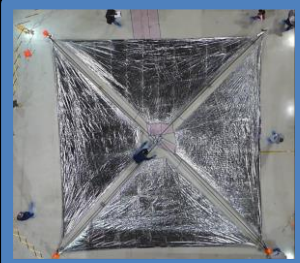




# Fundamentals of Systems Engineering

November 1, 2023

Access to Space for All  
Systems Engineering Webinar Series



# 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?



National Aeronautics and  
Space Administration



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



www.nasa.gov

# Systems Engineering Knowledge Base



## Knowledge Base

System Level  
Thinking and Basic  
Analytical Skills

Domain Specific  
Knowledge

System  
Engineering Roles

Professional  
Effectiveness Skills

- Customer
- Product
- Technology
- Organization

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

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

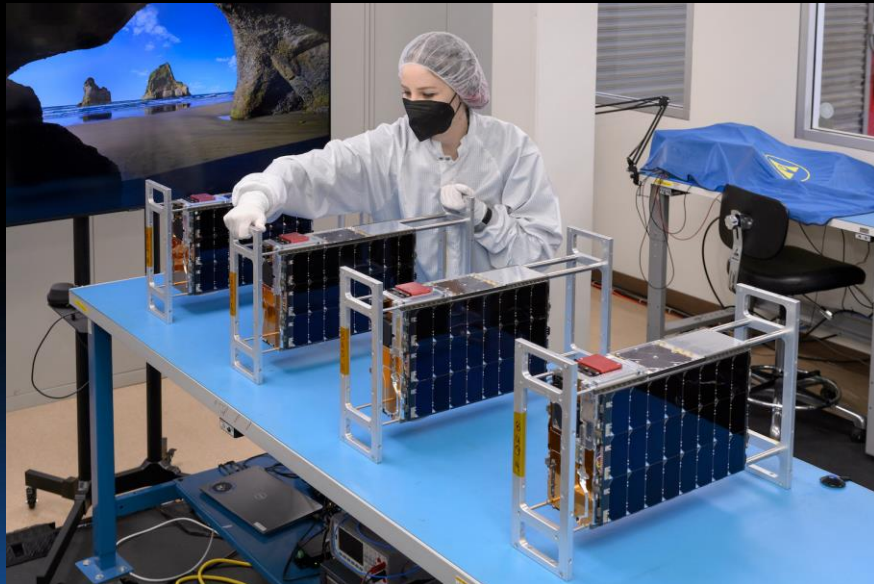


# What Does a Systems Engineer Do?

- 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

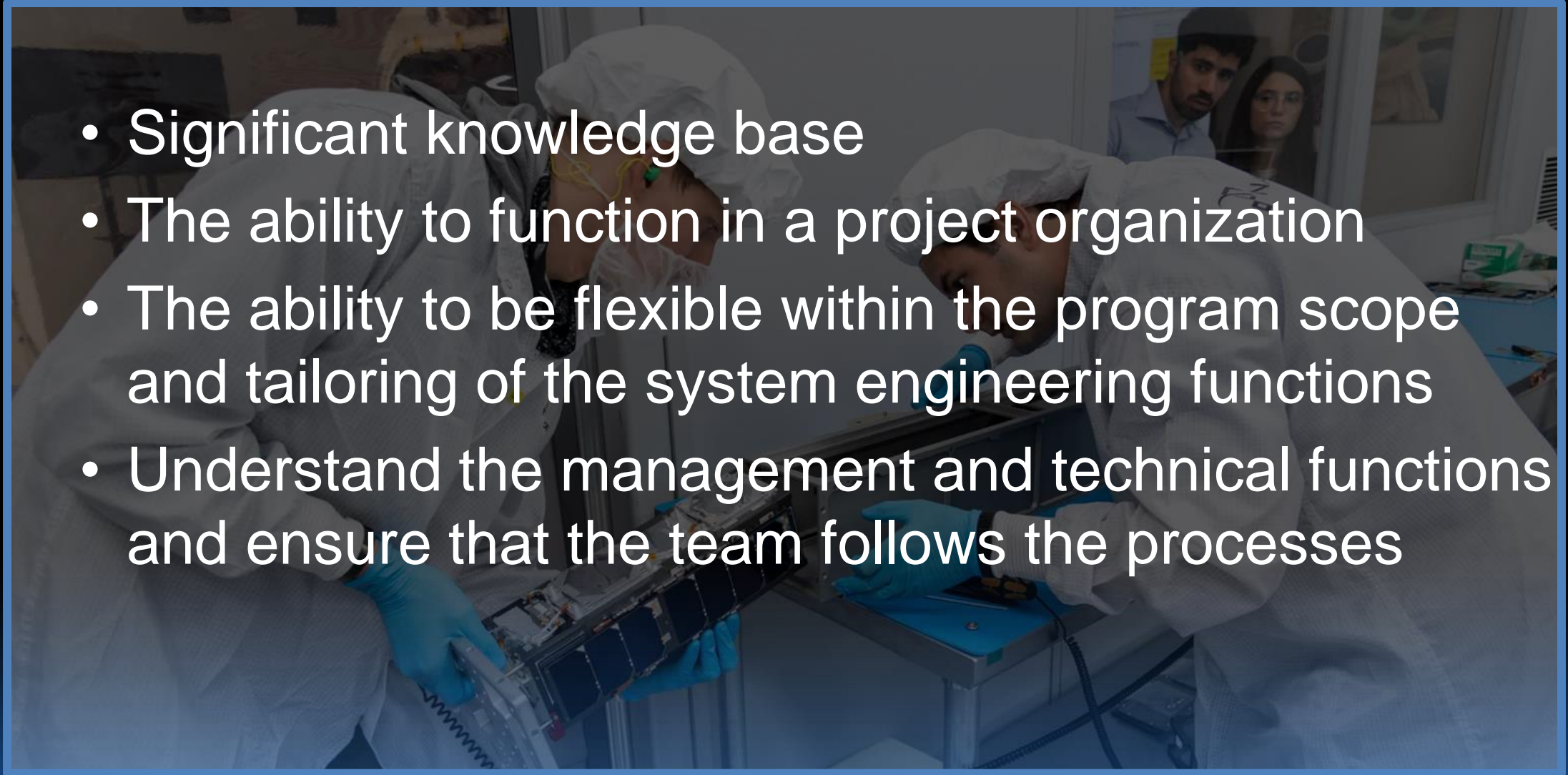


- Processes “Proper Paranoia”
- Manages Resources and Margins
- Good Communication Skills
- Self-Confident and Energy
- Has an Appreciation for Process

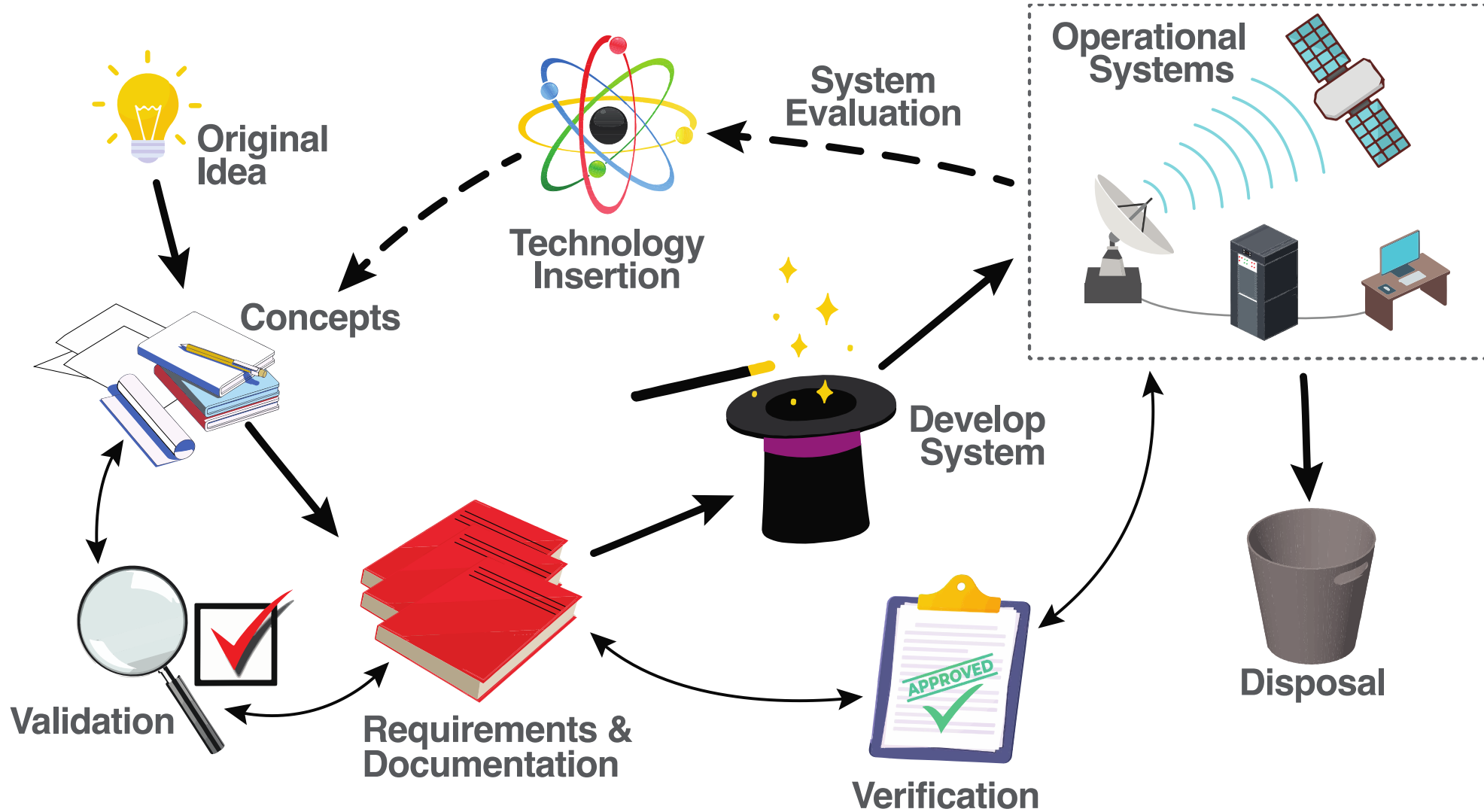
# What Does It Take to be a Systems Engineer?



