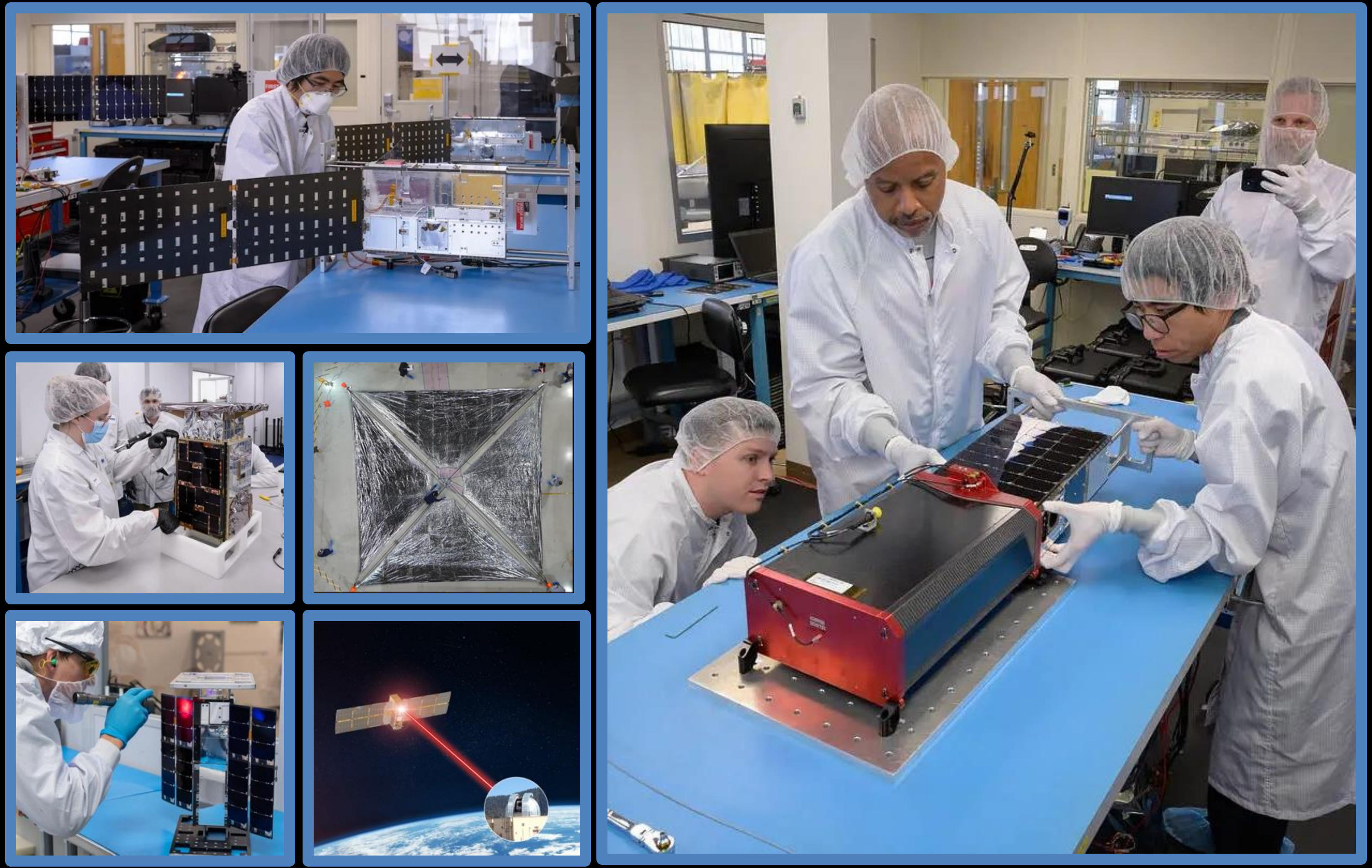

Project Lifecycle Reviews

November 27, 2024

Access to Space for All
Systems Engineering Webinar Series

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Webinar Overview

This webinar will dissect project lifecycle review elements and discuss their importance to project management. This overview includes:

- What are the elements of project life cycle phases?
- Which elements are required for each phase?
- What are the key milestones for the various phases?
- How is it determined to transition to the next phase?
- How does systems engineering and project management play a role in the different phases?

Purpose:
To provide attendees with information and knowledge of the project lifecycle review elements and how they relate to project management.

Elements of Project Lifecycle Phases

- Pre-Phase A: Concept Studies
  - "Feasibly systems concepts in the form of simulations, analysis, study reports, models, and mock-ups"
- Phase A: Concept and Technology Development
  - "System concept definition in the form of simulations, analysis, engineering models and mock-ups, and trade study definition"
- Phase B: Preliminary Design and Technology Completion
  - "End products in the form of mock-ups, trade study results, specification and interface documents, and prototypes"
- Phase C: Final Design and Fabrication
  - "End product detailed designs, end products component, fabrication, and software development"
- Phase D: System Assembly, Integration and Test, Launch
  - "Operations-ready system end product with supporting related enabling products"

Project Lifecycle Required Reviews

- Phase A: Concept and Technology Development
  - Systems Requirements Review (SRR) – “A review that examines the functional and performance requirements defined for the system and the preliminary program or project plan and ensures that the requirements and the selected concept will satisfy the mission.”
- Phase B: Preliminary Design and Technology Completion
  - Preliminary Design Review (PDR) – “A review that demonstrates that the preliminary design meets all systems requirements with acceptable risk and within the cost and schedule constraints and establishes the basis for proceeding with detailed design. It will show that the correct design option has been selected, interfaces have been identified, and verification methods have been described.”

