NASA Integrated Model-Centric Architecture (NIMA) Concept

Presented at the Model Based Engineering (MBE) Summit at NIST

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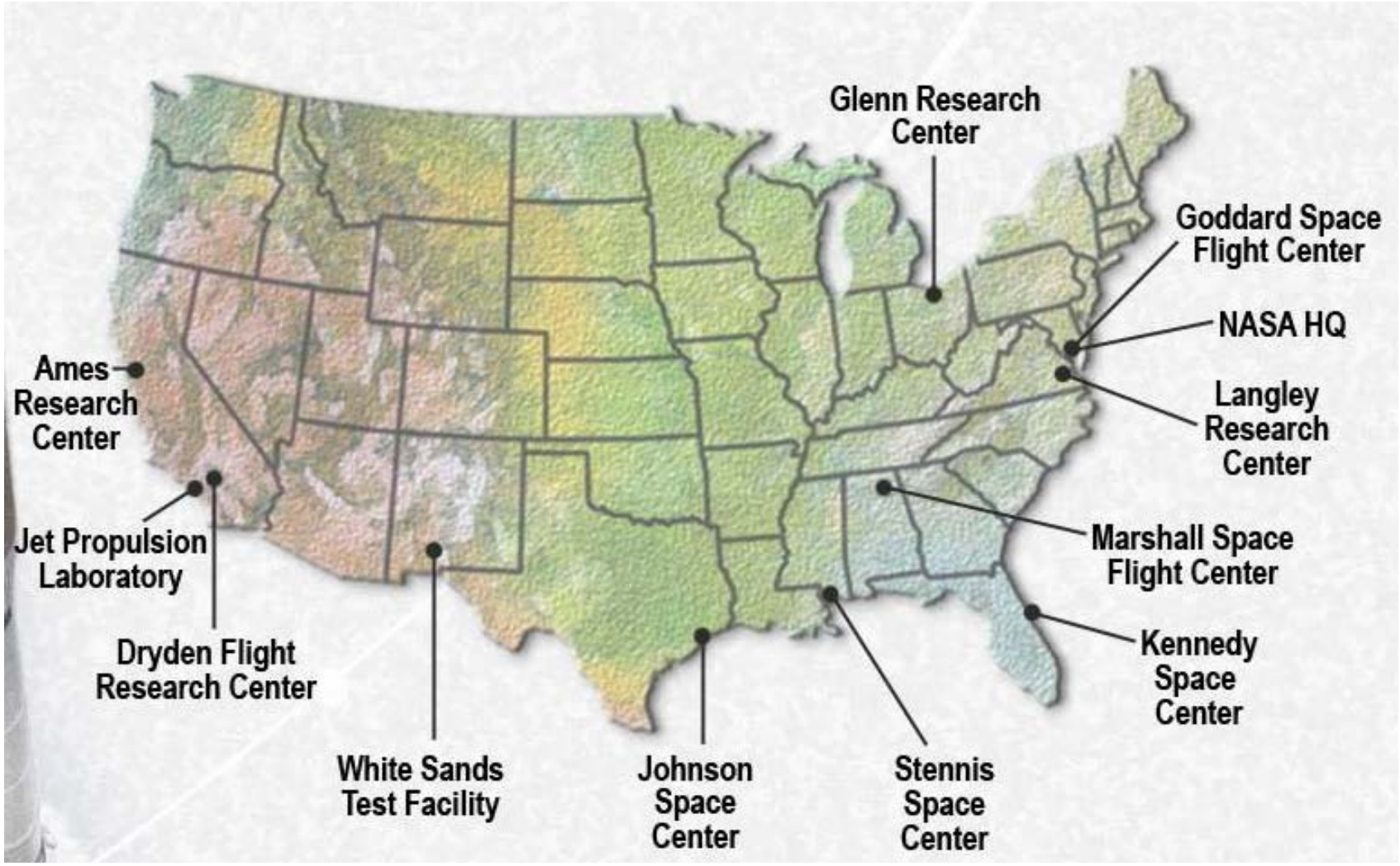
NASA Overview



