National Aeronautics and Space Administration

NASA Glenn Research Center

Systems Engineering the Future

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Purpose

- This Presentation will look at:

  The evolving nature of systems engineering at the National Aeronautics and Space Administration (NASA) and its Glenn Research Center

  Glenn Research Center application and practice of systems engineering

Enabling the NASA Vision

- The NASA Vision

  To reach for new heights and reveal the unknown so that what we do and learn will benefit all humankind

Robust systems engineering is critical to NASA as it carries out this mission

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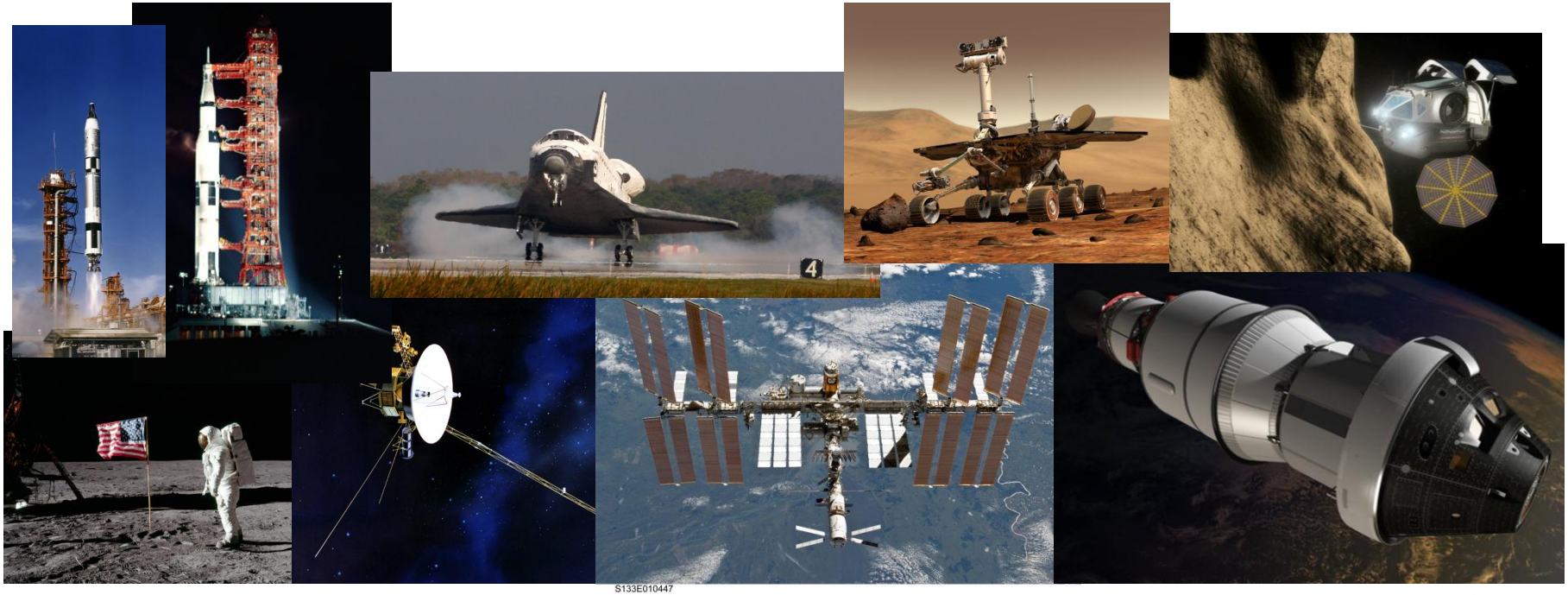
NASA Systems Engineering

- Over the years NASA has had many significant systems engineering achievements
- To accomplish future missions, NASA systems engineering capability will need to continue to evolve