Project Lifecycle Required Reviews Continued

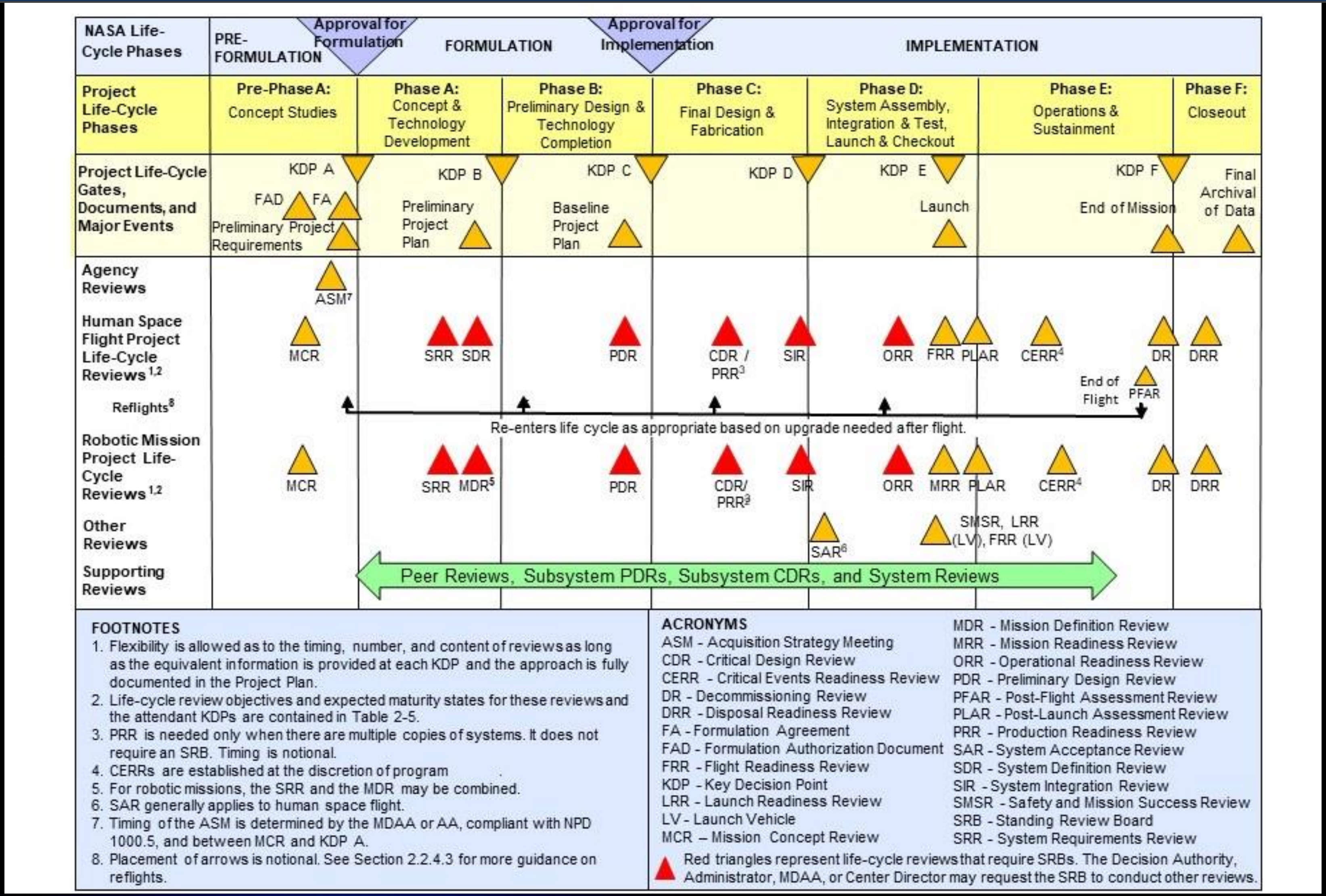
- Phase C: Final Design and Fabrication
    - Critical Design Review (CDR) – "A review that demonstrates that the maturity of the design is appropriate to support proceeding with full-scale fabrication, assembly, integration, and test, and that the technical effort is on track to complete the flight and ground system development and mission operations in order to meet mission performance requirements within the identified cost and schedule constraints."
- Phase D: System Assembly, Integration and Test, Launch
    - Operational Readiness Review (ORR) – "A review that examines the actual system characteristics and the procedures used in the system or product's operations and ensures that all system and support (flight and ground) hardware, software, personnel, procedures, and user documentation accurately reflects the deployed state of the system."

Standard Project Management at NASA

NPR 7120.5:
One-size-fits-all…except

Covers a range from Human Spaceflight (Class A) through Small Robotic Missions (Class D)

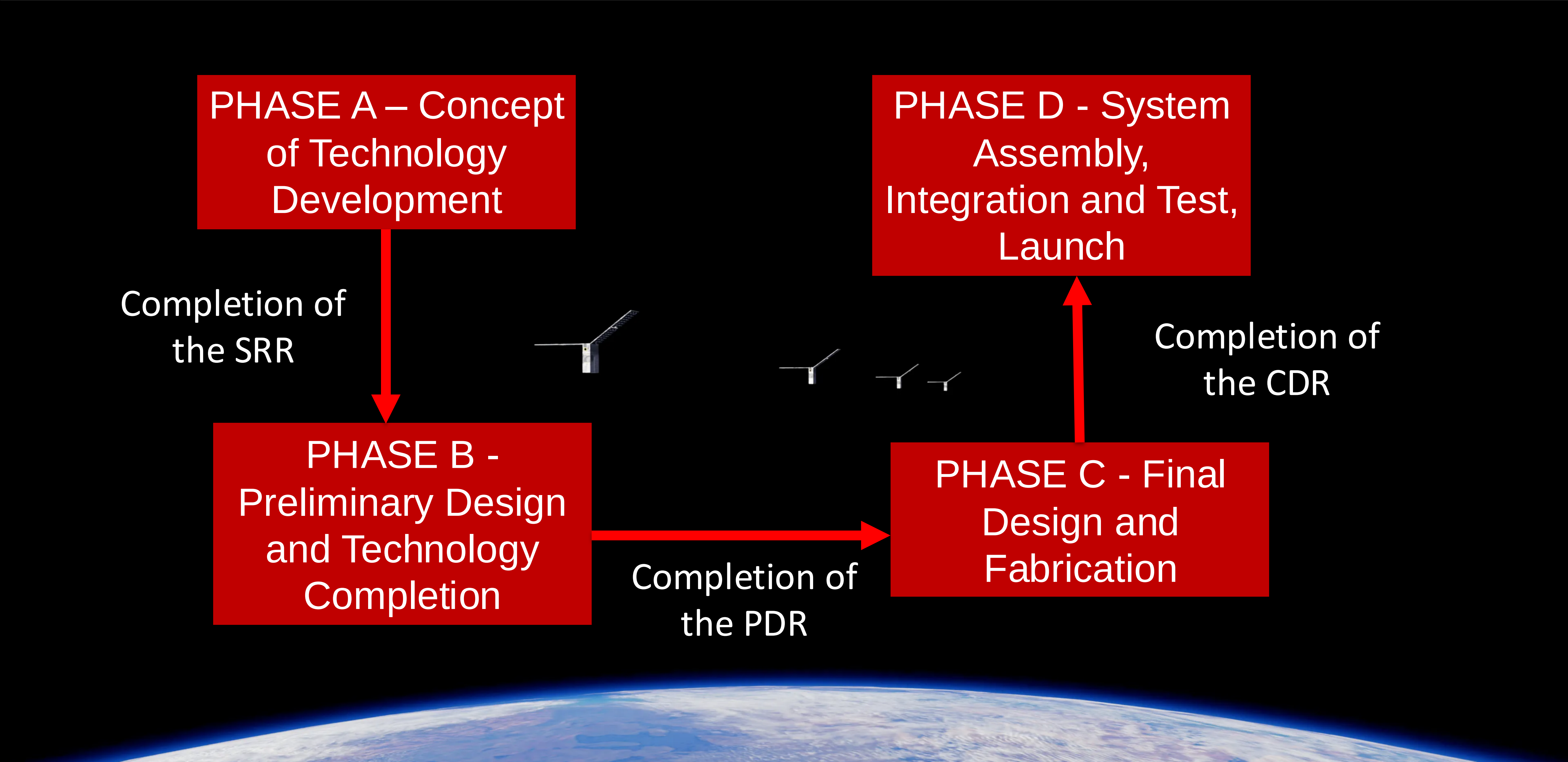
Efforts at streamlining have occurred around Class D missions