Variety of Missions

- **Aeronautics** – Pioneers and proves new flight technologies that improve our ability to explore and which have practical applications on Earth
  - Green aviation
  - Next Generation Air Transportation System (increasing safety and managing traffic congestion)

Test Flight of the blended wing body X-48B

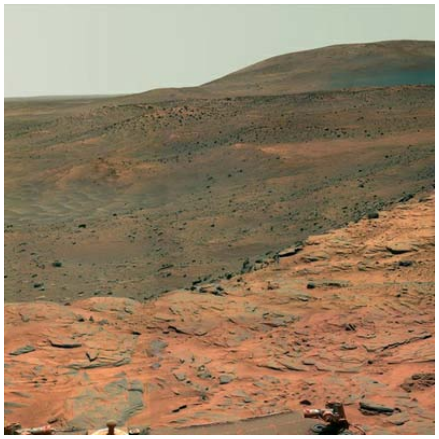
Subscale model wind tunnel testing

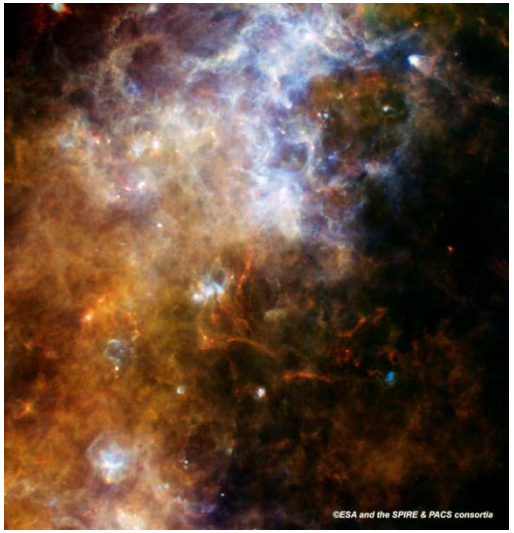
Supersonic jet concept

Researching ways to improve air traffic flow in NASA's Air Traffic Operations Lab

Variety of Missions (Cont'd)

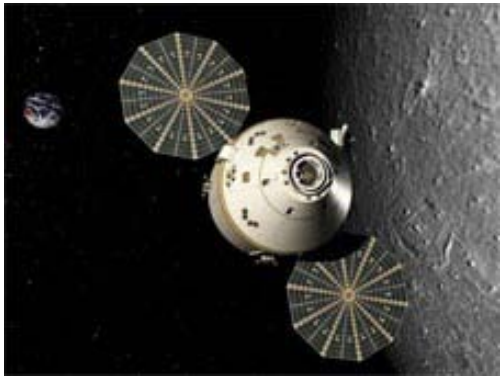
- **Science** – Explores the Earth, solar system and universe beyond; charts the best route of discovery; and reaps the benefits of Earth and space exploration for society
  - Earth: Weather, Carbon Cycle & Ecosystems, Water & Energy Cycles, Climate Variability & Change, Earth Surface & Interior, Atmospheric Composition
  - Heliophysics: Heliosphere, magnetospheres, Space Environment
  - Planets: Inner Solar System, Outer Solar System, Small Bodies
  - Astrophysics: Stars, Galaxies, black holes, the big bang, dark energy, dark matter, planets around other suns