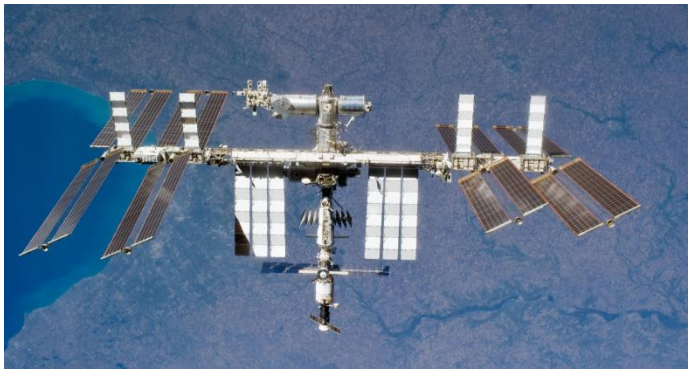


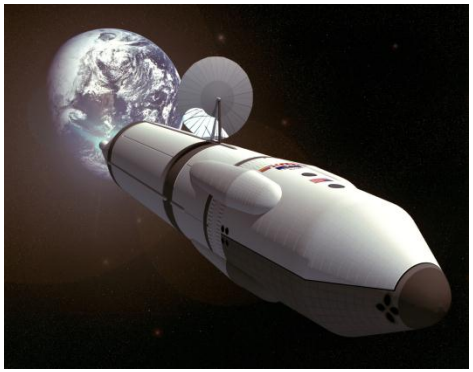
Complexity is a Major Issue

- Integration of systems create a major problem with complexity
  - Within in a system, interactions grow as N squared, or worse
  - Ability to understand and test becomes less certain
  - As more systems are added, the interfaces grow in a non-linear fashion
  - Many of the existing systems are old and not built for these interfaces
  - Conflicting or missing interface standards make it hard to define interface interactions
  - Hardware and software may be re-purposed and “heritage” compromised
  - Future systems will be integrated from multi-organizational, multi-national contributions, adding additional layers of complexity.
- Systems engineering must deal with this complexity
  - End-to-end systems engineering is needed, including “reengineering” of old systems
  - Robust M&S, verification and validation testing are a must

Supporting multi-decadal, multi-generation activities is a major challenge

- The International Space Station will have a lifespan of at least 20 years with evolving uses and constant changes
- Systems analyses show that as we explore beyond low earth orbit, launch costs will remain a driver and thus put a huge value in re-using systems already moved up the gravity well
  - We will need to track systems health and status against predictions and threshold
  - Systems will be modified, updated and repurposed multiple times
  - Operating environments and conditions may change from those used for design
  - Likely to want to use systems well beyond initial life objectives



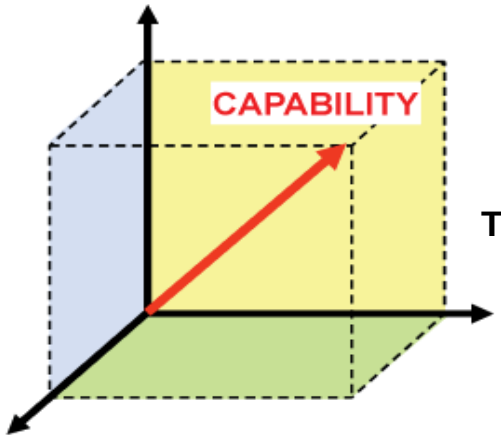


NASA Systems Engineering Capability

NPR 7123.1

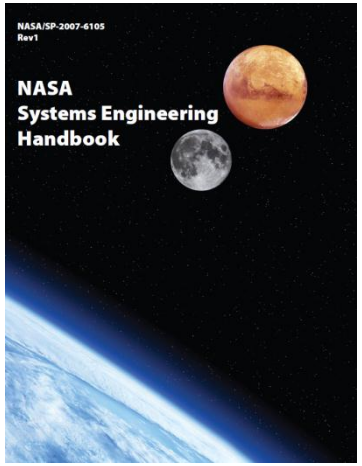
NASA
Systems Engineering
Processes &
Requirements

Common Technical Processes
- System Design, Product Realization, and Technical Management