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

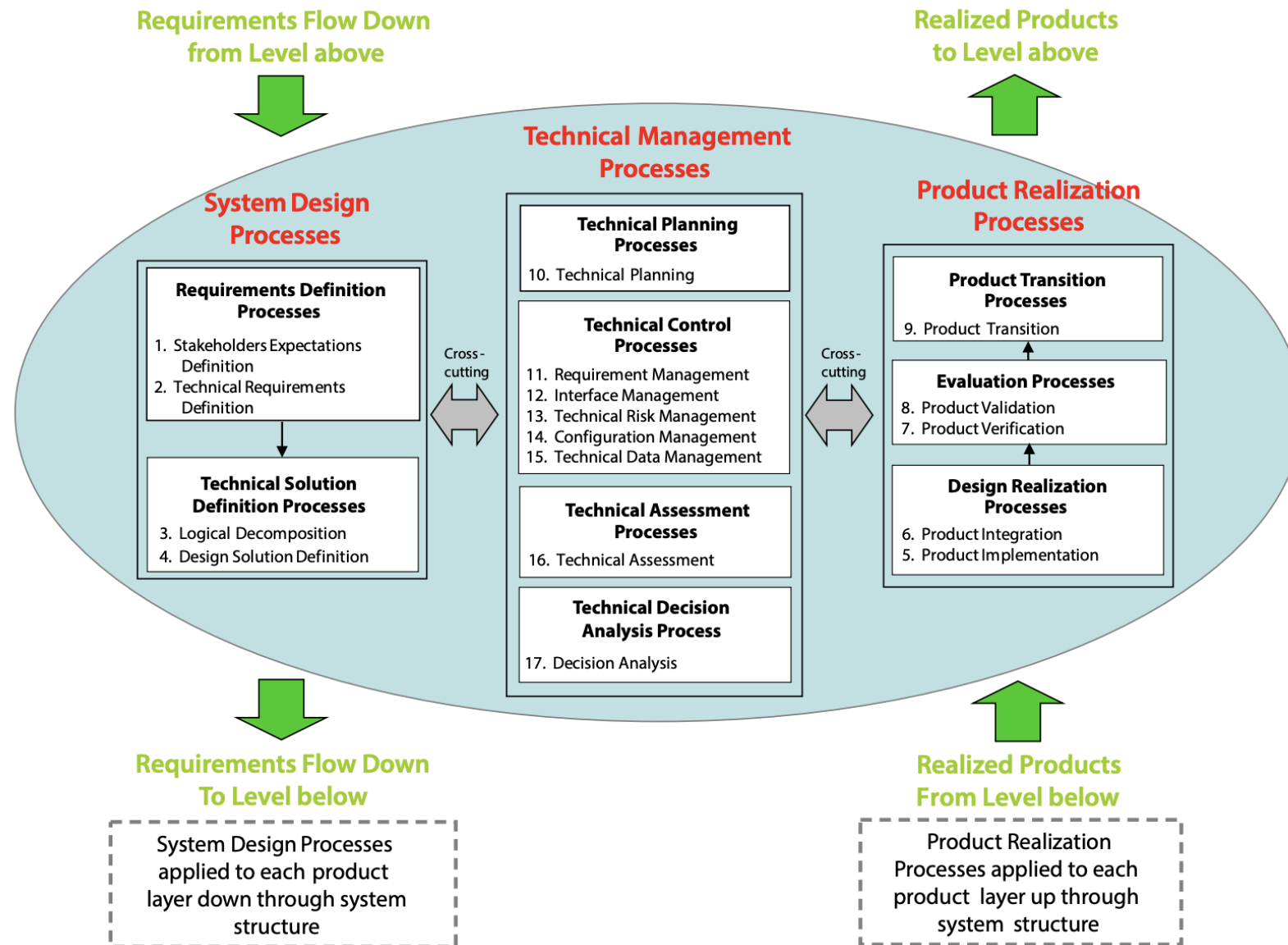


# Idea to Operational System





# The Systems Engineer Engine

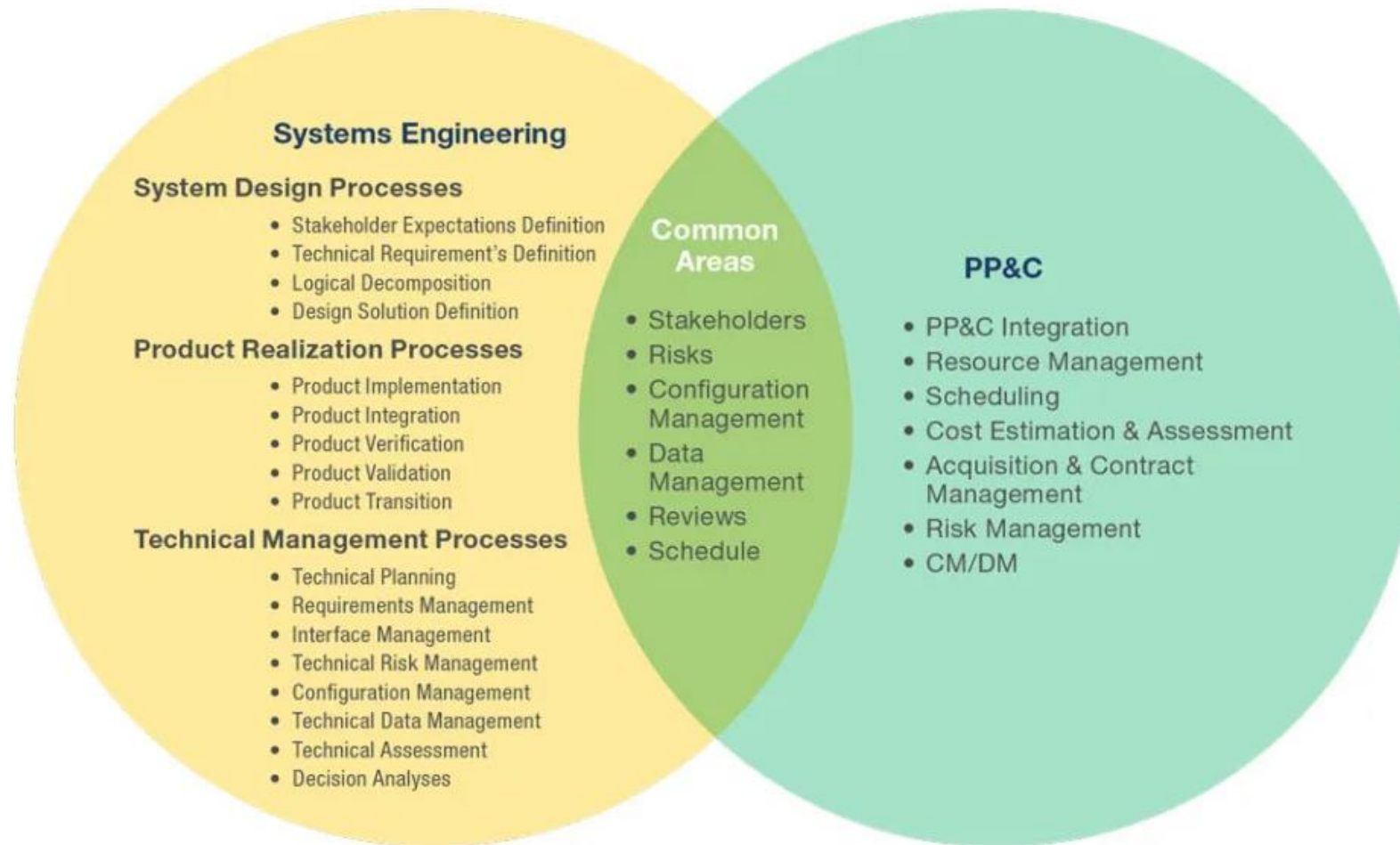