Key Milestones

- What are the key milestones associated with the following Phases:
  - Pre-Phase A: Concept Studies
  - Phase A: Concept and Technology Development
  - Phase B: Preliminary Design and Technology Completion
  - Phase C: Final Design and Fabrication
  - Phase D: System Assembly, Integration and Test, Launch

Transitions to the Next Phase



Project Sizes

Sizes range orders of magnitude from very large (Flag Ship) to very small (CubeSat)

Larger missions have low risk posture
Class B

MIDEX missions are in the middle
Class C

Smaller missions have higher risk posture
Class D or even lower

Project Management Models

Within NASA, there are two major “groupings”:

(1) NPR 7120.5 provides the NASA Space Flight Program and Project Management Requirements

- One size fits all has been a recurring problem
- Attempts at adjusting the model over time
- NPR 7120.5 Rev F is the latest version - One of the improvements is Enhanced Tailoring Guidance

(2) NPR 7120.8 provides NASA Research and Technology Program and Project Management Requirements

- This NPR is becoming more acceptable for some space flight missions
- Mostly technology missions in the past, but some are large (e.g. VIPER)

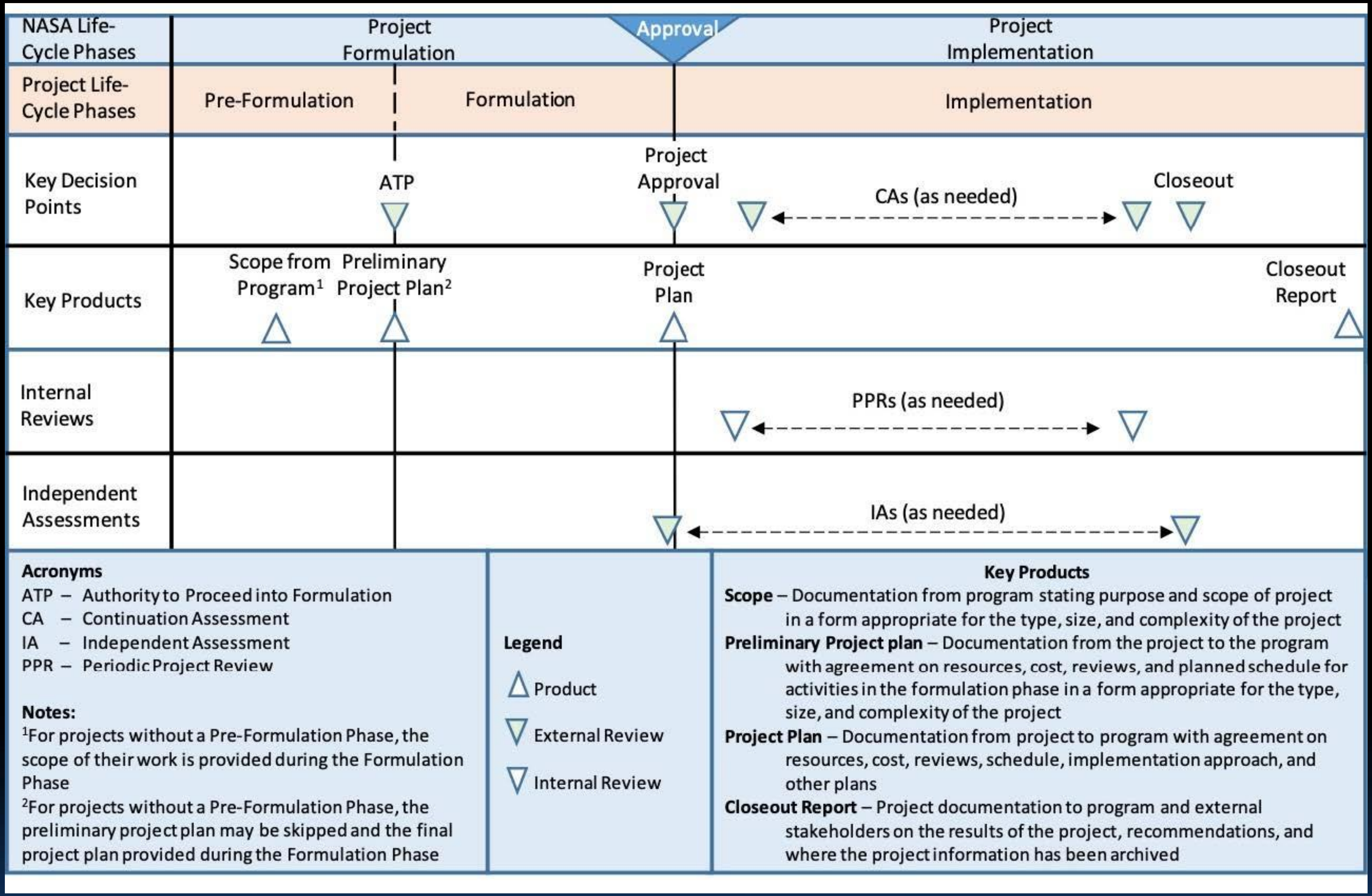
Alternate Project Management Model for Technology Programs

NPR 7120.8 is simpler in structure and easier to tailor

Becoming more acceptable for some space flight missions

Mostly lower cost technology missions in the past, but some are getting larger

Note that this can also encompass “Do No Harm” missions.