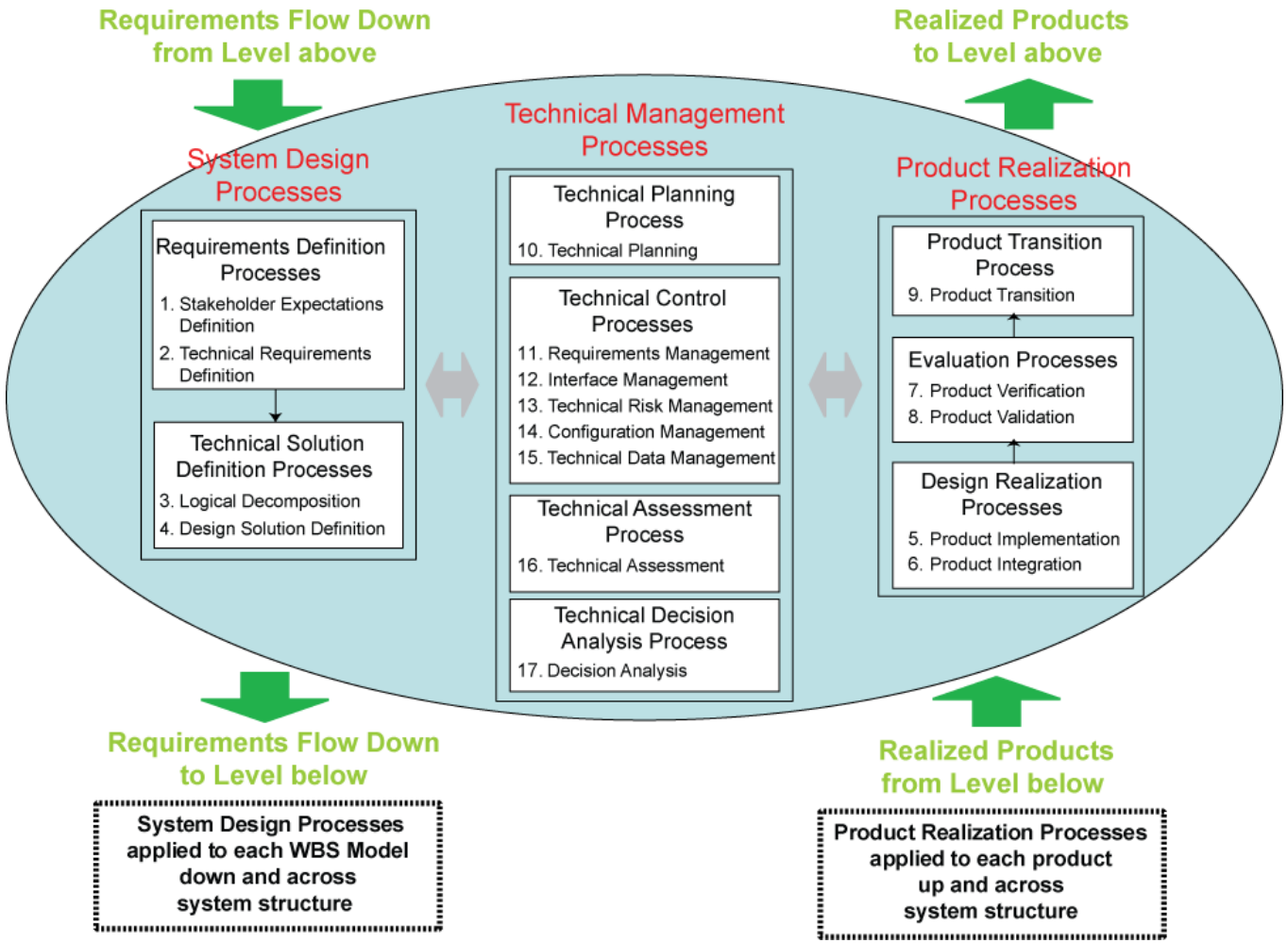
Tools and Methods
- Advanced Tools and Methods
- NASA SE Handbook and Guides
- Technical Measures and Assessments

Workforce
- Skills, Competencies, Teamwork,
- Ethics, Training, Experience



Systems Engineering Classes
Systems Engineering Behavioral Study
Systems Engineering Leadership Development Program

The NASA Systems Engineering Engine



Balancing the Art and Science of SE

Systems Engineering is both an Art and a Science

It takes both of these ingredients to make NASA a success

The Science are the processes – these provide the infrastructure, the tools with which to work

Systems Management, Analytic, Analysis, Decomposition, Drill Down

Left Brain

(language, sequential reasoning, rational, analytic, logical)

The Art is the human judgment, experience and innovative thinking that makes the project successful