# Systems Engineering in Context of Overall Project Management



## 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

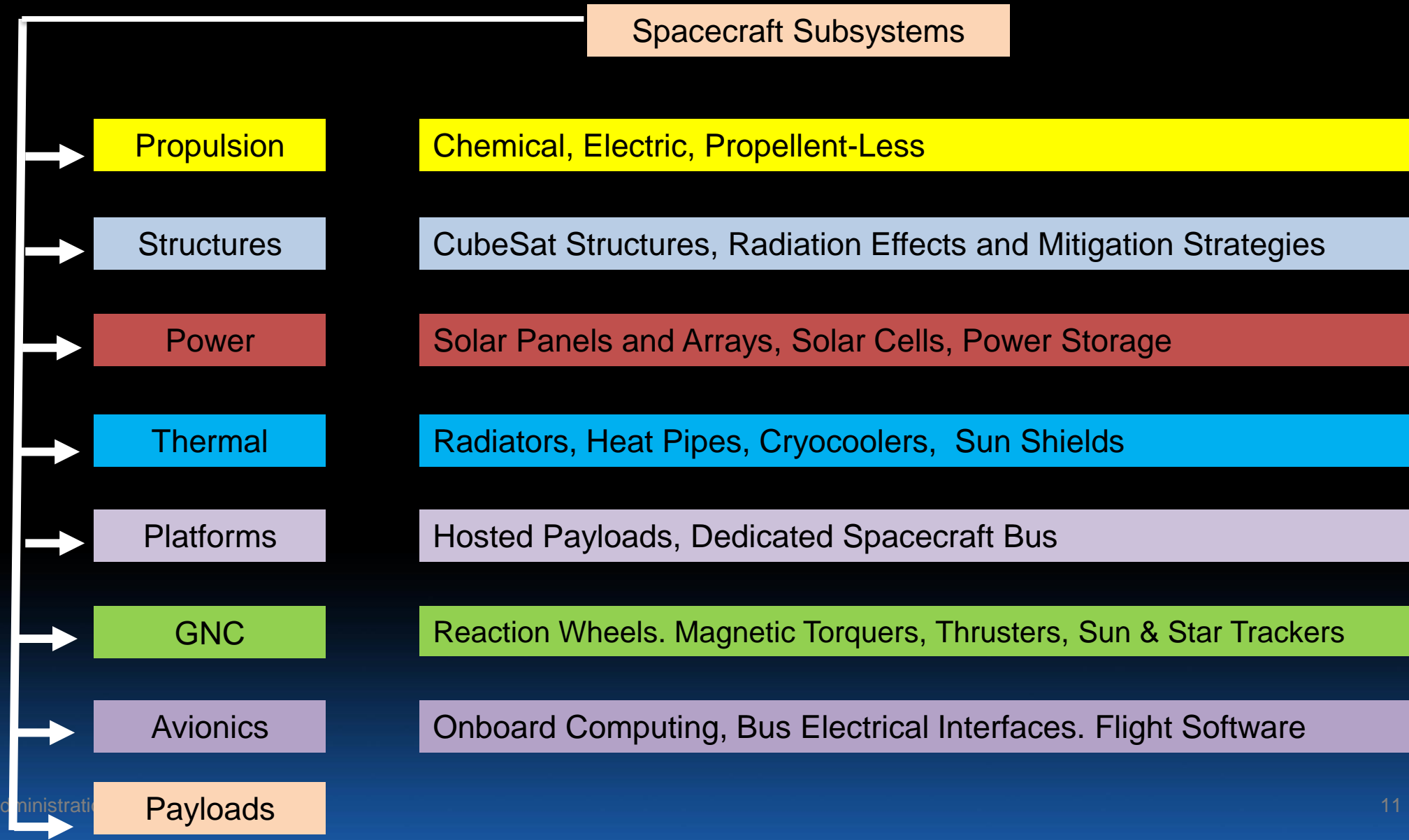


# What are the Elements of Managing a Small Spacecraft Project?