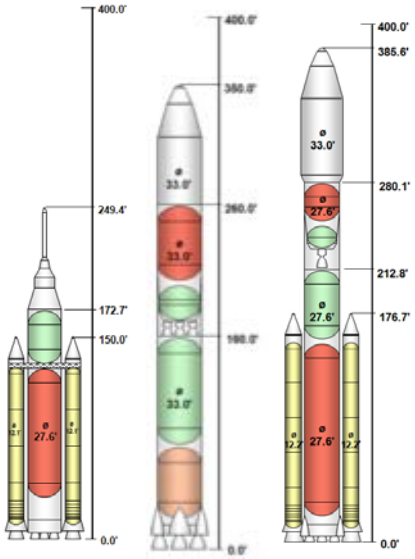




Variety of Missions (Cont'd)

- **Human Exploration and Operations** – Focuses on International Space Station operations and human exploration beyond low Earth orbit
  - ISS
  - Multi-Purpose Crewed Vehicle (Orion)
  - Space Launch System
  - 21st Century Ground Operations





Problem to be Solved

- Looking at our past experiences, our technical, cost and schedule performance needs to be enhanced in order to accomplish our future plans
- Some of the problems to be solved are:
  - Lack of affordability of projects and activities
  - Mission complexity is growing faster than our ability to manage it
  - Not identifying design or integration problems until late in lifecycle
  - Having to Search for data or supporting material during mission anomaly resolutions
  - Inability to share models in a collaborative environment
  - Ineffective use of precious testing time and resources
  - Too many design reviews that reviews documents vice the design
  - System design emerges from the pieces, not from an architecture
  - Use of unvalidated models in simulations leading to incorrect/invalid results
- Moving to a more model-centric philosophy within the Agency will help resolve many of these issues

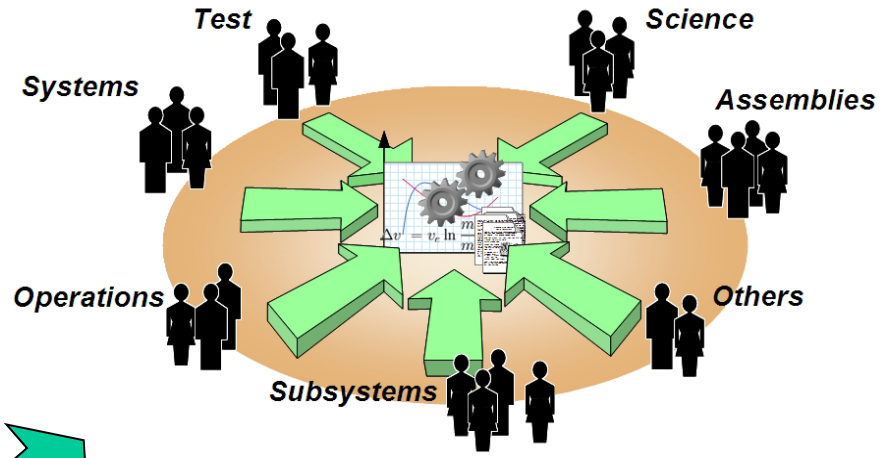
Model-Centric Concept

Goals

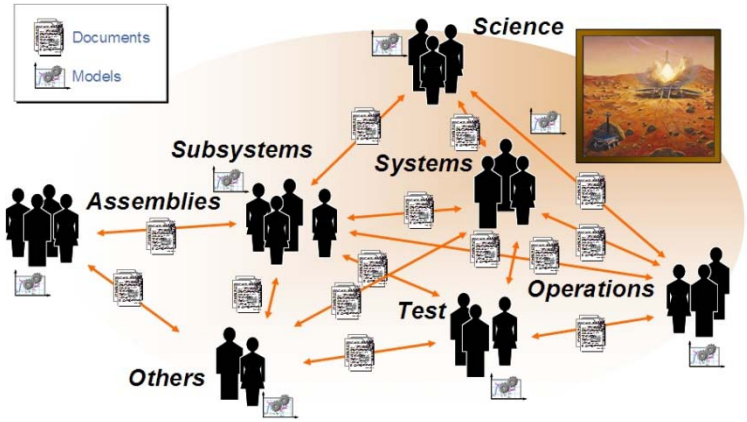
- **Goal 1:** Increase *affordability* through use of a model-centric architecture
- **Goal 2:** Achieve *interoperability* within and among programs/projects, centers and external partners through use of a model-centric architecture
- **Goal 3:** Inform/train invigorate *workforce* on model-centric architecture
- **Goal 4:** Improve product *quality* and success through use of a model-centric architecture

