iPAS: AES Flight System Technology Maturation for Human Spaceflight

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Technology Maturation for Human Spaceflight

- NASA Goal: Human Exploration Beyond Earth Orbit
- NASA Strategy: Mature Technologies for future missions
- Key Elements to this strategy
  - Capabilities-Driven: find and mature the right tech
  - Mission-Context: ensure right tech meets NASA goals
  - Mission-Agnostic: adjust to NASA strategies

Advanced Exploration Systems (AES) Program

- Rapidly developing prototype systems
- Demonstrating key capabilities
- Validating operational concepts

AAE
Avionics
Architecture for
Exploration

Elements of Technology Maturation

- System Integration: Project, Engineering, Operations
  - Evaluate Technologies in the context of product creation and delivery
- Technology risk buy-down through Testing
  - Apply new technologies to meaningful tests within a mission context
- Parallel Development with ad-hoc Integration
  - Projects can develop independently within controlled area
  - Develop an environment to allow easy multi-project integration
- Applying new SE&I approaches
  - Consider new methodologies and tools
  - Apply within a test context that creates product

Integrated Power, Avionics, and Software (iPAS)

- Environment to mature and demonstrate technologies
- Three elements of iPAS
  - The Iron Bird: Mission Systems (Vehicle, Operations)
    - Support the development of a *common avionics, hardware, software, and operations architecture* that can be applied over various missions
  - The Iron Nest: Testbed Systems
    - Provide a *common testbed framework* that supports integrated hardware/software testing for a variety of applications
  - The Process: Improving SE&I techniques and assessments

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  - The Iron Nest: Testbed Systems

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iPAS Testbay: The Nest

- Location that accommodates hardware/software integration
  - Early in the project lifecycle
  - Leveraging off existing capabilities
- Provide shared services (reduced development and V&V)
  - Test Orchestration
  - Modeling and Simulation
  - Configuration Control of data
  - Security and integrity issues
- Access to hardware analogs
  - Power, propulsion, crew displays
- Data Integration Networks
  - Within the lab
  - To other JSC labs
  - To other Centers