Managing a project consists of three main objectives:

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



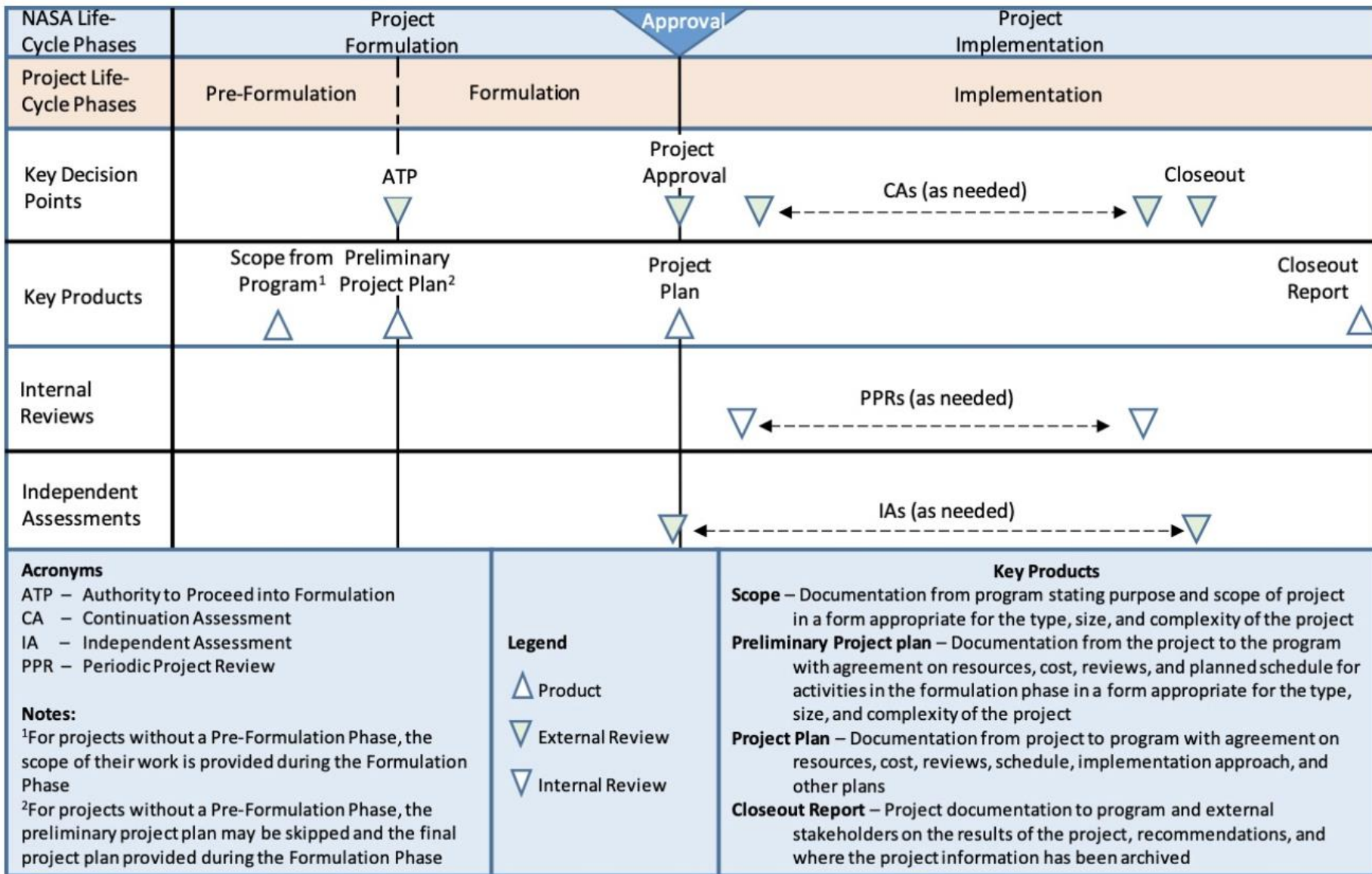
# What are the Elements of a Project's Life Cycle Phases?



