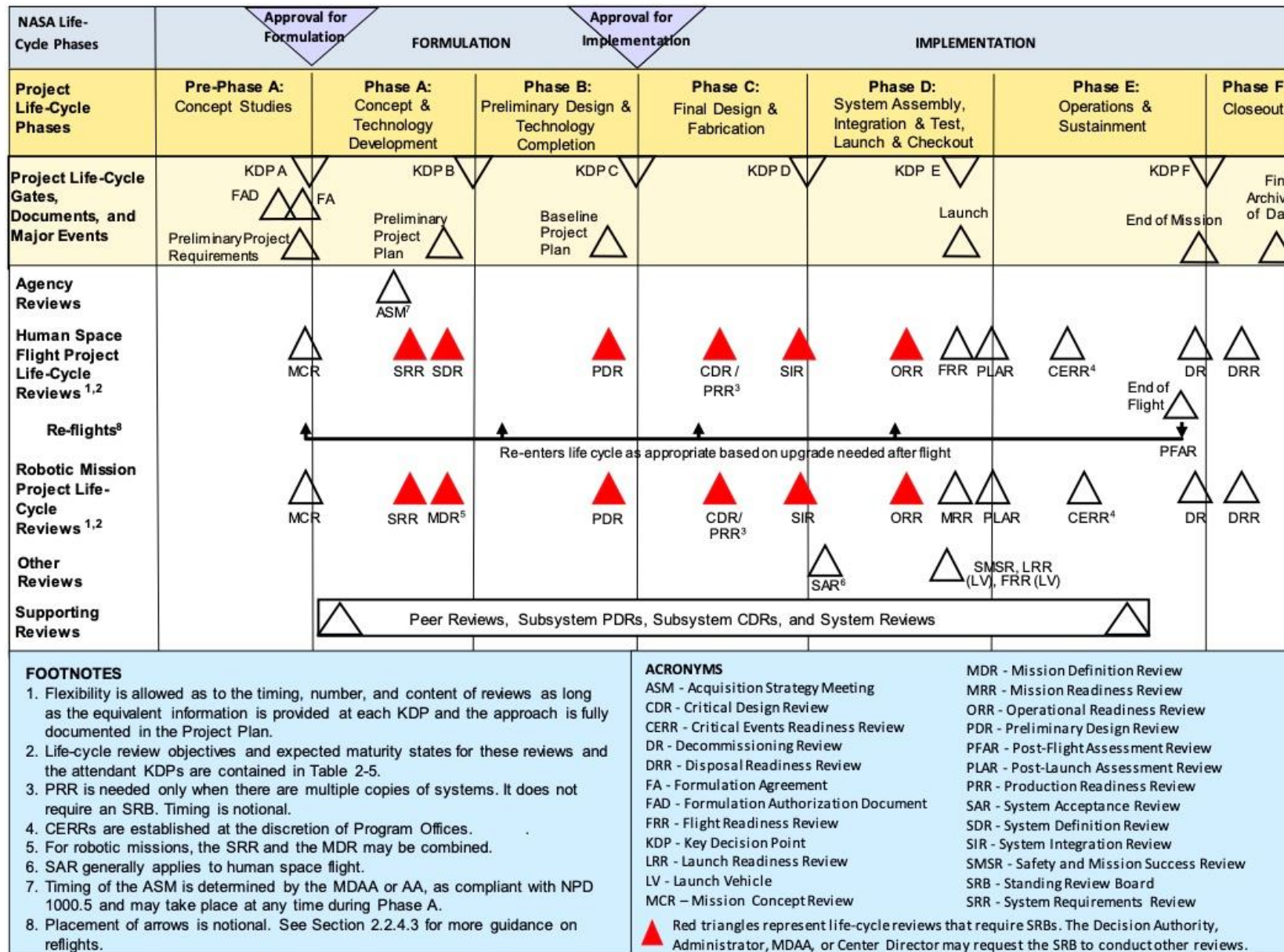


Project Life Cycle per NPR 7120.8A: NASA Research and Technology Program and Project Management Requirements





Project Life Cycle per NPR 7120.5F: NASA Space Flight Program and Project Management Requirements



What are the Roles and Responsibilities of a Systems Engineer?

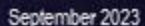


- The exact role and responsibility of the systems engineer may change from project to project depending on the size and complexity of the project and from phase to phase of the life cycle.
- For large projects, there may be one or more systems engineers.
- For small projects, the project manager may sometimes perform these practices. But whoever assumes those responsibilities, the systems engineering functions should be performed.
- The actual assignment of the roles and responsibilities of the named systems engineer may also therefore vary.
- The lead systems engineer ensures that the system technically fulfills the defined needs and requirements and that a proper systems engineering approach is being followed.
- The systems engineer oversees the project's systems engineering activities as performed by the technical team and directs, communicates, monitors, and coordinates tasks.
- The systems engineer reviews and evaluates the technical aspects of the project to ensure that the systems/subsystems engineering processes are functioning properly and evolves the system from concept to product.
- The entire technical team is involved in the systems engineering process.

Why Does NASA Use Systems Engineering?



The engineering of NASA systems requires a systematic and disciplined set of processes that are applied recursively and iteratively for the design, development, operation, maintenance, and closeout of systems throughout the life cycle of the programs and projects. The systems engineering discipline serves this purpose.