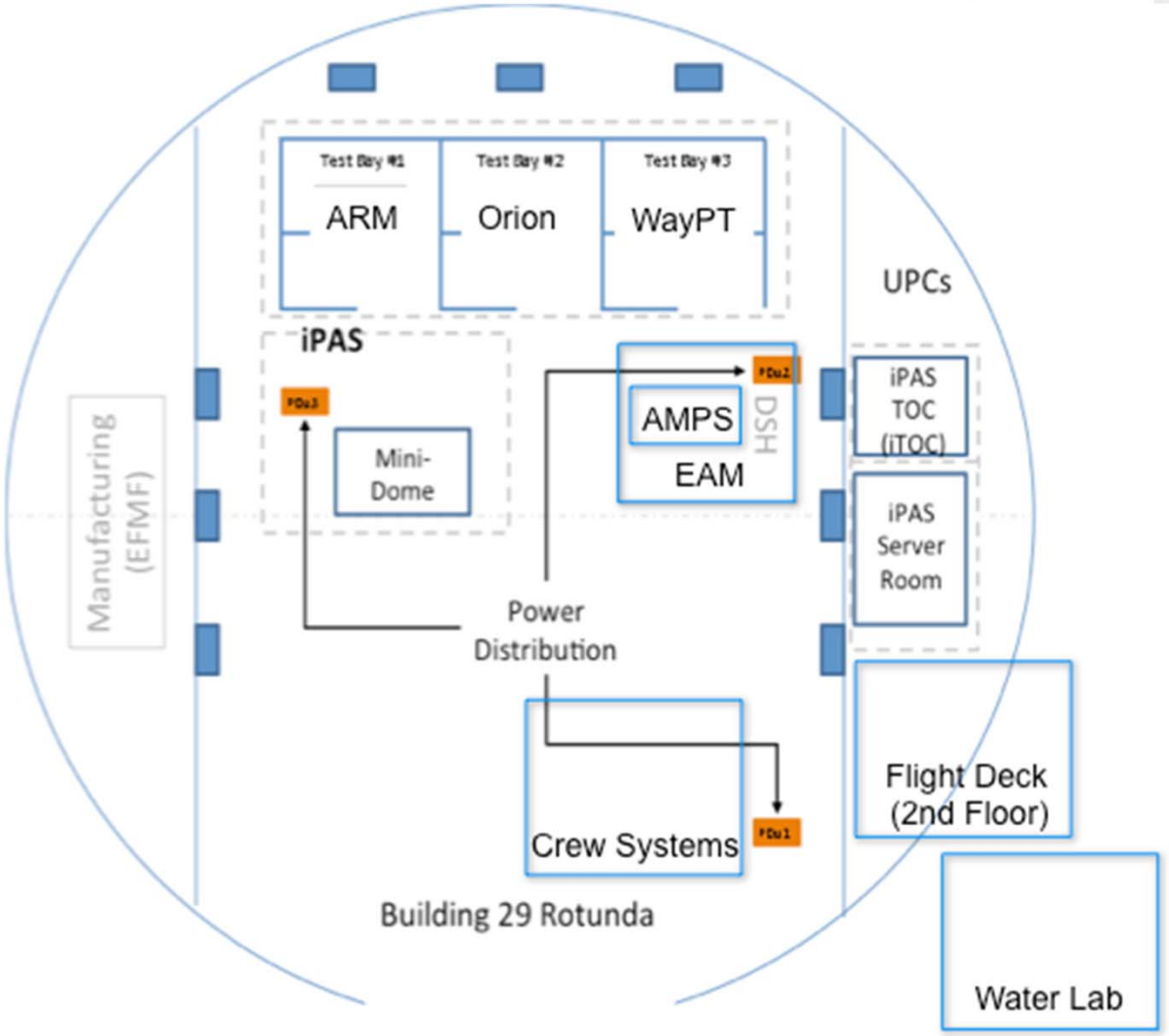
The Nest

iPAS Vehicle – Iron Bird

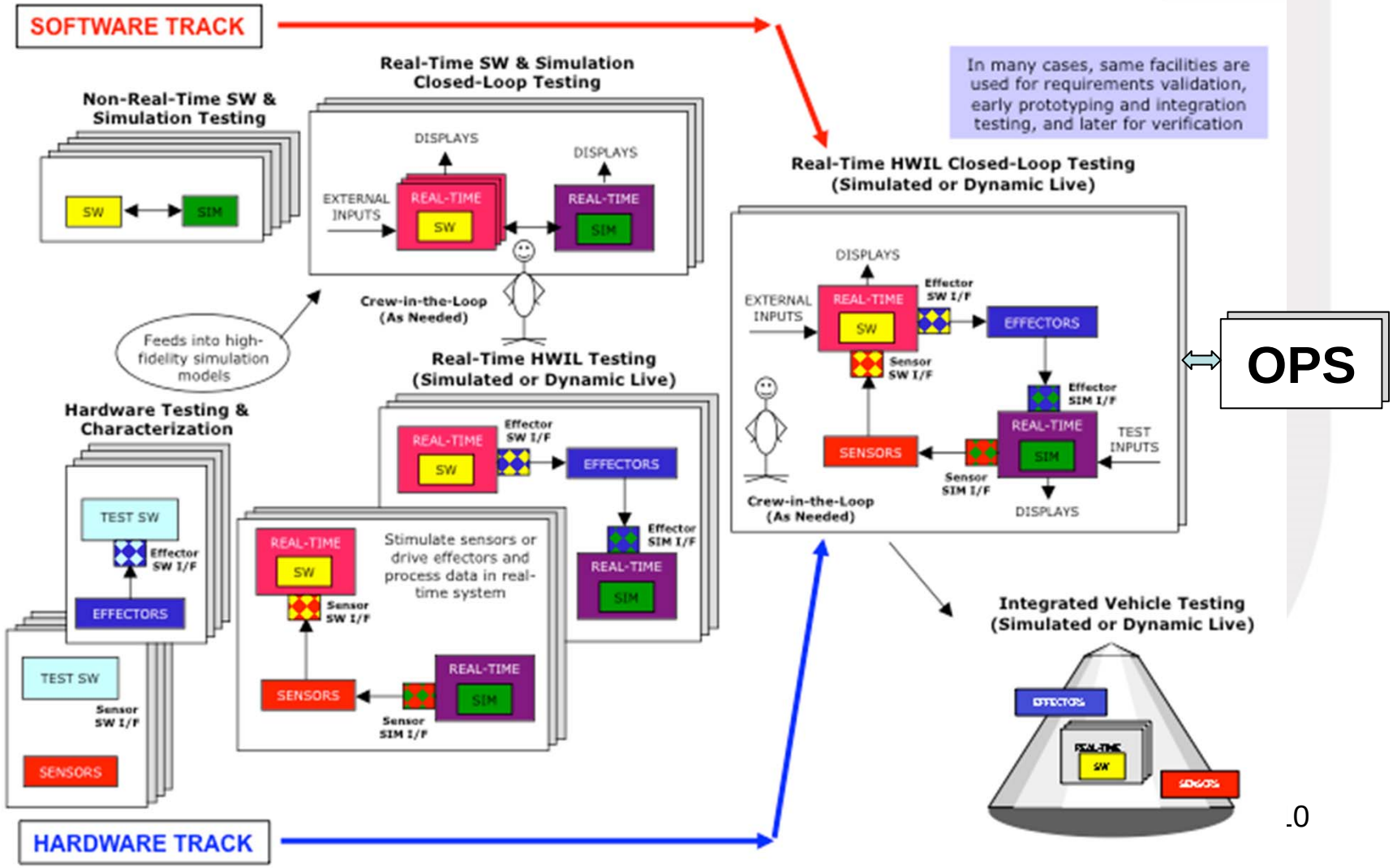
- Hardware and software products
  - Engineering Units, and eventually flight units as well
  - System Analogs (battery emulators, cold gas jets)
- Current Components
  - Hardware: AAE
    - Processors, Networks, Comm
    - Power, Propulsion, Crew Life Support
  - Software: CFS
    - Framework-independent algorithms
      - » GN&C, Vehicle Health, Comm, Crew Displays
    - Core Flight Software (CFS) product line
- Integration with Operations
  - Ground Systems: Launch Control
  - Mission Operations
  - Communication Infrastructure

The Bird

iPAS Floorplan : Multiple, Parallel Development Teams



Design, Development, Test, and Evaluation (DDTE)