	Phase	Purpose	Typical Output
<b>F o r m u l a t i o n</b>	Pre-Phase A: Concept Studies	To produce a broad spectrum of ideas and alternatives for missions from which new programs/projects can be selected. Determine feasibility of desired system, develop mission concepts, draft system-level requirements, identify potential technology needs.	Feasible system concepts in the form of simulations, analysis, study reports, models, and mockups
	Phase A: Concept and Technology Development	To determine the feasibility and desirability of a suggested new major system and establish an initial baseline compatibility with NASA's strategic plans. Develop final mission concept, system-level requirements, and needed system structure technology developments.	System concept definition in the form of simulations, analysis, engineering models, and mockups and trade study definition
	Phase B: Preliminary Design and Technology Completion	To define the project in enough detail to establish an initial baseline capable of meeting mission needs. Develop system structure and product (and enabling product) requirements and generate a preliminary design for each system structure end product.	End products in the form of mockups, trade study results, specification and interface documents, and prototypes
<b>I m p l e m e n t a t i o n</b>	Phase C: Final Design and Fabrication	To complete the detailed design of the system (and its associated subsystems, including its operations systems), fabricate hardware and code software. Generate final designs for each system structure end product.	End products detailed designs, end product component fabrication, and software development
	Phase D: System Assembly, Integration and Test, Launch	To assemble and integrate the products to create the system, mean-while developing confidence that it will be able to meet the system requirements. Launch and prepare for operations. Perform system end product implementation, assembly, integration and test, and transition to use.	Operations-ready system end products with supporting related enabling products
	Phase E: Operations and Sustainment	To conduct the mission and meet the initially identified need and maintain support for that need. Implement the mission operations plan.	Desired system
	Phase F: Closeout	To implement the systems decommissioning/disposal plan developed in Phase E and perform analyses of the returned data and any returned samples.	Product closeout



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



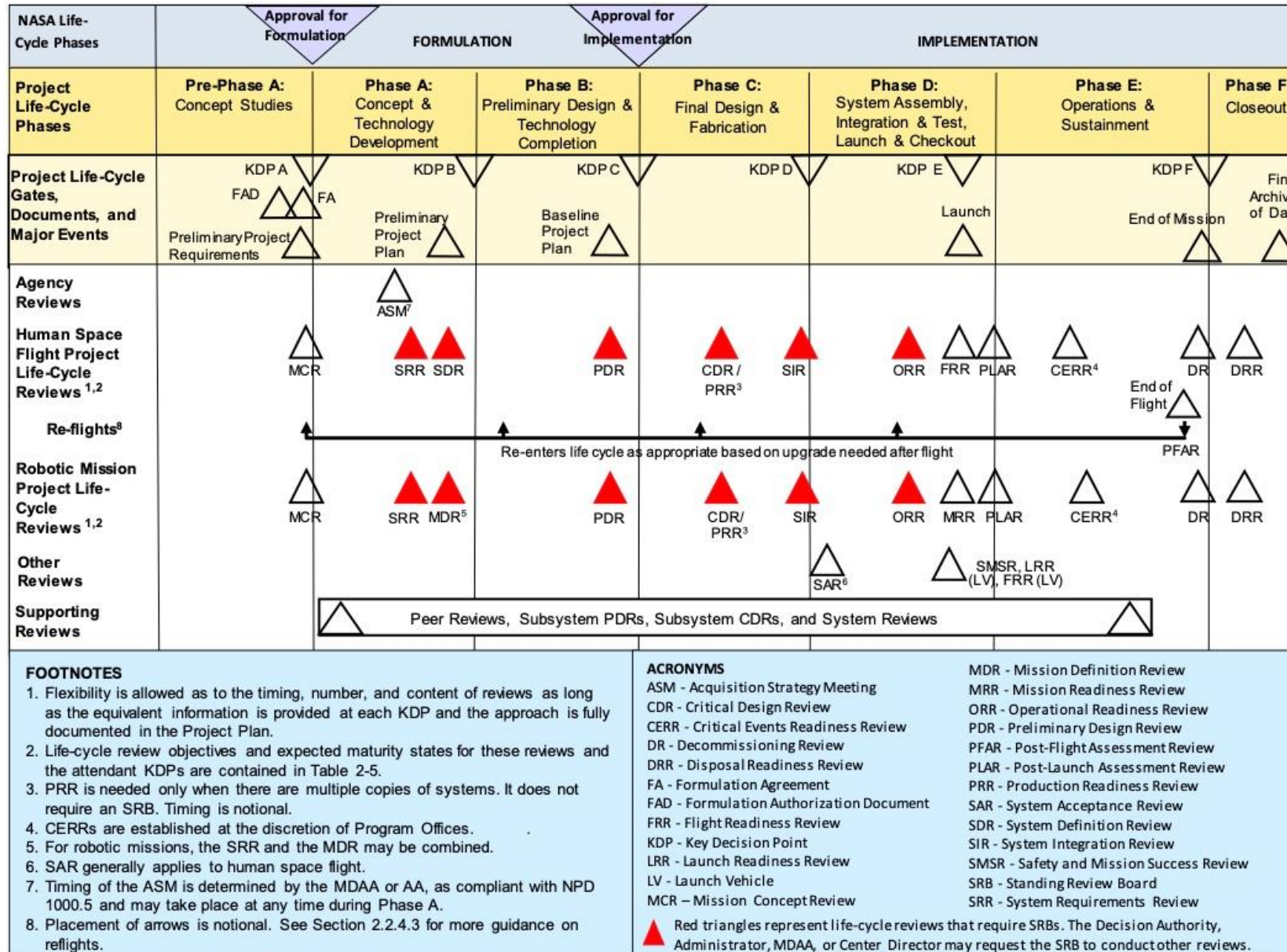
# What are the key Program Life Cycle Reviews?