General Model-Centric Vision

Mission: Advance from our current document-centric engineering practice to one in which structural, behavioral, physics and simulation-based models representing the technical designs are integrated and evolve throughout the life-cycle, supporting trade studies, design verification and system V&V



Future: Reusable model-driven with integration & simulation capability



Today: Document driven & standalone models

To do this we must provide:

- Modeling development environment and standards
- Reusable models repository
- Tool/model integration
- Training
- User community support
- Partnerships

Use Throughout Lifecycle

- Use of a model-centric enterprise system throughout the lifecycle of a product will greatly enhance its quality and affordability
  - Work products will be built and matured seamlessly eliminating need to re-create them over the lifecycle
- Example products are:

Pre-Phase A	Phase A	Phase B	Phase C	Phase D	Phase E	Phase F
Concept Studies	Concept & Tech Dev.	Prelim. Design	Final Design & Fab	Assembly, test & Launch	Ops & Sustainment	Closeout
Conceptual Models Cost Estimation	Requirements Functional Flows	CAD designs Analysis Models Prototype test data Refined Costs	Refined CAD Refined Analysis Engineering Data Manufacturing	Integration Simulations Verification Certification	Operations Anomalies Simulations Science Data	Decommissioning Simulations Data Archiving Final Costs

Enhances Sound Engineering Practices and Experience – Does Not Replace It!

Vision/Use Case Examples

- Determining the effect/impact of a requirement change
- Working a mission anomaly

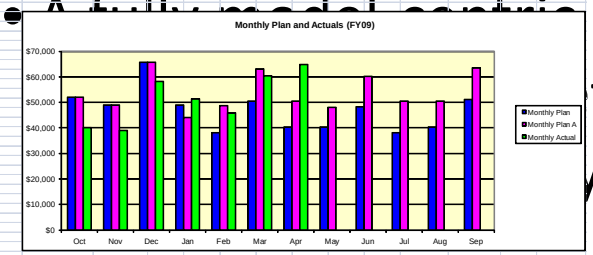
Determining an Effect of a Requirement Change

- Premise: Late in a development cycle a key requirement is changed.
- A fully modeled architecture program will [illegible] effect of that [illegible] viewpoints

This Plan A is an adjusted Plan to reflect the current requirements

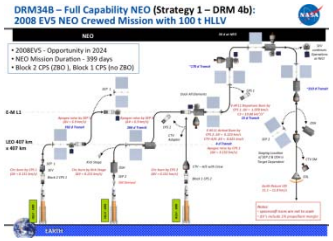
CHeCS All Subsystems	Oct	Nov	Dec	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep
	Planned	Planned	Planned	Planned	Planned	Planned	Planned	Planned	Planned	Planned	Planned	Planned
Total Labor	$34,447	$35,689	$37,248	$39,498	$35,567	$36,964	$37,248	$34,750	$34,750	$35,564	$37,593	$37,248
Plan	$48,447	$46,689	$51,248	$41,128	$45,351	$58,697	$46,964	$44,750	$56,167	$46,964	$46,964	$56,518
Total Non-Labor	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0
Fee (@ 100%)	$3,512	$3,310	$3,432	$2,642	$2,575	$3,733	$2,725	$2,500	$3,238	$2,764	$2,720	$3,294
Total Cost Plus Fee	$51,959	$49,001	$65,680	$49,001	$38,146	$50,390	$40,318	$40,318	$48,219	$38,146	$40,318	$51,012
Cummulative	$51,959	$100,961	$166,641	$215,642	$253,788	$304,178	$344,497	$384,815	$433,034	$471,179	$511,498	$562,510