Technical Leadership, Intuitive, Synthesis, Holistic, Big Picture

Right Brain

(nonverbal, nonlinear, instinctive, recognizes patterns & emotions)

http://www.nasa.gov/pdf/311198main_Art_and_Sci_of_SE_LONG_1_20_09.pdf

Glenn Research Center

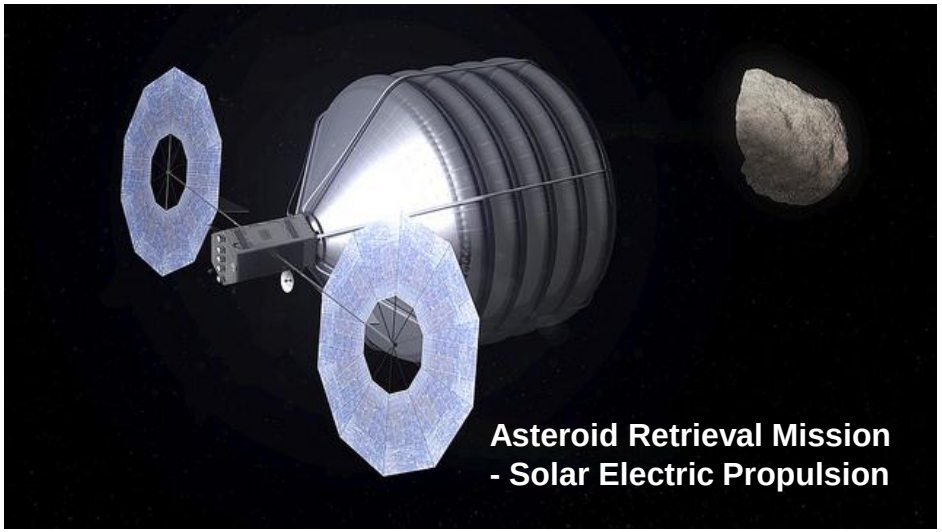
Glenn's Mission: We drive research, technology, and systems to advance aviation, enable exploration of the universe, and improve life on Earth

Lewis Field
(Cleveland)
- 350 acres
- 1626 civil servants and 1511 contractors

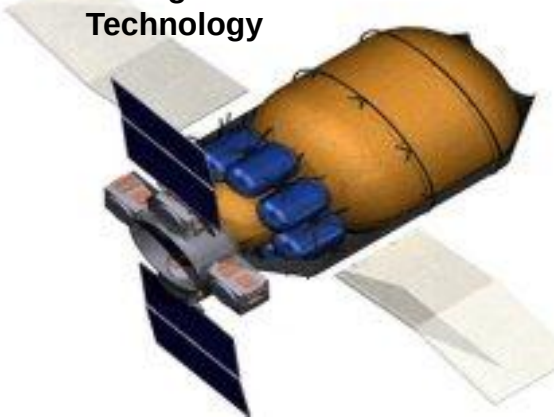
Plum Brook Station Test Site
(Sandusky)
- 6500 acres
- 11 civil servants and 102 contractors

A Key Player in Critical Agency Programs

A Key Player in Future Agency Programs



Cryogenic Propellant Storage and Transfer Technology



Aeronautics Integrated Systems
- Environmentally Responsible Aviation

Space Launch System
- Cargo Fairing

Systems Engineering Initiatives at Glenn

- Active involvement in Agency initiatives
- Glenn specific processes to compliment Agency process requirements
- Training programs
  - Systems Engineers
  - Product Engineers
  - Cross training in safety and mission assurance
- Formal lessons learned processes
- *COllaborative Modeling for Parametric Assessment of Space Systems* (COMPASS)
- Model based systems engineering

COMPASS Concurrent Engineering Team

(*COllaborative Modeling for Parametric Assessment of Space Systems)*

The COMPASS **team** is a multidisciplinary concurrent engineering team whose **primary purpose is to** perform **integrated vehicle systems analysis** and provide **conceptual designs and trades** for both Exploration and Space Science Missions.

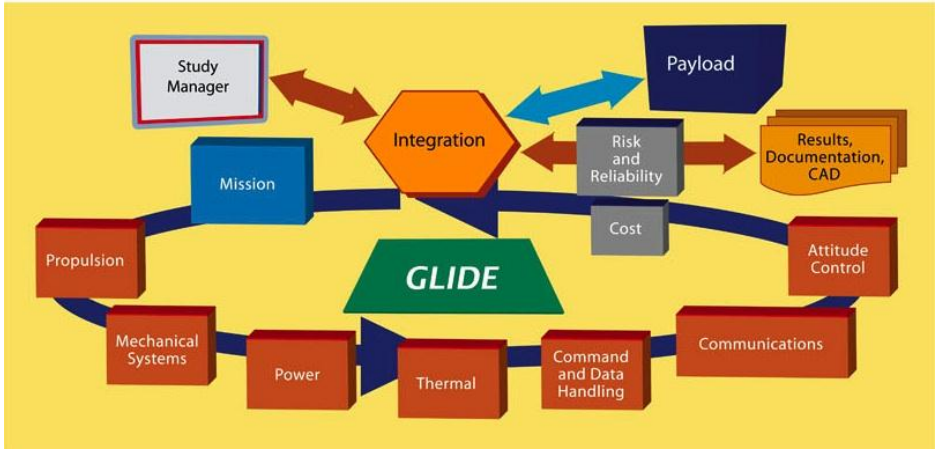
Team formally established in 2006, Mission Driven