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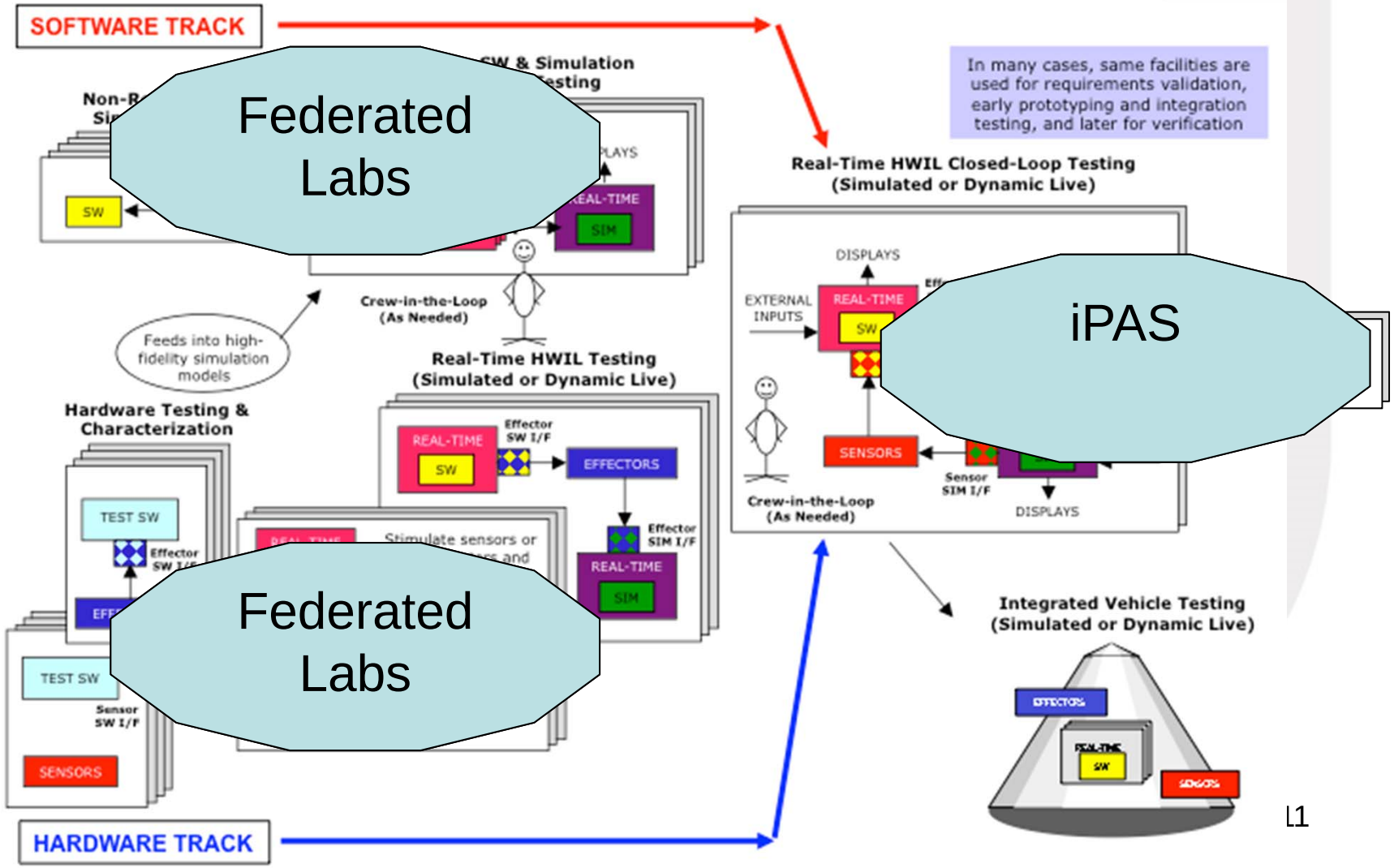
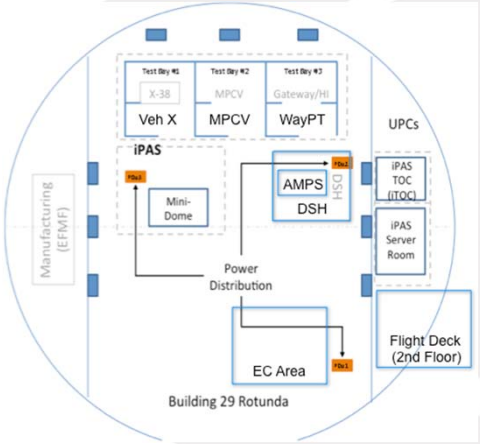


Co-located Technology Maturation

Core Flight SW
- Framework
- Apps Store
- GNC Apps
- Hardware Apps

Avionics
- Processors
- Networks
- Wireless
- Comm



Delay Tolerant Net
- Mission eval
- DTN on Radio
- DTN on Computer

Adv Modular Pwr
- Power Systems
- Integration with avionics in DSH

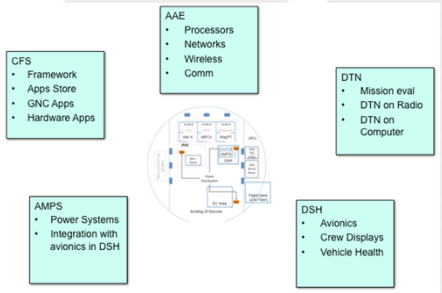
Habitat
- Avionics
- Crew Displays
- Vehicle Health

Inter-Center Test Network : Engage Remote Facilities

B30 – Mission Ops
- MCC emulator
- SNRF interface
- Telemetry and commanding

B16 – GNC/Dome
- Star Tracker
- Star Field
- Cockpits
- Dome

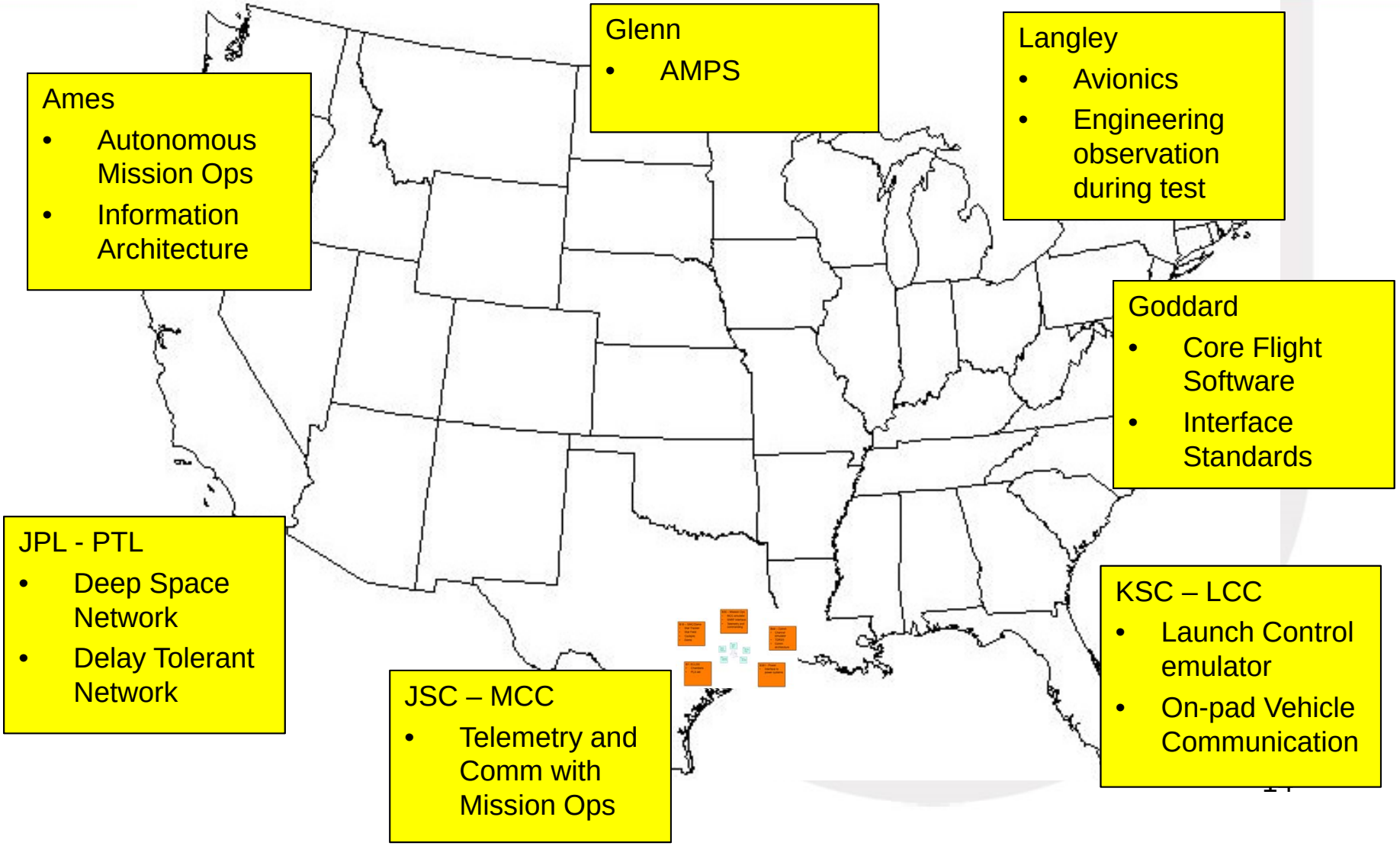
B44 – Comm
- Channel simulator
- TDRSS
- Comm architecture