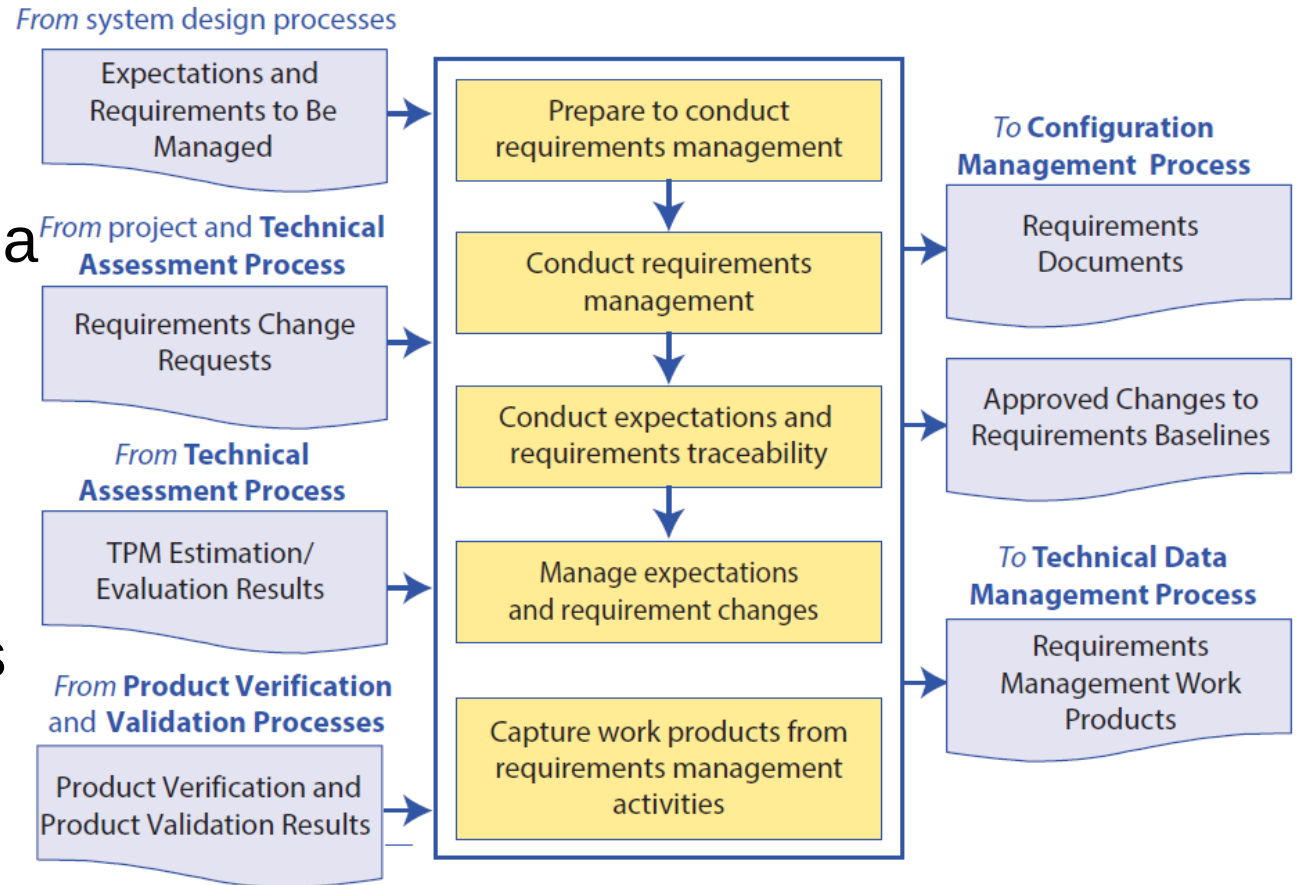


Upcoming Webinar: Requirements and System Design



This webinar will cover discussions on the requirement and systems design aspects.

- How do you define requirements for a small spacecraft mission?
- Why are requirements important to NASA missions?
- How trade studies are used to determine parts selection and why is it important?
- What is a concept of operations (ConOps) and why is it vital to a NASA mission?



Steps to Requirements Development for Systems and Subsystems

1. Customer and User Identification

7. Functional Attributes to Technical Characteristics

2. Prioritize Customer Objectives and Needs

8. Establish Quantifiable Requirements

3. Define Constraints

9. Note Interfaces & Hardware/Software Relationships

4. Customer Needs to Functional Attributes

10. Decompose Functional Requirements

5. Develop Functional Requirements

11. Iterate to Reconcile Requirements & Implementation

6. Establish Functional Flow

References



NASA Procedural Requirements 7123.1D, Systems Engineering Processes and Requirements, Expiration Date: July 05, 2028

<https://nodis3.gsfc.nasa.gov/displayDir.cfm?t=NPR&c=7123&s=1B>

NASA Procedural Requirements 7120.8A, NASA Research and Technology Program and Project Management Requirements, Expiration Date: September 14, 2028

<https://nodis3.gsfc.nasa.gov/displayDir.cfm?t=NPR&c=7120&s=8A>

NASA Procedural Requirements 7120.5F, **NASA Space Flight Program and Project Management Requirements**, Expiration Date: **August 3, 2026**

<https://nodis3.gsfc.nasa.gov/displayDir.cfm?t=NPR&c=7120&s=5E>

NASA SP-2016-6105 Rev2, NASA Systems Engineering Handbook

[https://lws.larc.nasa.gov/vfmo/pdf_files/\[NASA-SP-2016-6105_Rev2_\]nasa_systems_engineering_handbook_0.pdf](https://lws.larc.nasa.gov/vfmo/pdf_files/[NASA-SP-2016-6105_Rev2_]nasa_systems_engineering_handbook_0.pdf)

Questions?



www.nasa.gov/smallsat-institute/