<b>Key Reviews</b>	<b>Definition/Context</b>
System Requirements Review (SRR)	What are we building?
Preliminary Design Review (PDR)	Does the design close analytically?
Critical Design Review (CDR)	Are you ready to build/test?
Flight Readiness Review (FRR)	Are you ready to launch/operate?



# 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.

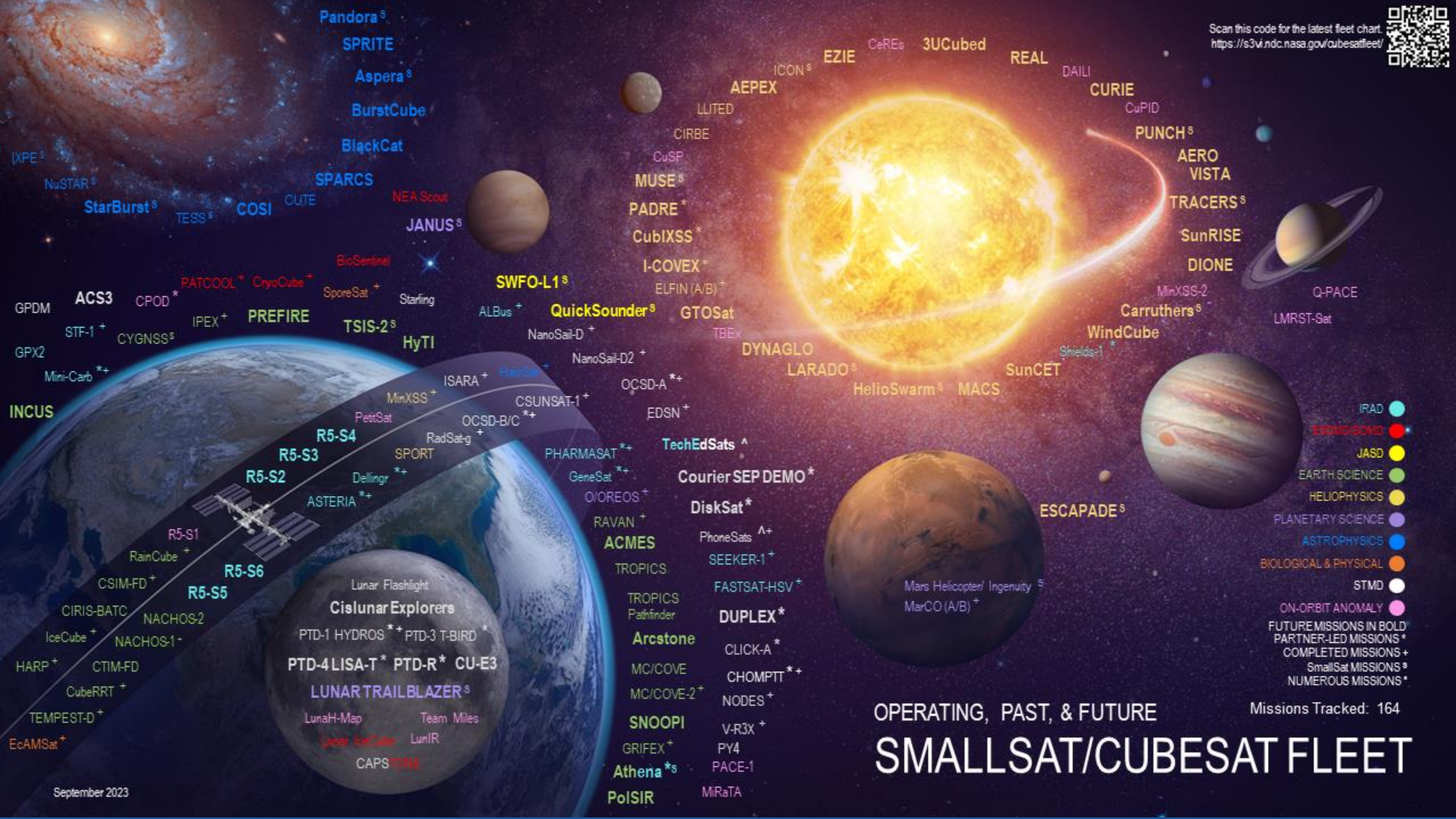


# Why Does NASA Use Systems Engineering?



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.