Similarities between mission classes

Complexity of Interfaces

- CubeSats and SmallSats often have the same number and complexity of interfaces

Systems Engineering

- Even for smaller teams, the SE principles are still important

Operations

- To MOS, all missions no matter the size are just points in space
  - Note: LEO is the exception, because of the support infrastructure
- The main variability is the operational risk posture and ops tempo

Systems Block Diagram

- Components are smaller but the diagram is often the same

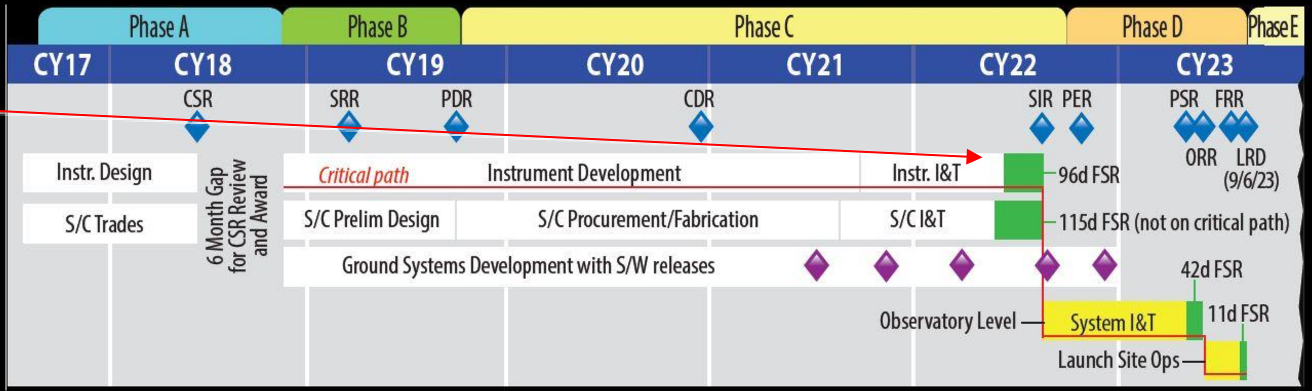
Differences between mission classes

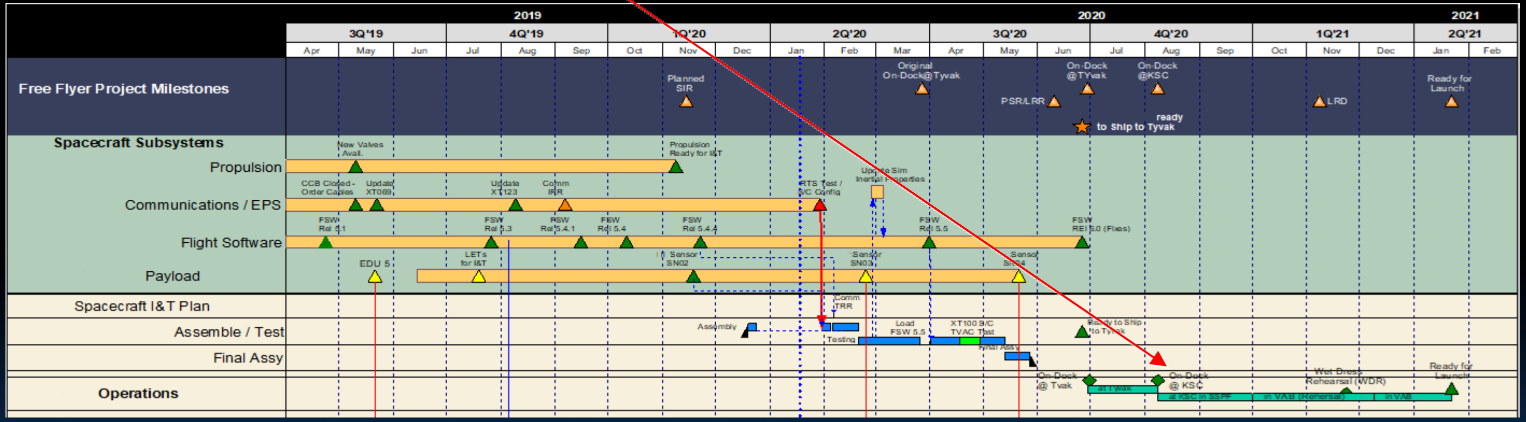
- Small Missions have fewer cost reserves (if any)
  - Smaller 0-10% vs Larger 25-30%
- Schedule
  - Larger Missions: Funded schedule reserve along critical path at risk points
  - Smaller Missions: Unfunded Margin at end after delivery
- Range Safety
  - CubeSats are encapsulated and usually have inert prop with less stored energy
  - SmallSats (for deep space) are cantilever mounted (vibe) and often have prop systems with significant stored energy (monitoring and inhibits)
- Flight Dynamics
  - CubeSats in LEO can leverage GPS
  - SmallSats in Deep Space depend on ground tracking/ranging and OD analysis
- Attitude Control
  - CubeSats in LEO can leverage the Earth's magnetic field to manage momentum
  - SmallSats in Deep Space need a means of dumping momentum (thrusters)
- GSE Approach (Lifts, Transport, etc.): Size is important!