CHeCS All Subsystems	Oct	Nov	Dec	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep
	Planned	Actual	Planned	Actual	Planned	Actual	Planned	Actual	Planned	Actual	Planned	Actual
Total Labor	$34,447	$37,248	$39,689	$38,498	$41,248	$34,248	$41,248	$41,248	$45,248	$42,248	$38,697	$36,048
Total Non-Labor	$0	$0	$0	$0	$0	$0	$0	$0	$0	$3,248	$0	$2,248
Fee (at 100%)	$3,512	$2,703	$3,312	$2,642	$4,449	$3,922	$2,983	$3,476	$3,209	$3,094	$4,256	$4,061
Total Cost Plus Fee	$51,959	$39,979	$49,001	$39,080	$65,680	$58,168	$44,112	$53,425	$48,639	$45,764	$62,953	$60,403
Cumm. Forecast	$51,959	$39,979	$88,980	$79,058	$144,738	$137,226	$181,338	$188,652	$237,291	$234,415	$297,368	$294,818

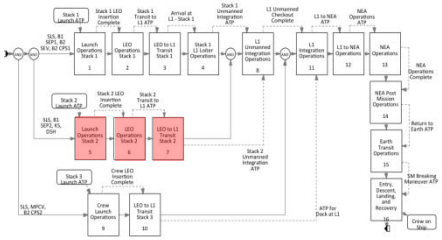


	Oct	Nov	Dec	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep
Monthly Plan	$51,959	$49,001	$65,680	$49,001	$38,146	$50,390	$40,318	$40,318	$48,219	$38,146	$40,318	$51,012
Monthly Plan A	$51,959	$49,001	$65,680	$44,112	$48,639	$62,953	$50,369	$47,994	$60,239	$50,369	$50,369	$63,406
Monthly Actual	$39,979	$39,080	$58,168	$51,425	$45,764	$60,403	$64,781	$0	$0	$0	$0	$0