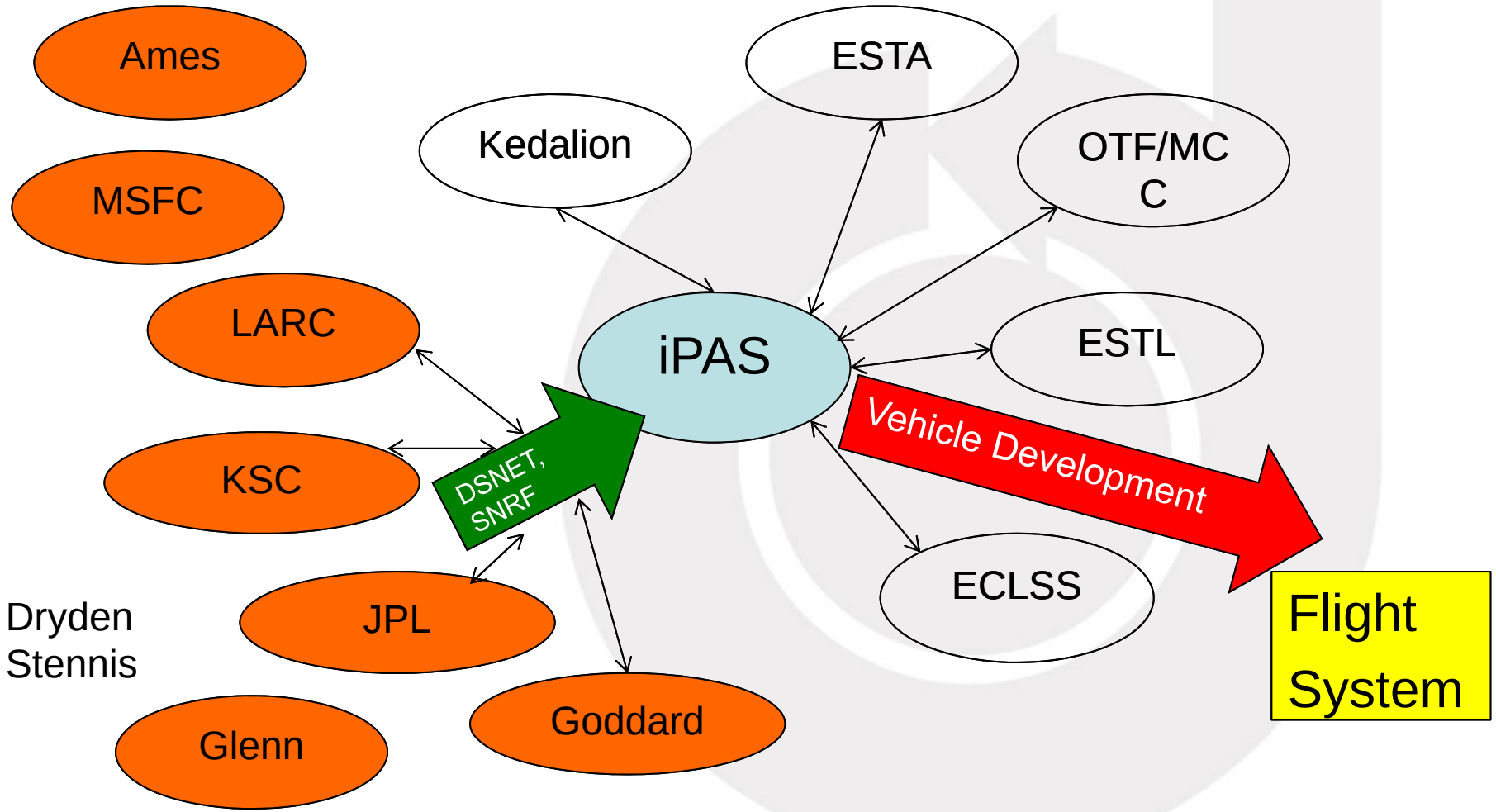
B7- ECLSS
- Chambers
- PLS lab

B361 - Power
- Interface to power systems

Multi-Center Integration



Federation of Labs: Integrated, Distributed Testing



Mature Technologies, Wherever They Are

Flight Deck of the Future (F.F)

- Develop Technology for Human/System Interfaces
- Goals
  - Develop and mature next-generation human interfaces
  - Infuse HSI methodology earlier in the design process
  - Support technical communication across disciplines (integration)
  - Create partnerships with Industry and Academia
- Critical element of iPAS
  - Tie human systems with flight-like avionics
  - Evaluate within a mission context
  - Look at failure modes and responses