Differences: Schedule Management

Schedule Margins

- MIDEX: Distributed on CP at Risk Points
- Small Missions: Held at I&T or Storage





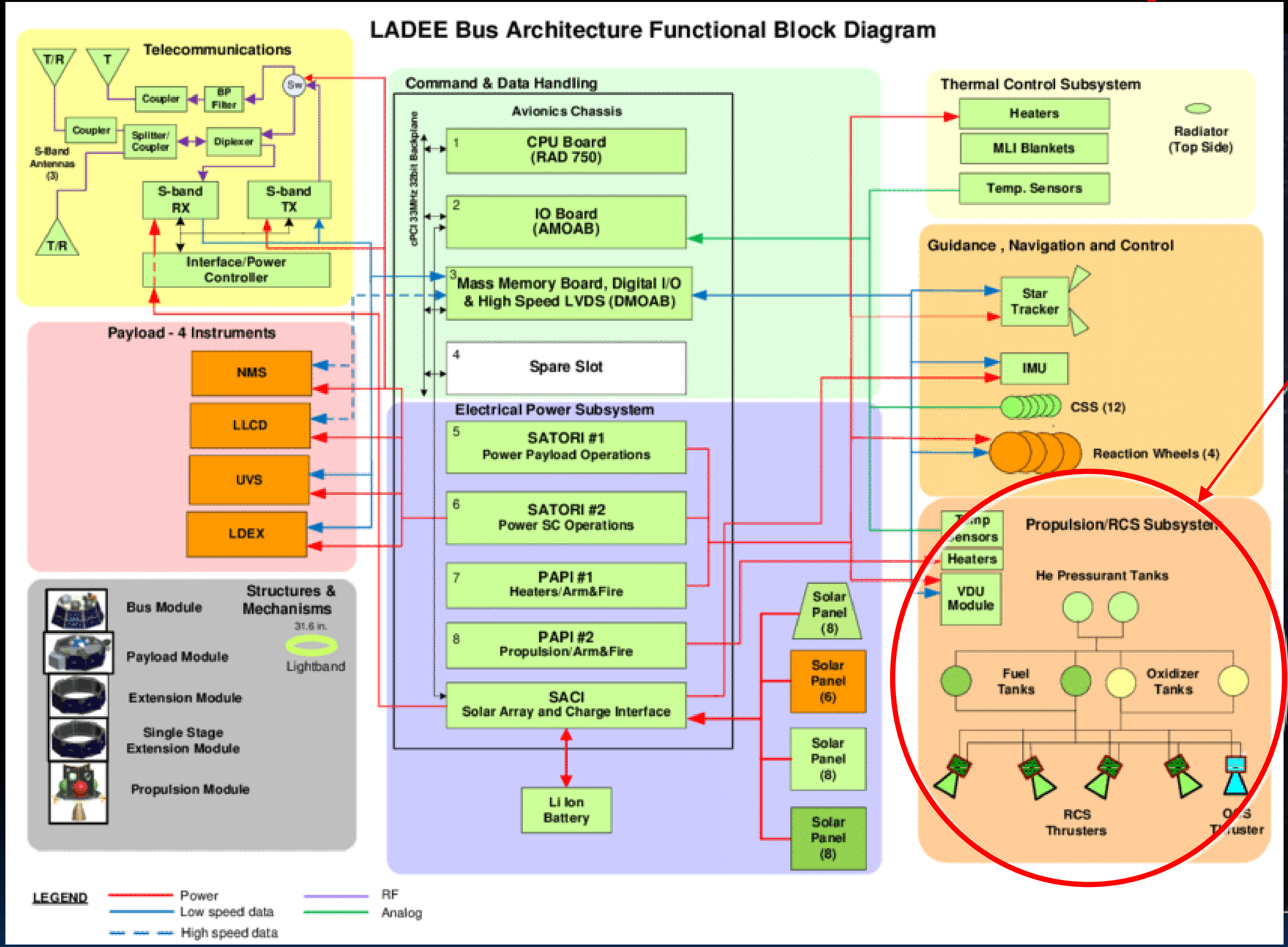
Cost Reserves

- MIDEX: 25%-30% CTG
- Small Missions: 0%-10% ATP

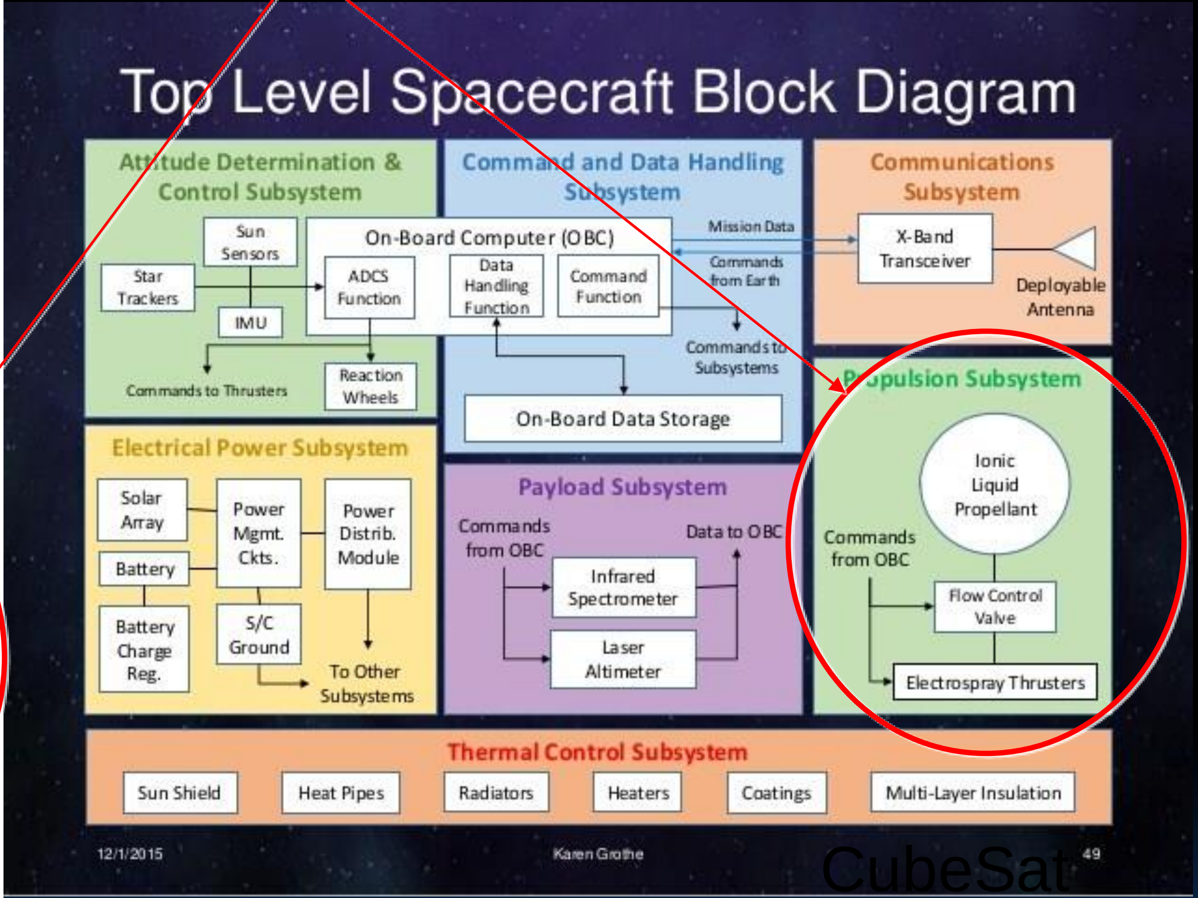
Differences: System Complexity

Systems Block Diagram