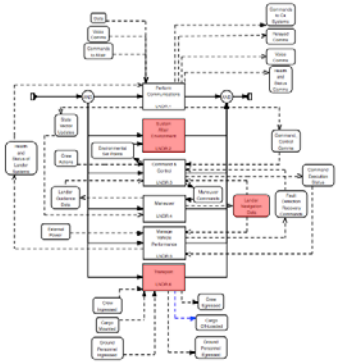
Cost Impacts



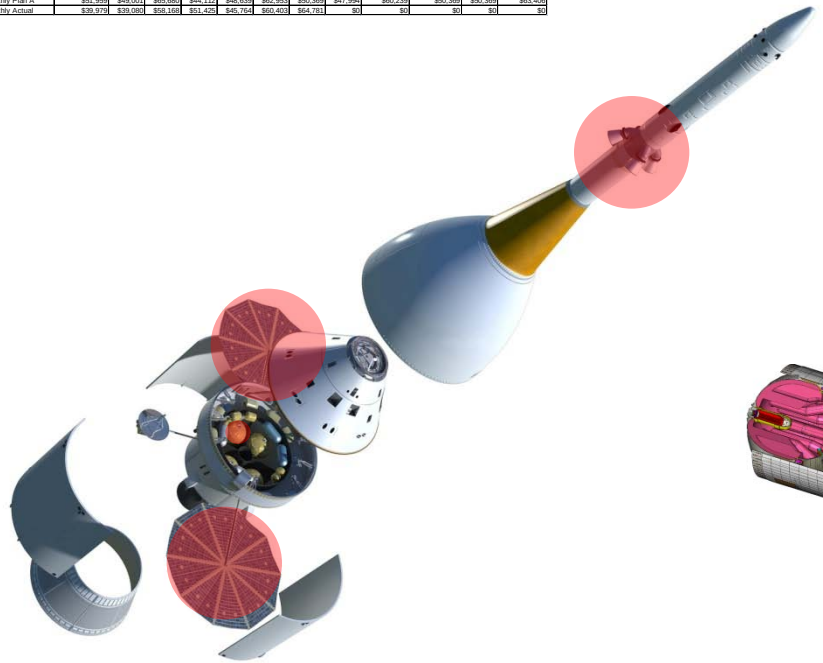
DRM Affected

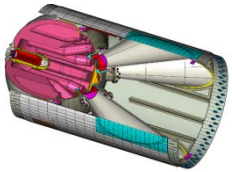


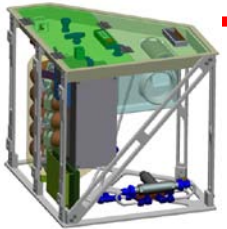
Mission Segment Affected



Functions Affected







Parts Affected

Scenario 1: Generic In-Flight Anomaly

10 years ago we developed a Flagship Class spacecraft.

Nearing the end of a very long cruise mode, the vehicle must be configured for planetary arrival.

While coming out of cruise, the self-monitoring system on the CEU indicates a device on one processor card is not functioning properly.

Mission team has <u>12 hours to fix the problem</u> prior to entering into orbit or the mission will be lost.

The Question at hand: What data will be needed, and how does a PM plan for it a decade or more beforehand?

IFA Data Needs < 4 hrs: Partial List

- ✓ As-designed/as-purchased/as-tested/as-built/as-flown product structure and definition
- ✓ Circuit card schematic
- ✓ Specifications (e.g., materials, acceptance testing)

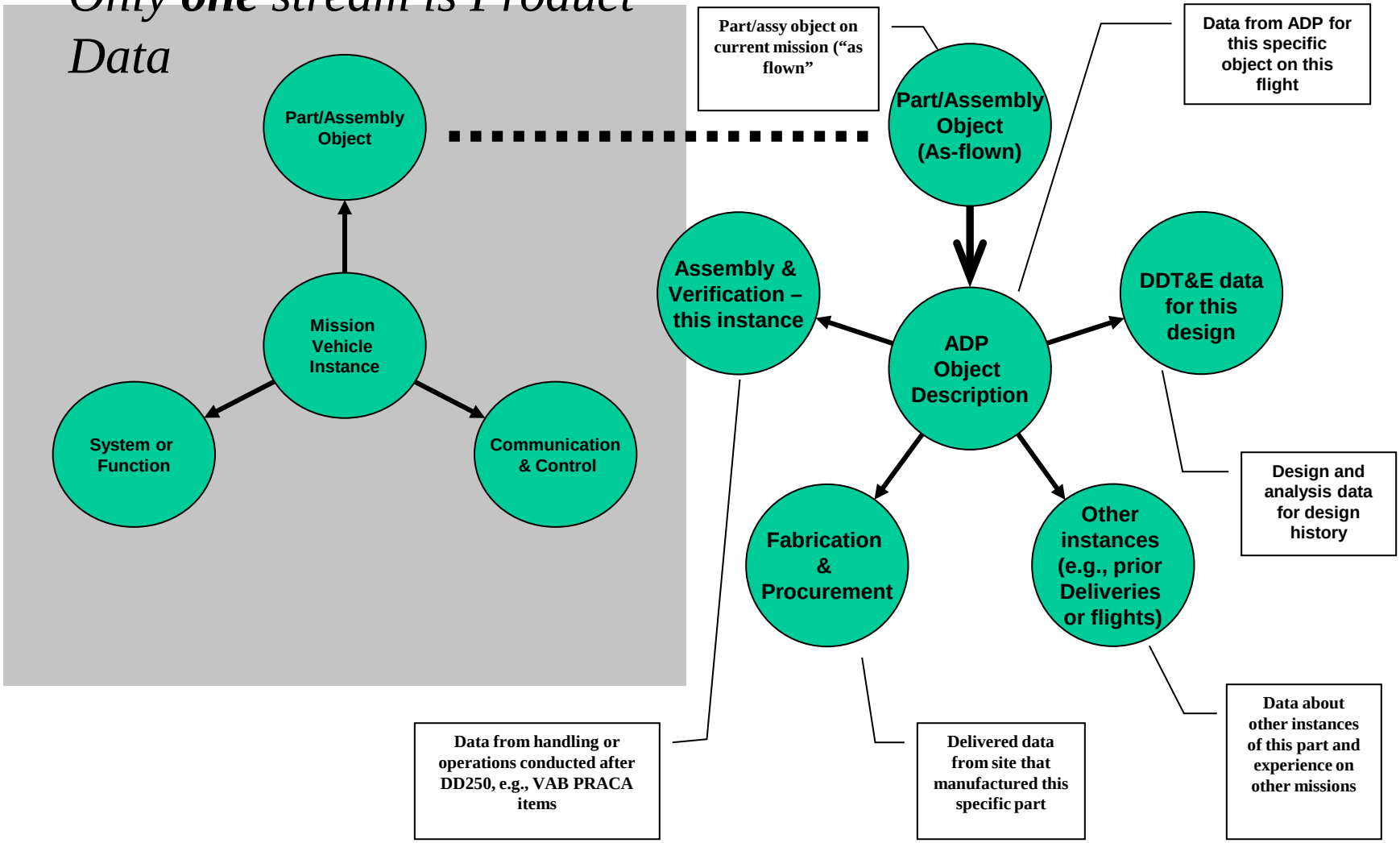
- ✓ Where (else) used
- ✓ Location and status of spares
- ✓ Firmware, software, parameters
- ✓ Circuit card testing and failure history