COMPASS products tailored to support proposals, project reviews per NPR 7123.1 (especially MCRs & SRRs) and implementation of technologies

COMPASS works very closely with other NASA flight centers, Gov't Organizations, Industry, and Projects

The concurrent engineering process produces solid engineering designs quickly without the rework needed by isolated teams

Design Process

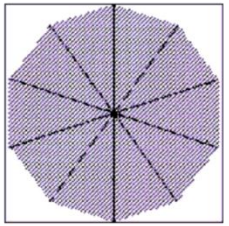


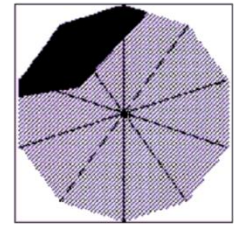
Data Transfer Process

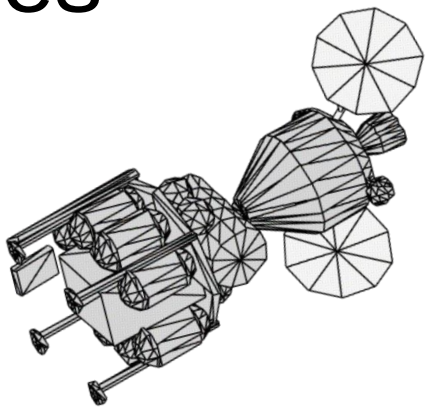
Subsystem models integrated via a vehicle Master Equipment List worksheet

Systems Analysis Competencies

Modeling and simulation, code development, alternative design evaluation and optimization, anomaly resolution, and Certification of Flight Readiness (CoFR) support







Power Systems

- ISS, Orion, SEP Stage

Space Propulsion Systems

- Chemical, electric, nuclear

Aero Propulsion

- Advanced subsonic, super and hypersonic

Mission Design and Performance

- Trajectory, guidance, navigation, and control

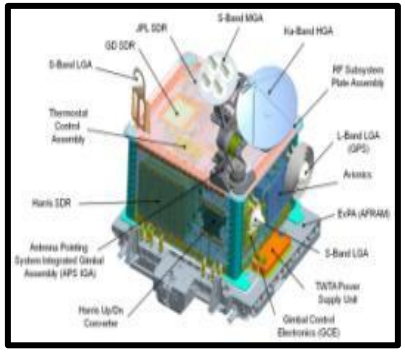
Control Systems

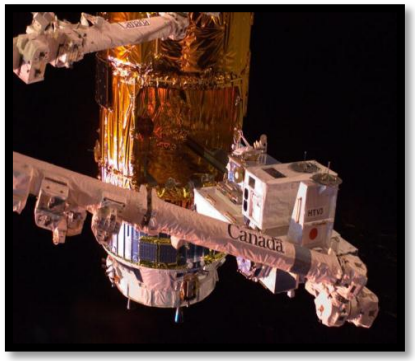
Communication Systems

Integrated System Concepts

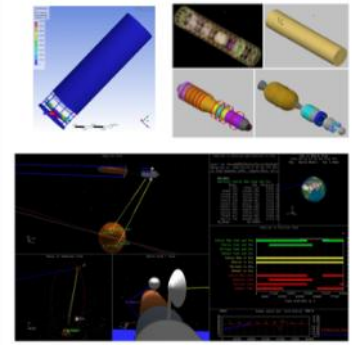
Systems Engineering Excellence on Space Communications and Navigation (SCaN) Testbed