Propulsion complexity is one of the differences



Credit: Biswas, Gautam & Khorasgani, et al. (2016). An Approach To Mode and Anomaly Detection With Spacecraft Telemetry Data. International Journal of Prognostics and Health Management.

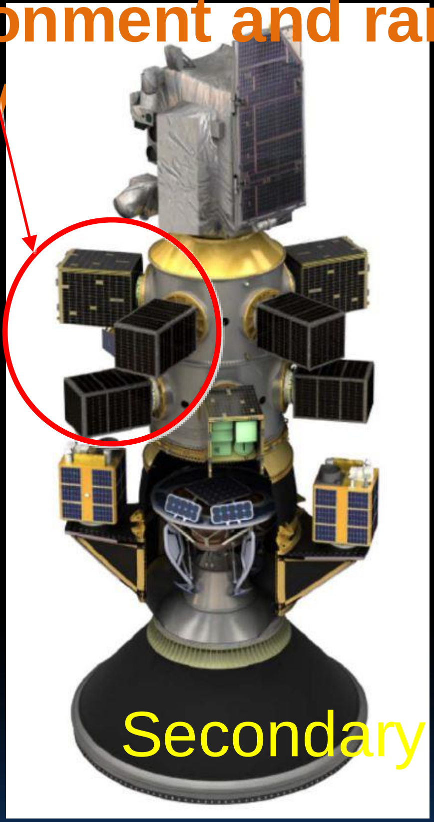


Credit: Karen Grothe Capstone Project: Conceptual Mercury CubeSat Mission, Loyola Marymount University