- ✓ Impact analysis of failure (e.g., FMEA)
- ✓ Failure history of components in similar settings
- ✓ History of component/card/sub-system behavior over course of mission
- ✓ Trades/Design Rationale

ACCESS to the Right data by the Right People at the Right Time is the desired end state.

IFA Support Requires Multiple Streams

*Only **one** stream is Product Data*



Notional Model for Multi-path Product Data Streams

Scenario 2: Development Data Deluge

We are seeing some very large amounts of data created during Design & Testing

- ✓ Scale of product, types of analysis & testing, procurement strategy affect this
- ✓ But no project or product is immune

Illustrative Cases from Constellation Program (CxP)

- ✓ Core Input for Analysis: Outer Mold Line
- ✓ Analysis, Testing & Simulation Data Deluge
- ✓ Sample Documents & CAD Models: Ares & Orion at PDR

*** Documents: Ares 1 PDR reviewed ~500 documents and two drawings with ~38,000 documents in Ares ICE Windchill Project Folders**

CAD: 16 months later at Orion PDR, LMSSC delivered ~11,000 discrete 3D models for Service Module, Crew Module, Launch Abort System (with ~250,000 versions, iterations, or variants in LMSSC's Windchill vault)

** - Does not include the material at any primes or on local vaults or servers at the centers.*

"How Big is the Problem"?"
(Life Cycle Data Management Challenge)

The amount, type, and fidelity of the data generated and requiring storage and access increases over the program life cycle. The scale and complexity of the storage and retrieval system will need to respond to these challenges.

 Source: CxP ISO Office

How do we establish a Model Centric Environment and Culture?