- Four year, fast track development effort, $100M payload integrating SOA Software Defined Radios from three suppliers, launched on Japanese H-II vehicle for integration on ISS, over 1000 system level requirements and team that peaked at over 200 people.
- Streamlined reviews using table-top approach and standing review board for continuity reduced burden on the engineering team.
- Design Integration resolved complex systems issues including payload deployment and Antenna Pointing System.
- Physical integration activity accommodated components delivered on often unpredictable schedules, maintained strict process control on flight hardware work, maintained close coordination with facility test managers.
- Single External Integration Team established to interface with JAXA and ISS for focused communication. Both H-II vehicle and ISS ELC platform were in co-development.
- Incremental build and test approach saved six months of schedule and $12M in cost.
- Combined system and subsystem assembly and test positions into a single lead, which enabled the identification of testing workarounds.
- Verification leads met with requirements owners to ensure agreement on data needed for compliance.

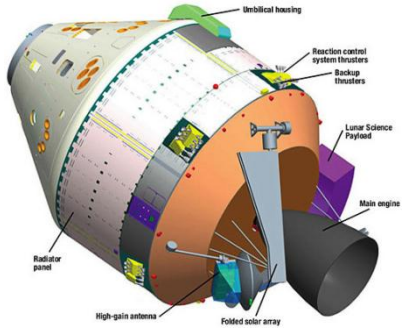




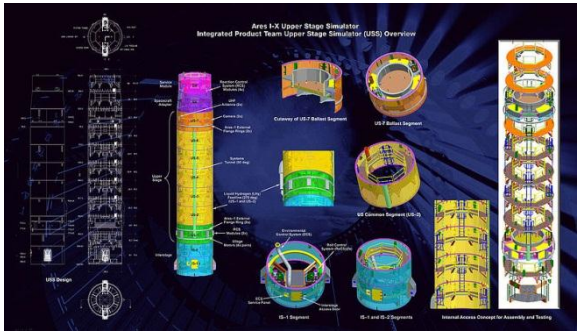
Systems Engineering at Glenn



Concept Studies



Concept Development



System Design & Prototypes

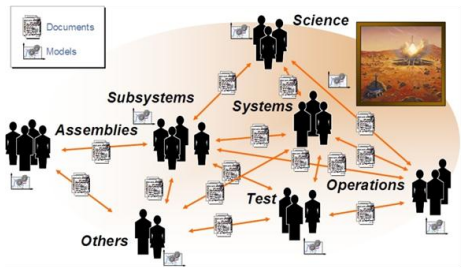
Fabrication & Assembly

Test

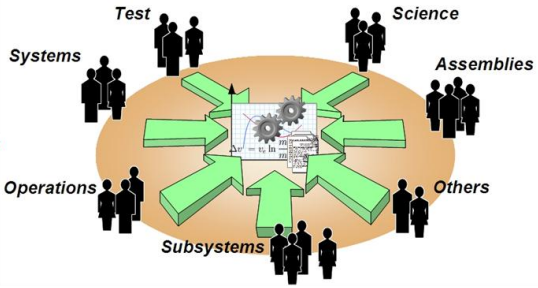
Flight/Operations

Model Based Systems Engineering (MBSE)

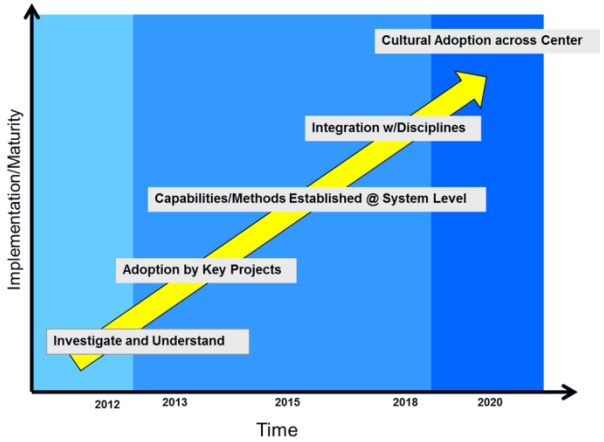
- Accelerating complexity drives a need for improved ways of doing systems engineering
- Computer-based tools have the ability to help manage this complexity while increasing productivity and reducing errors
- Glenn Research Center has begun a process to incorporate MBSE capabilities