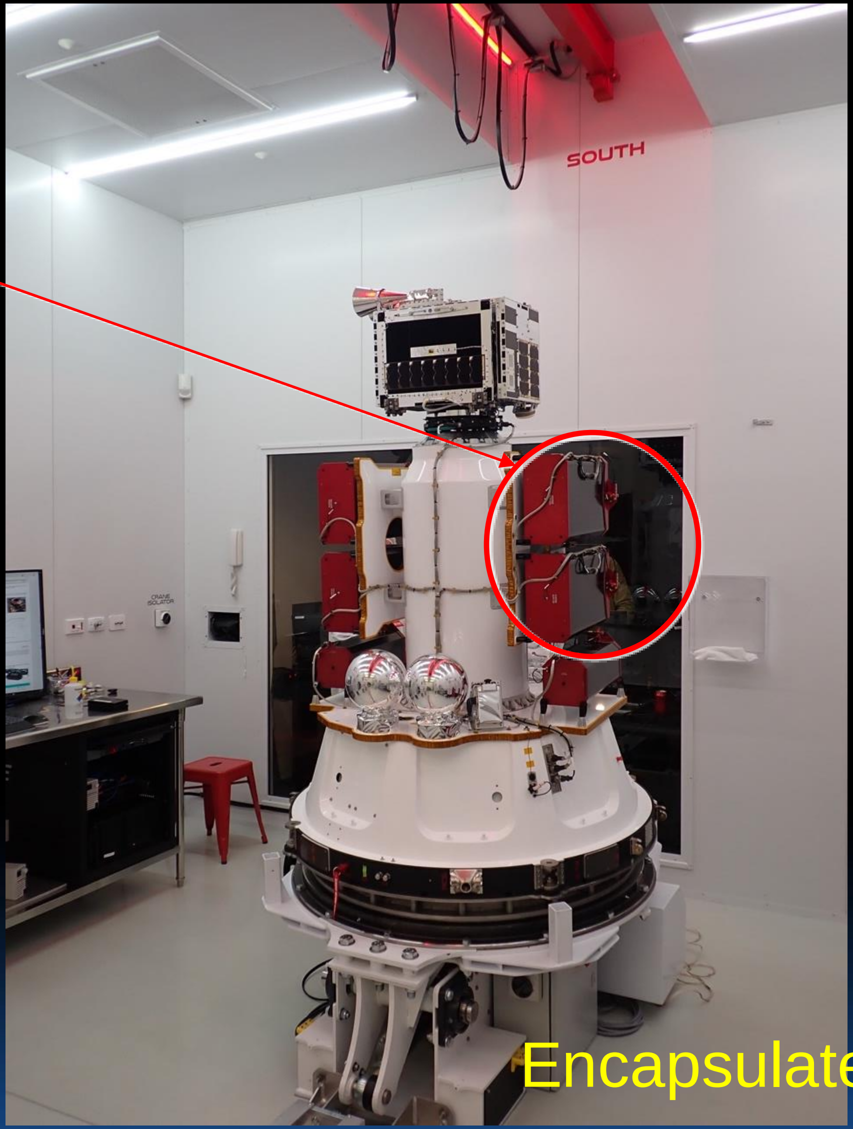
Differences: Launch Accommodation

Launch Access

SmallSats are not encapsulated, so launch environment and range safety



Credit: Caffrey - Rideshare/Multi-Manifest Payload Overview 2019



Differences: Ground Handling

Critical Lifts

Differences: Transport

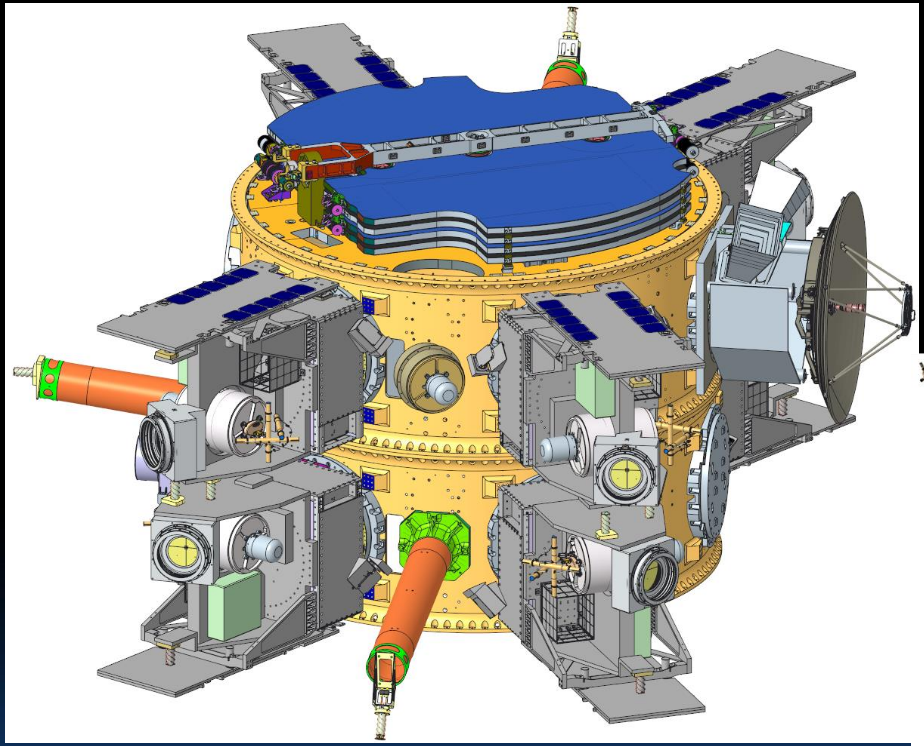
Transport

CubeSat

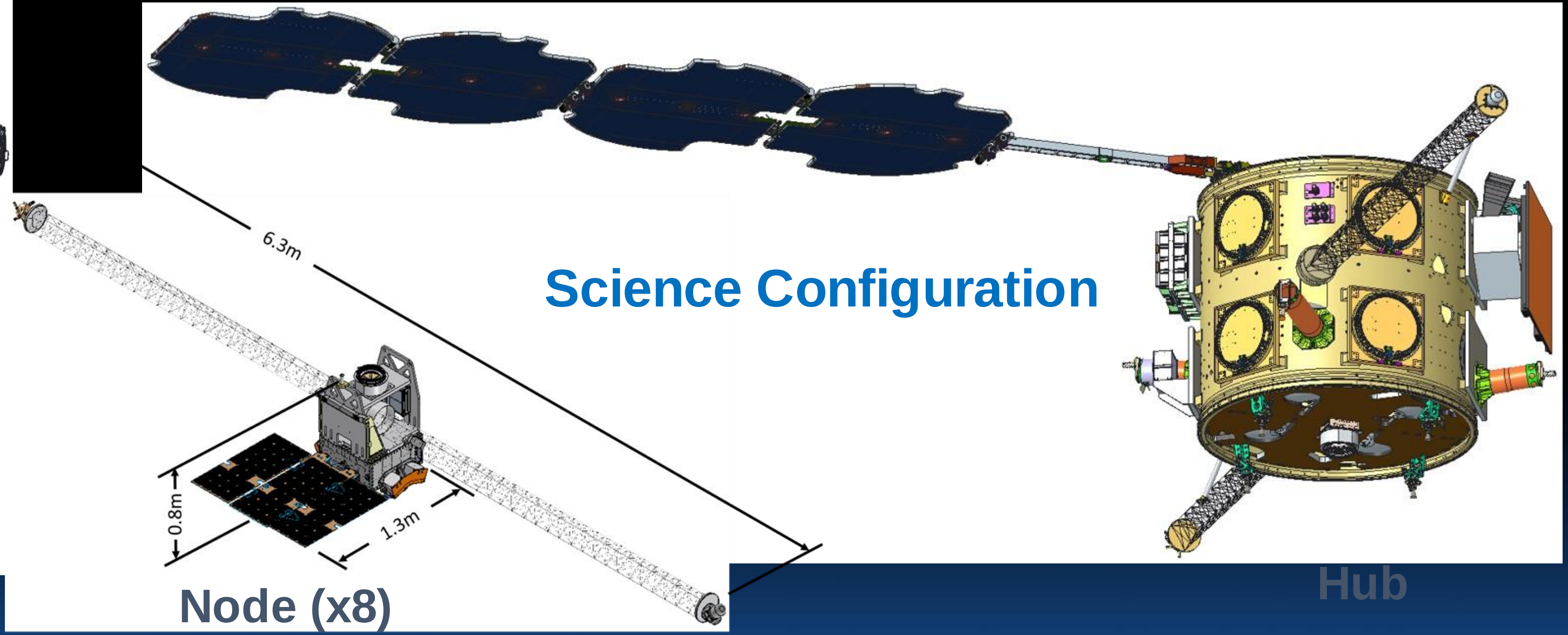
MIDEX and SmallSat (depending on size)

Example: HelioSwarm - A SmallSat MIDEX Mission

HelioSwarm is a NASA science mission that uses a powered-ESPA bus to carry a swarm of 8 SmallSats to HEO. Once deployed, the 9 spacecraft become a heliophysics observatory