Augmented Reality & Computer Vision

Smart Fabrics

Deformable Displays

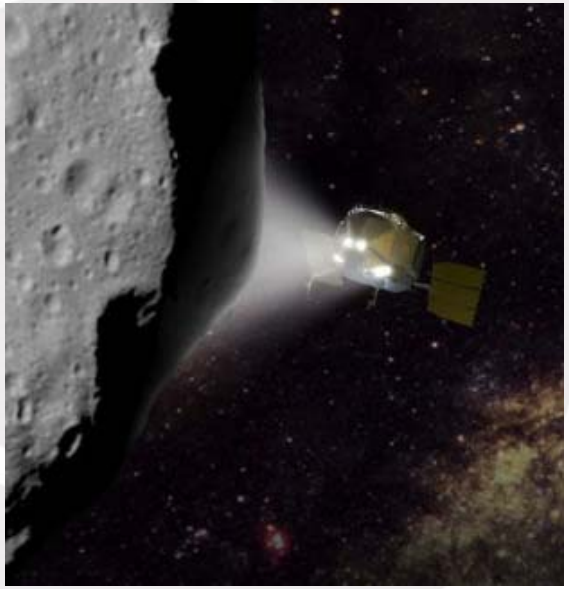
Gesture-Driven Input

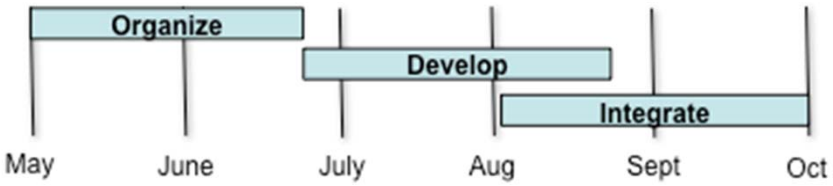
AES Technology Maturation for Human Spaceflight

- 2011: Asteroid Visitation Mission
- 2012: L2 Waypoint Mission
- 2013: Asteroid Redirect Mission

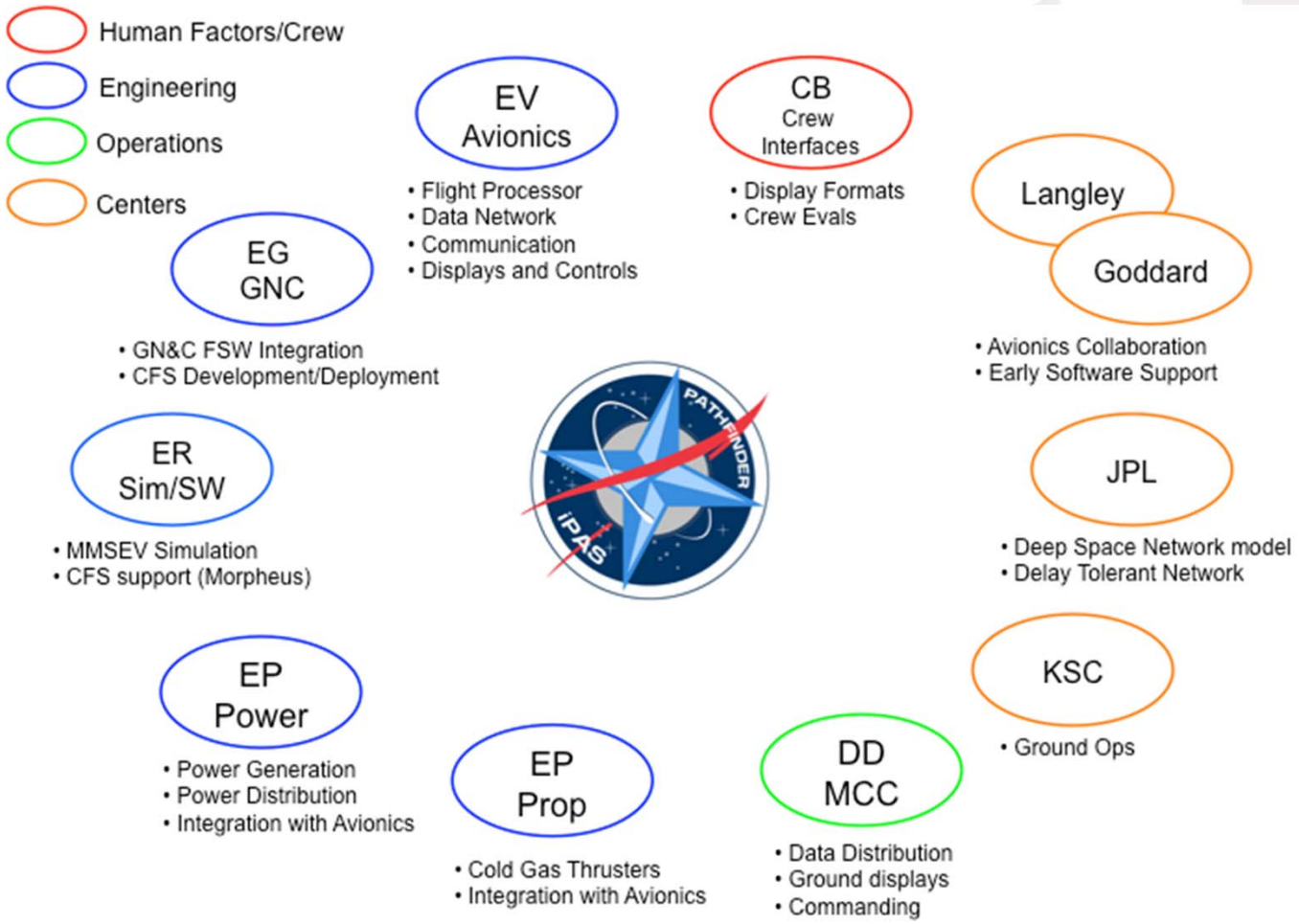
Asteroid Visitation Mission

- Mission: Demonstrate a Crewed Mission to Asteroid
  - *Meaningful, organizing vision for integration*
  - But consider the products and integration independent of mission
  - Be prepared to apply capabilities to different missions
- May 2011: Authority to Proceed
- Organized the Pathfinder team
  - Engineering, Operations, Centeres
- Developed 4 Month Sprint
  - Identify elements in hand (McGyver)
  - Incrementally add hardware and software
  - Show integrated test