Scan this code for the latest fleet chart.  
<https://s3vi.ndc.nasa.gov/cubesat/fleet/>



# OPERATING, PAST, & FUTURE SMALLSAT/CUBESAT FLEET

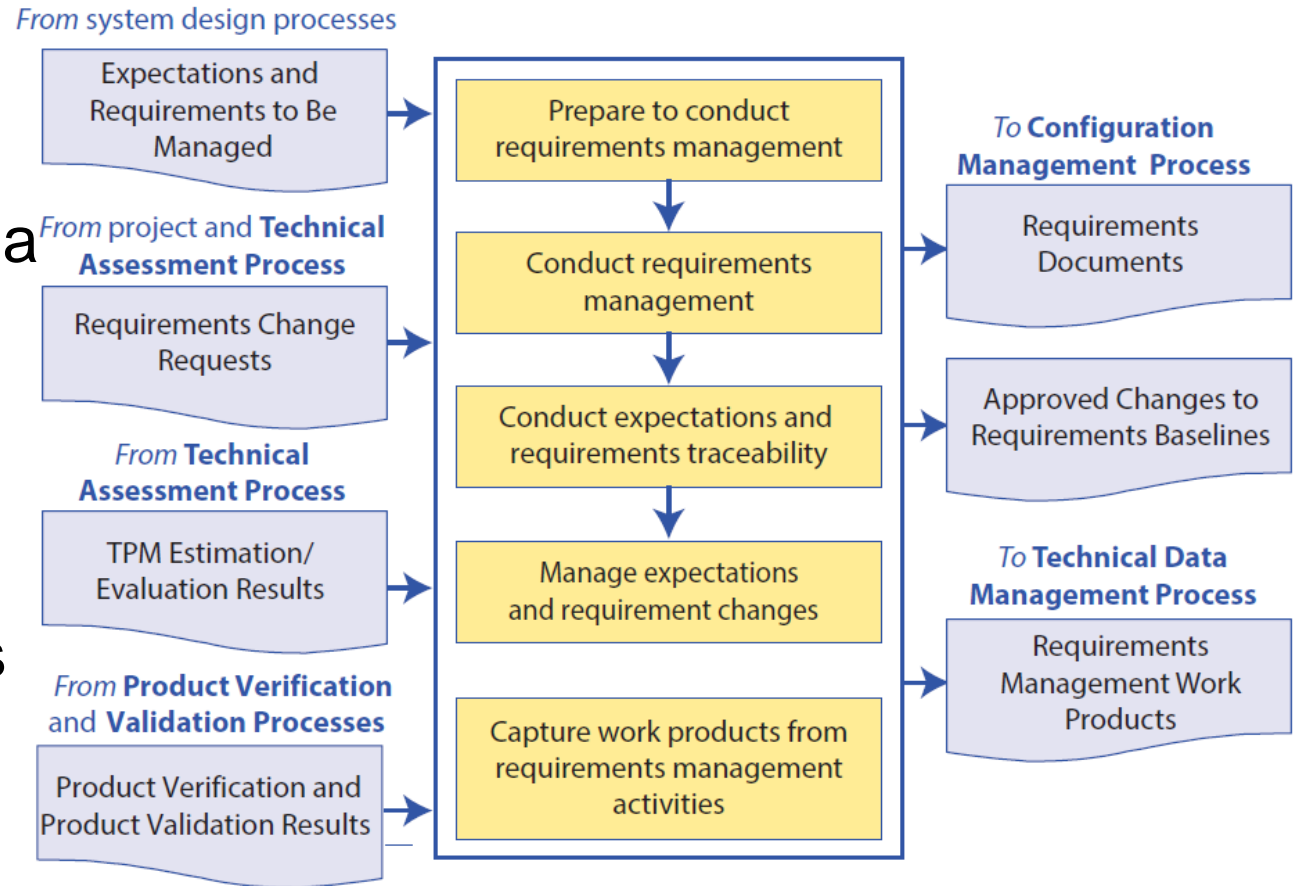
Missions Tracked: 164

# 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/](http://www.nasa.gov/smallsat-institute/)

- NASA Procedural Requirements (NPR) 7120.5: NASA Spaceflight Program and Project Management Requirements
  - Establishes the requirements that NASA formulates and implements space flight programs and projects
- NASA Procedural Requirements (NPR) 7120.8: NASA Research and Technology Program and Project Management Requirements
  - Research and Technology typically using ground systems or sub-orbital vehicles, aircraft, sounding rockets, and balloons)
  - More recently CubeSats, SmallSats, ISS payloads have been included