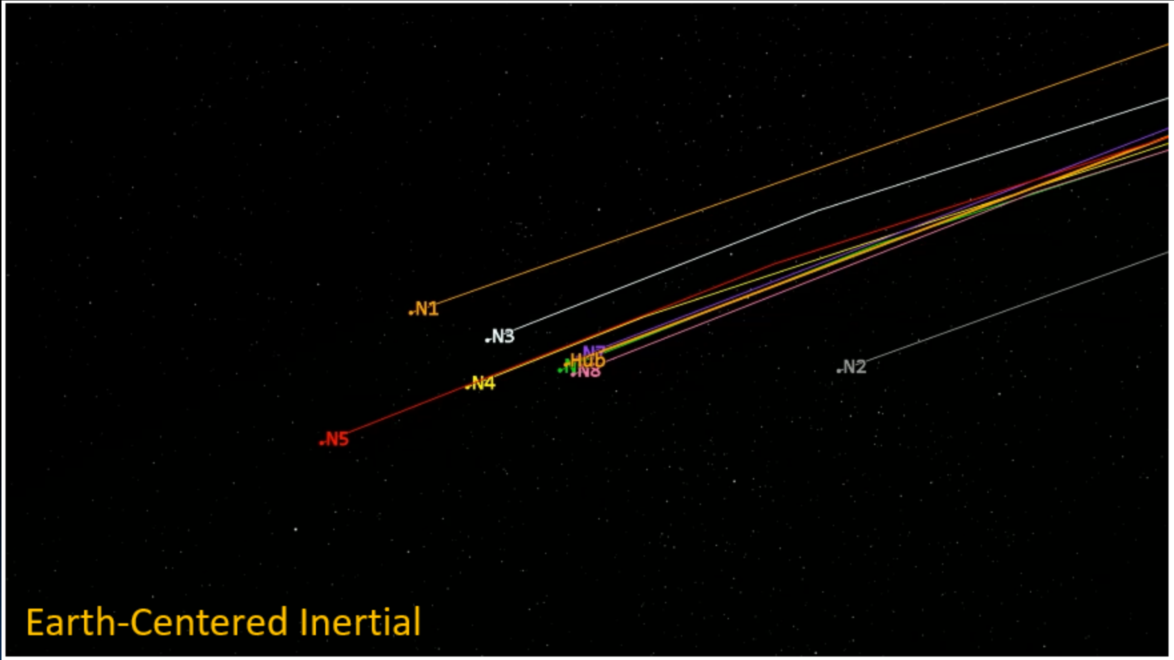


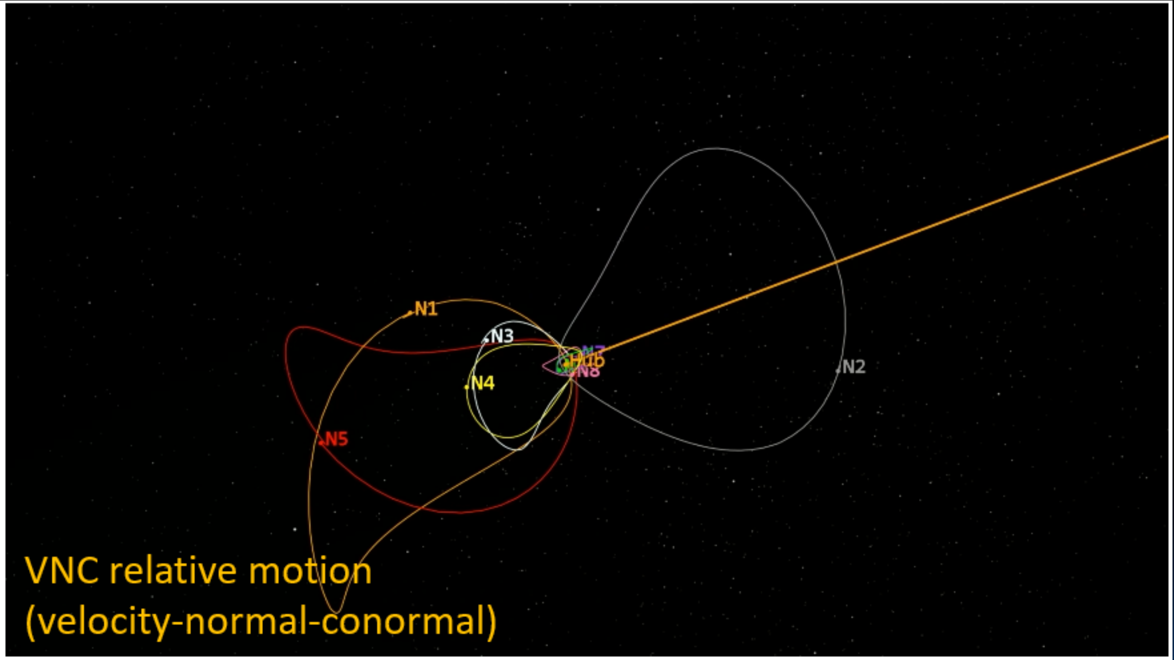
Transfer to Science Orbit



HelioSwarm: Spacecraft Relative Motion

- The Nodes do not orbit the Hub; they orbit the Earth
- Relative motion is an emergent property from tiny differences in observatory members’ orbits **around the Earth**





Same motion, different reference frame

Management Challenges

SmallSat missions are more expensive than CubeSats, so along with that comes:

- Organizational Priority
  - Smaller Projects are usually lower priority for senior management

- Lack of key tools to solve problems:
  - Minimal cost and schedule reserves

- Fractional Staff:
  - Competing priorities with their other work

- Type of Staff:
  - Breadth vs Depth
  - Attracting Heavy Lifters

So Which Size Project is Harder to Manage?

- Smaller projects are more difficult to staff
- Smaller projects are more brittle to problems
- Smaller projects have fewer tools available to solve problems

But

- Larger projects have more complicated organizational structures
- Larger projects have execution inertia, so often less nimble
- Larger projects have more politics
- Larger projects fail more spectacularly

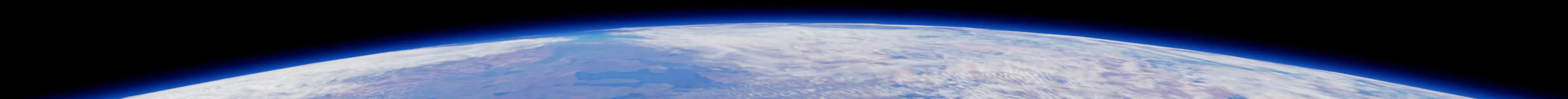
Conclusion: SmallSat missions are technically similar to CubeSat missions, but the increased size and cost brings added complexity.

Upcoming Webinar: Model Based Systems Engineering

This webinar will cover an introduction to Model Based Systems Engineering (MBSE). This overview includes:

- What is MBSE and why is it important to NASA missions?
- How do you begin using MBSE to develop a small spacecraft project?
- What examples of missions that utilized MBSE?
- How do you relate mission requirements to MBSE?

Purpose:
To provide attendees with information and knowledge of Model Based Systems Engineering and how it plays a vital roll in developing small spacecraft projects.



Questions?

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