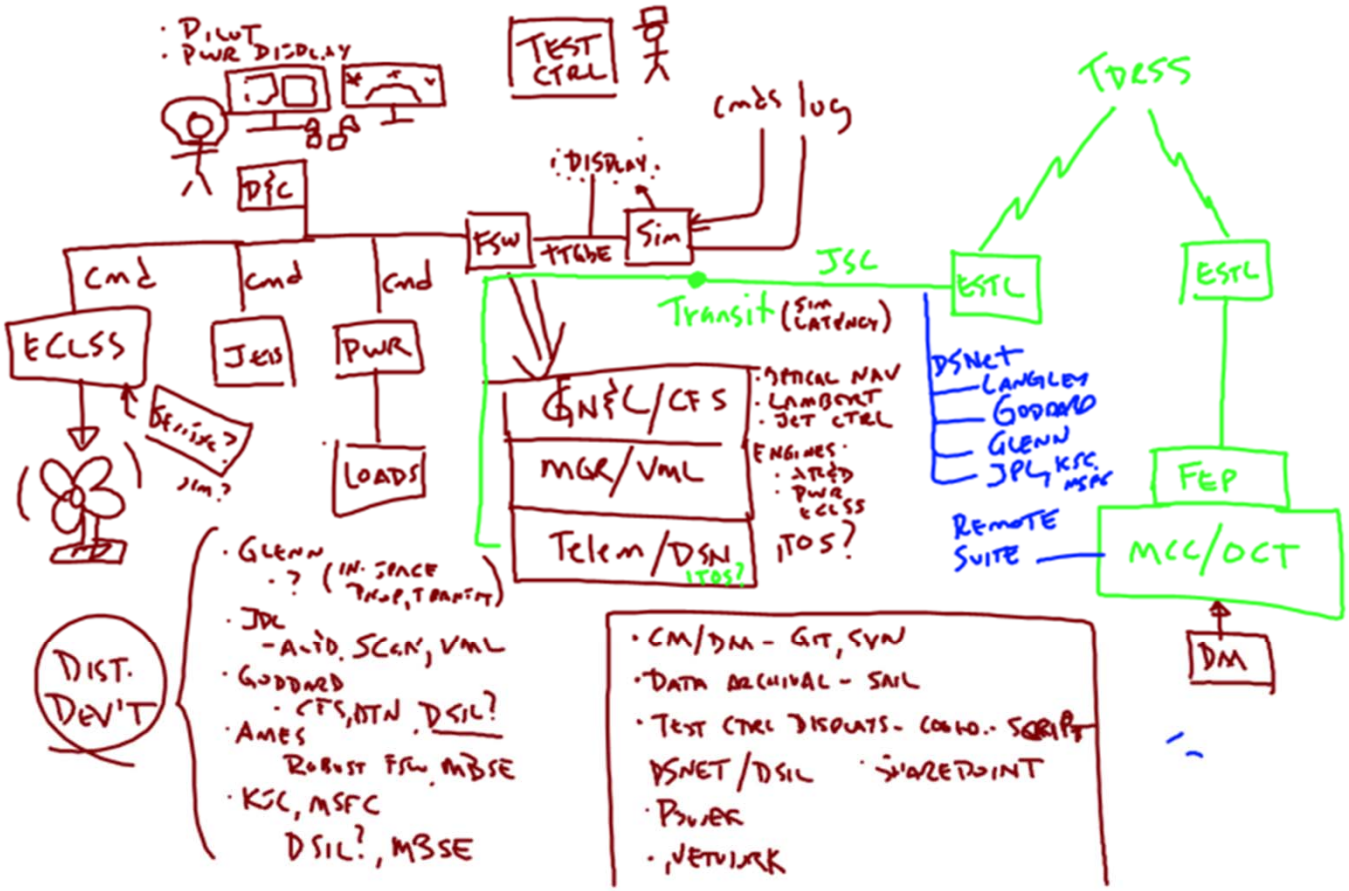




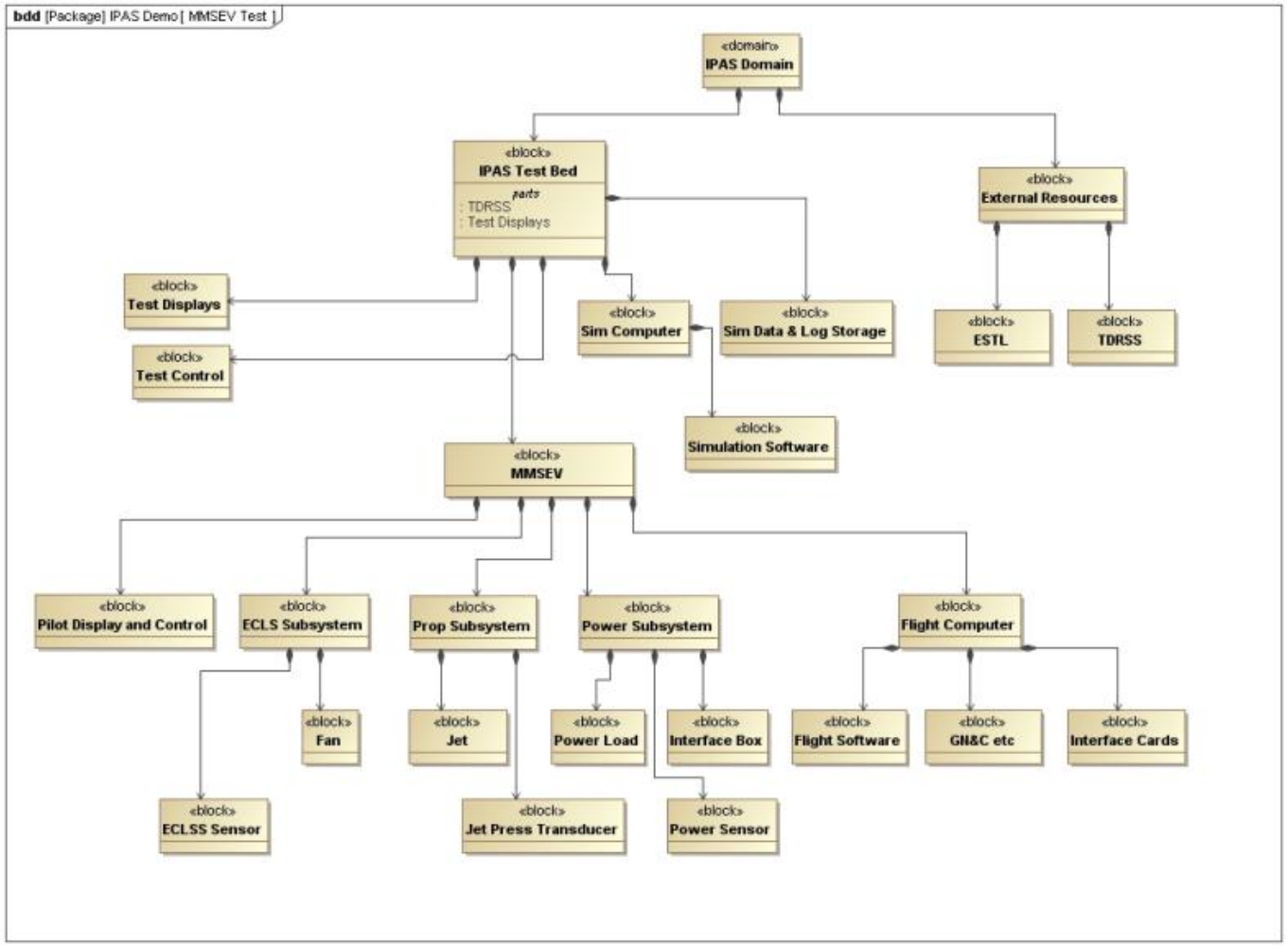
iPAS Pathfinder Team



Whiteboard Project Formulation