Communities of Practice

- This effort is primarily the integration and expansion of the work already being performed separately in the following Communities of Practice (CoP):
  - Model-Based Systems Engineering (MBSE)
  - Product Data and Lifecycle Management (PDLM)
  - Models and Simulation (M&S)
  - Computer Aided Design (CAD)
    - Mechanical CAD
    - Electrical CAD
- The tools and methodologies are being employed by these CoPs in support of existing and future Project and Programs
- By having a common vision we will be able to coordinate and enhance this work in a more effective way, learning and leveraging off each others discoveries and insights

Teams

- **Team 1: Benchmarking** – this team will be doing benchmarking trips and research. Trips will be to external organizations such as Boeing, LM, ATK, Whirlpool, etc. and will also be internal to other NASA centers. Also included are web and literature searches to determine the real value of moving an organization to a model-centric basis.
- **Team 2: Foundations** – this team will look at the basics needed for this effort – framework, data integrity, reuse of models, etc.
- **Team 3: Current Architecture** – this team will identify the current existing architectures at each of the centers and its readiness to handle moving to a model-centric culture. Includes identification of any issues and gaps with the current IT structure.
- **Team 4: ConOps** – this team will work on a more detailed Concept of Operations depicting how we would use a model-centric architecture, use cases, examples, etc.
- **Team 5: Communications Plan** – this team will identify who are our stakeholders, what are their expectations and how will we need to communicate with them to ensure the success of moving to a model-centric culture.
- **Team 6: Pilots** – this team will identify the work that is currently being performed at each of the centers and determine if there are additional pilots that need to be initiated in FY12 in order to move a area forward in accomplishing the model-centric architecture
- **Team 7: Workforce Capabilities** – this team will look at what capabilities/skills will be needed to accomplish a model-centric culture, what capabilities/skills we already have, determine capability/skill gaps and develop a training plan for closing that gap.

Multi-Year Roadmap

Phase 1: Preparation

Key Activities:

- Establish a common vision
- Establish an integrated governance structure
- Develop a Strategic Plan with Needs, Goals and Objectives
- Develop a detailed roadmap/Implementation Plan
- Establish a model-centric friendly infrastructure that facilitates collaborative activities
- Perform piloted capabilities for key areas
- Identify and develop initial standards, policies and processes
- Develop a cadre of trained users
- Develop User's guides and handbooks
- Establish an initial CM controlled model repository

Phase II: Implementation

Key Activities:

- Incrementally bring on more capabilities per Implementation Plan
- Develop/update standards, policies and processes as new capabilities are brought on-line
- Establish a standard suite of modeling tools and methodologies
- Populate the CM controlled repository with validated reusable models created from formulation to implementation
- Train at all levels – users, managers, executives
- Identify what's not working and fix it
- Identify what is working and duplicate it

Phase III: Sustaining/Improving

Key Capabilities:

- A fully operational model-centric Infrastructure that enables integration of physical models with domain discipline analytical models, simulations and cost models to support activities throughout lifecycle from concept through disposal
- A matured model-based development methodology and standards with training support
- A fully CM controlled operational model repositories that collaboratively managed by projects, lines and Institution
- Models as well as processes/methodologies are continuously improved and updates as more experience is gained

Continuous Practice

FY11 → FY18

Benefits

- Moving to a model-centric culture will provide NASA many benefits
  - Enhanced affordability
  - Increased ability for collaboration
  - Identification of problems earlier
  - Quicker and more accurate diagnosis and resolution of mission anomalies
  - More effective use of testing resources
  - Better cost estimation and control
  - Better, more effective design reviews
  - Quicker understanding of cost, schedule and technical impacts of requirement or design changes
  - Enhanced ability to do systems engineering
  - Quicker and more accurate analysis/simulations

In Closing

NASA Programs face <u>non-trivial</u> challenges re: Product data

- ✓ Distributed, production & use over extended life span
- ✓ Mixture of internal and external sources – Centers, primes, academia; NASA cannot control how things are done
- ✓ Need access to PRE-RELEASE product data
  - ✓ Early decision support
  - ✓ High analysis demands, high volumes of ancillary data
- ✓ Long project life cycles
- ✓ Need for IFA reach-back
- ✓ Need a flexible solution within NASA due to project diversity

"OUT OF ALL SIX 'REVISION C'S I PREFER MINE"

Questions???