NASA Systems Engineering Challenges

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Purpose

- Challenges of utilizing advanced methods to develop and support New and Existing Projects
  - Affordability
  - Rapid prototyping
  - Quickly navigate the trade space
  - Accuracy
  - Integration of multi-organizational products

Strategy to support 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.

- Major Initiatives
  - Affordability
  - Improve Program and Project Management
  - *Revitalize Systems Engineering*
  - *Infusion of advanced techniques*
  - *Distributed engineering*
  - *Develop Workforce*

OCE Objectives for Systems Engineering

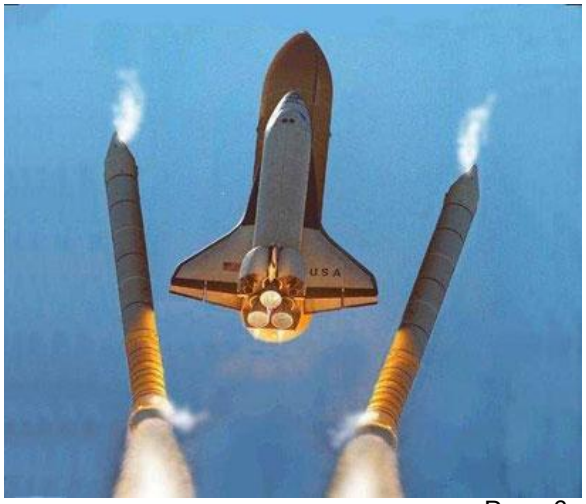
- *Vision:* A premier systems engineering capability widely recognized for its leadership and expertise in the engineering of systems and subsystems to enable NASA to provide leading edge aerospace research, products and services

SE APPROACH

- NASA has developed and implemented best practices that constitute an updated approach to systems engineering to be used for all NASA missions
- Our approach:
  - Learn from ours and others experience;
    - Lessons learned
    - Knowledge capture and transfer
    - Benchmark
    - SELDP
    - Mentoring
    - Develop and employ the best SE practices, tools and methods for NASA

Modeling and Simulation are Essential

- Modern engineering is critically dependent on modeling and simulation to allow building complex systems
  - Large Hadron Collider team spent comparable amounts of money on M&S and the system build- wildly expensive to change tunnels
  - Companies use simulations anchored in tests to “wring out” crash worthiness of designs
  - In crewed space flight, we have to risk crew in an all out flight with few test flights



Vision for MBSE

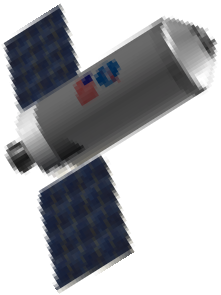
- Current Engineering environment
  - Document based artifacts
  - Spec, drawings and requirements
  - Domain oriented discipline models
  - Legacy Tools
- Desired future Engineering Environment
  - Model based artifacts
  - Seamless data flow
  - Distributed teams

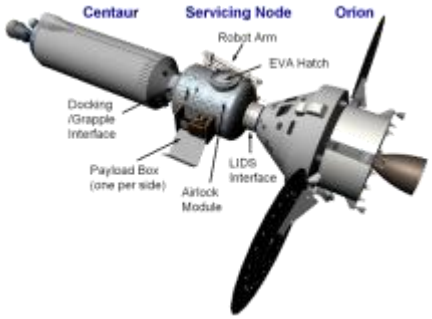
Complexity is a Major Issue

- Integration of systems create a major problem with complexity
  - Within 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

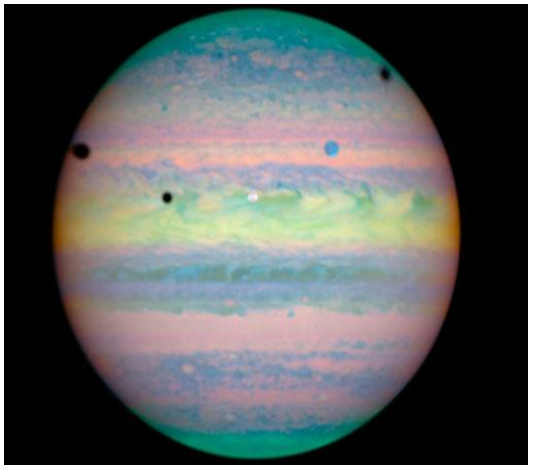
- The International Space Station will have a lifespan of at least 20 years with evolving uses and constant changes
- Systems analyses show that as we explore beyond low earth orbit, launch costs will remain a driver and thus put a huge value in re-using systems already moved up the gravity well
  -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