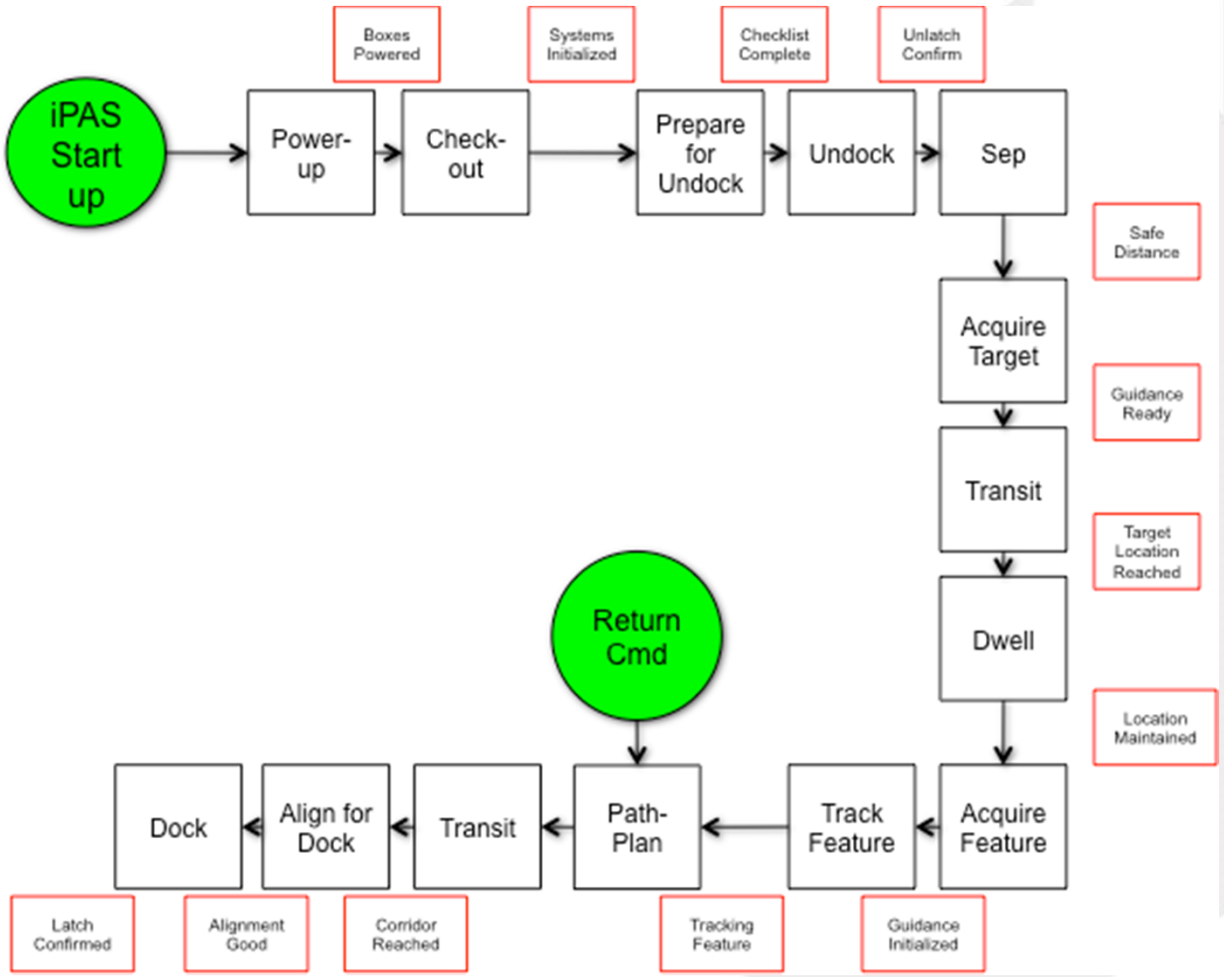


Model Based System Engineering (MBSE)



Model Based System Engineering (MBSE)