Today: Standalone models related through documents

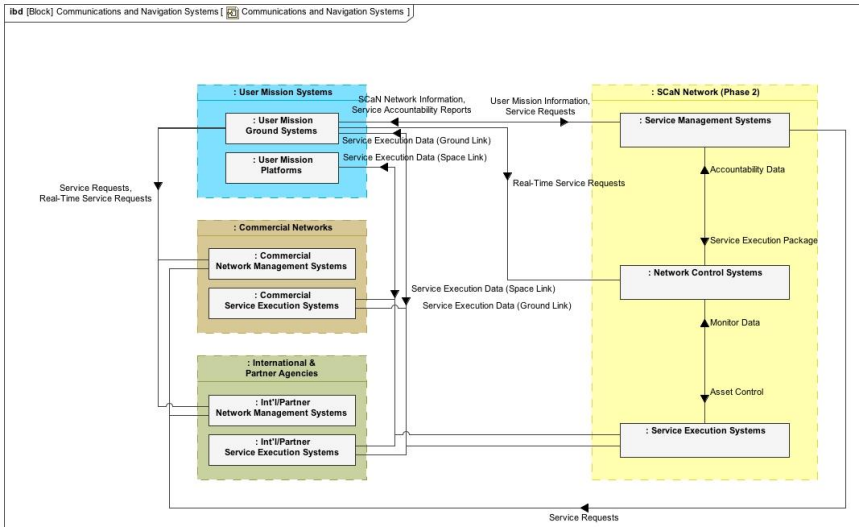


Future: Shared system model with multiple views, and connected to discipline models



Space Communications and Navigation (SCaN) Model-Based Systems Engineering

- Improved communications for the multi-center team
  - Consolidated 50 to100 charts into one model
  - Eliminated inconsistencies in diagrams
  - Everyone uses the same model and terminology
    - ➢examples: architecture elements and their names



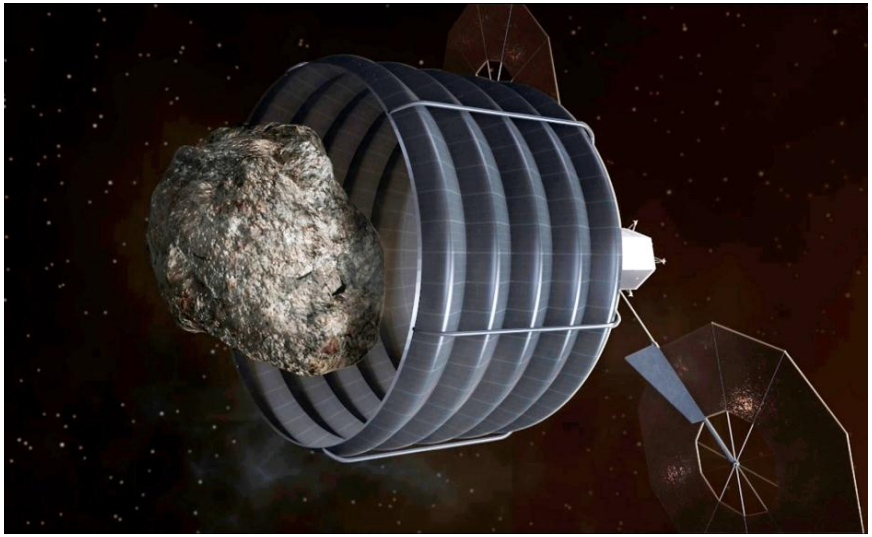
- Improved productivity
  - Exponential increase in number of models and diagrams developed due to collaborative environment for multiple users
  - Represent large, complex projects, within constrained schedule and cost, that were considered impossible to do using classic SE methods
  - Every model element has a meaning
- Improved interactions with prime contractor
  - Prime contractor for SGSS (Space Network Ground Segment Sustainment) project uses MBSE

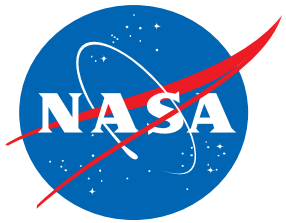
Summary

- Implementing the NASA strategic vision and mission requires an emphasis on systems engineering.
- The future will rely more heavily on flexible teaming in many dimensions but will present additional challenges for systems engineering teams

In order to implement this vision, NASA and its Glenn Research Center is pursuing an approach that takes into consideration the latest advances of systems engineering in Academia, Industry and other Government agencies.

We have accomplished a lot but we must do a great deal more to be efficient and effective, and make rapid progress in a highly constrained environment.




NASA