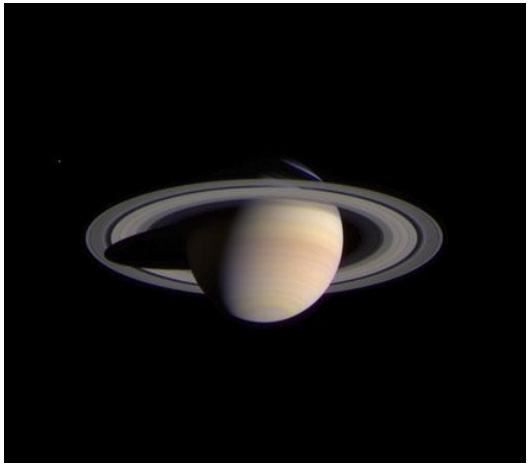




Modeling Issues

- Ever since Archimedes, we have used mathematical models as a representation of reality, yet we still lose sight of:
  - The underlying assumptions
  - The range of validity and accuracy
  - The degree to which it has been validated by data and experience
  - …..and confuse accuracy and precision
- The real behaviors and uncertainties tend to get hidden when using deterministic methods and models
  - Allowables, margins, safety factors, etc all hide the uncertain nature of our world
  - How do we pull of the “masks” and yet preserve the efficiencies these methods allow





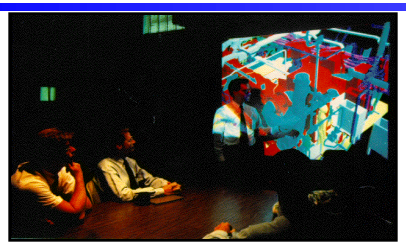
All models are wrong, some models are useful – George Box

Use and Challenges vary throughout the life cycle

- Early Phases; conduct Systems Analysis and trade studies
  - Exercise through CONOPS
  - Rapidly dismiss faulty options
  - Develop feasible, cost effective options
  - Identify advanced technology requirements
  - How to enable modeling that provides the needed fidelity yet can be done quickly and cheaply?
  - Current methods tend to be “wetware” intense.
  - Need rapid and effective teaming

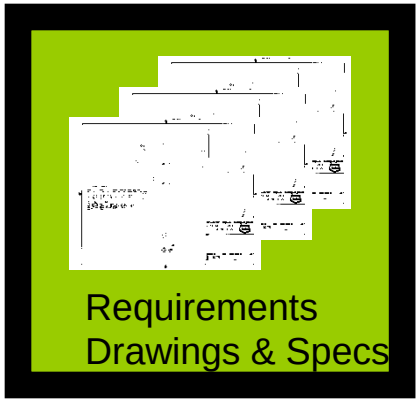
- Development
  - Refine Design, support Validation & Verification
  - Enhance manufacturing
  - How to better enable integration of discipline oriented design tools into systems models that capture functional and performance behaviors
  - How to capture system design rationale, assumptions and other “background” data.
  - How do we develop the standards that allow lossless integration across organization and tool boundaries?
- Operations
  - Provide data for ops team, resolve in flight issues, address parts obsolescence
  - How do we make the full suite of information captured during design and development available to the operators without having prior knowledge of their needs?

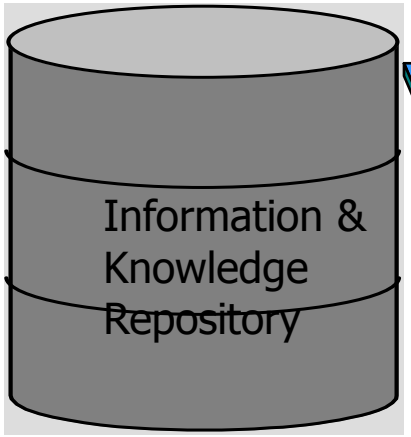
Integrated Product/ Mission Model Enables Design/Build Process

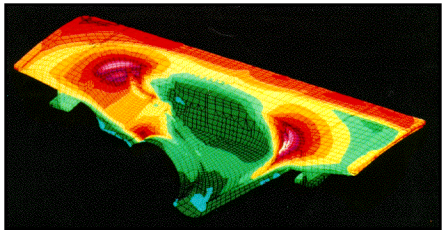


Planning

Manufacturing







Analysis

Product Model Integrates:

- Build Strategy
- System's Geometry
- System's Requirements
- Test and Verification Planning
- Operations Planning

Test & Operations

Supports Developing Data One Time to use for the full Lifecycle

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 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 – we need your help!