Mission Context: Develop Concept of Operations

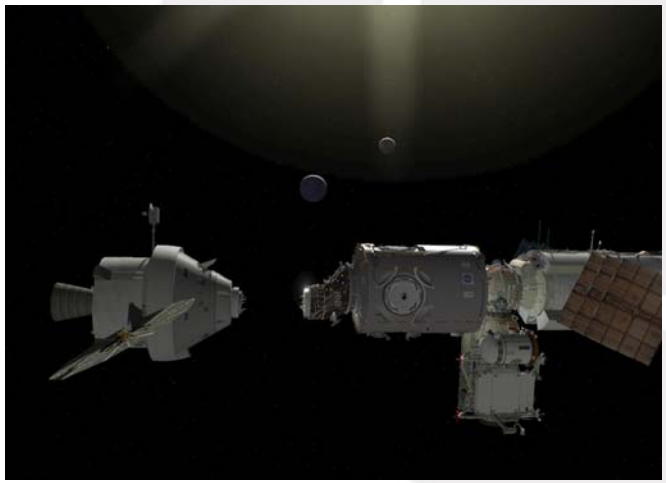


First Integrated Test: September 2011

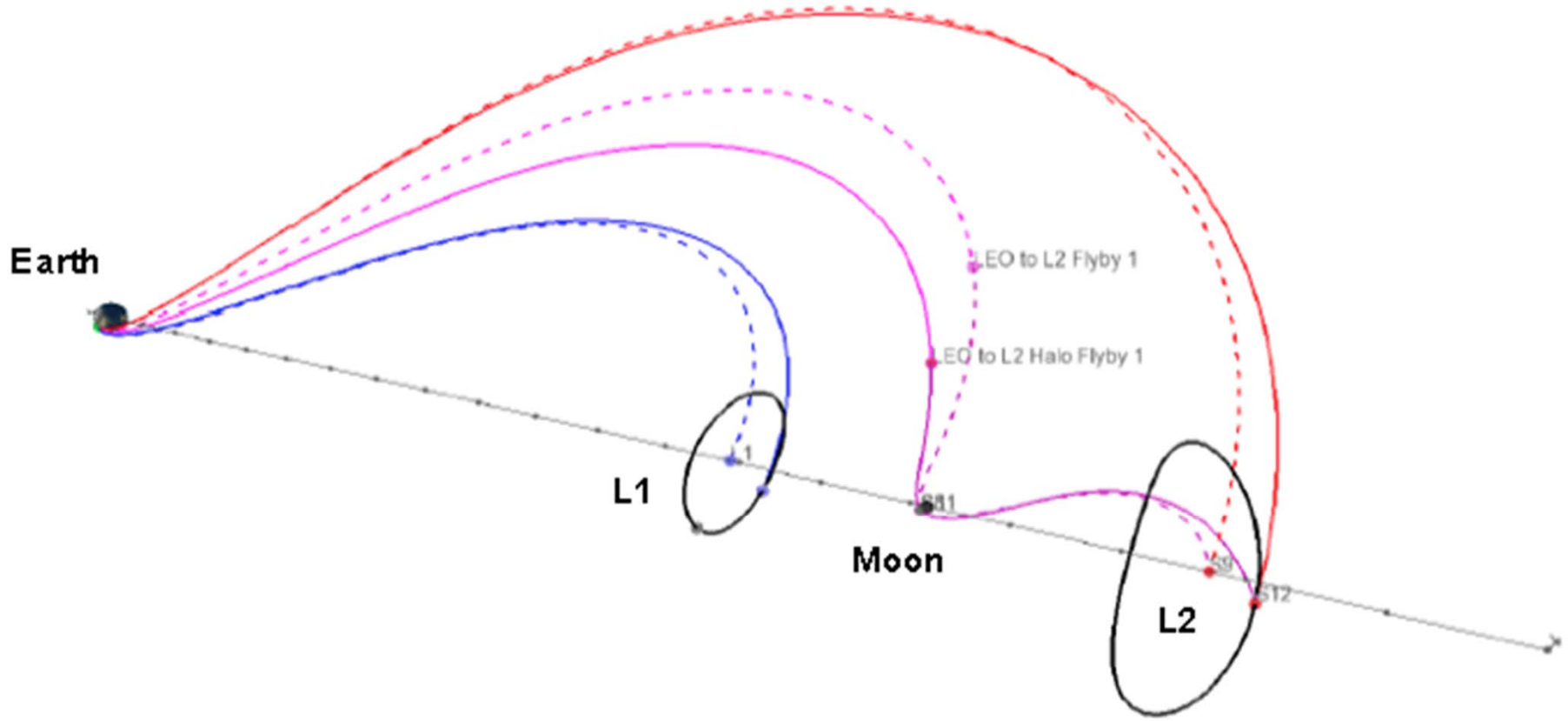
- Successfully delivered system by end of September
- Presented results to JSC Engineering Directorate
  - Included products of several AES Projects, integrated together
- Received a NASA Group Achievement Award

Second Test: L2 Waypoint Mission

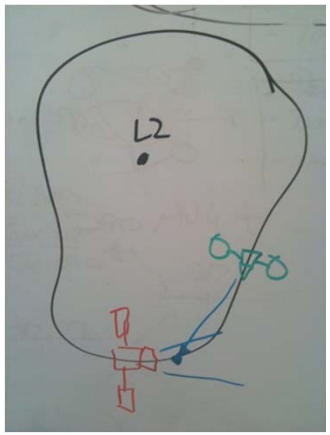
- Apply iPAS capabilities to a new mission (Reuse)
  - CFS, C&DH, simulation, operations interfaces
- Add new capabilities to support test (Expand)
  - Orion FSW, solar array emulator, software radio, ECLSS
  - New technologies: In Space Manufacturing, Plume impingement



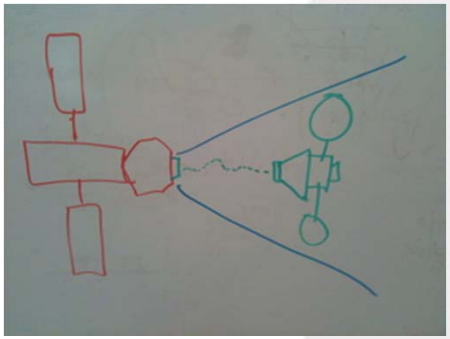
Waypoint Scenario Development



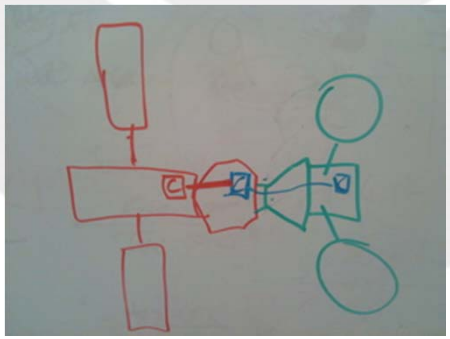
Orion AR&D with Vehicle at Earth/Moon L2



Rendezvous in L2 Halo Orbit

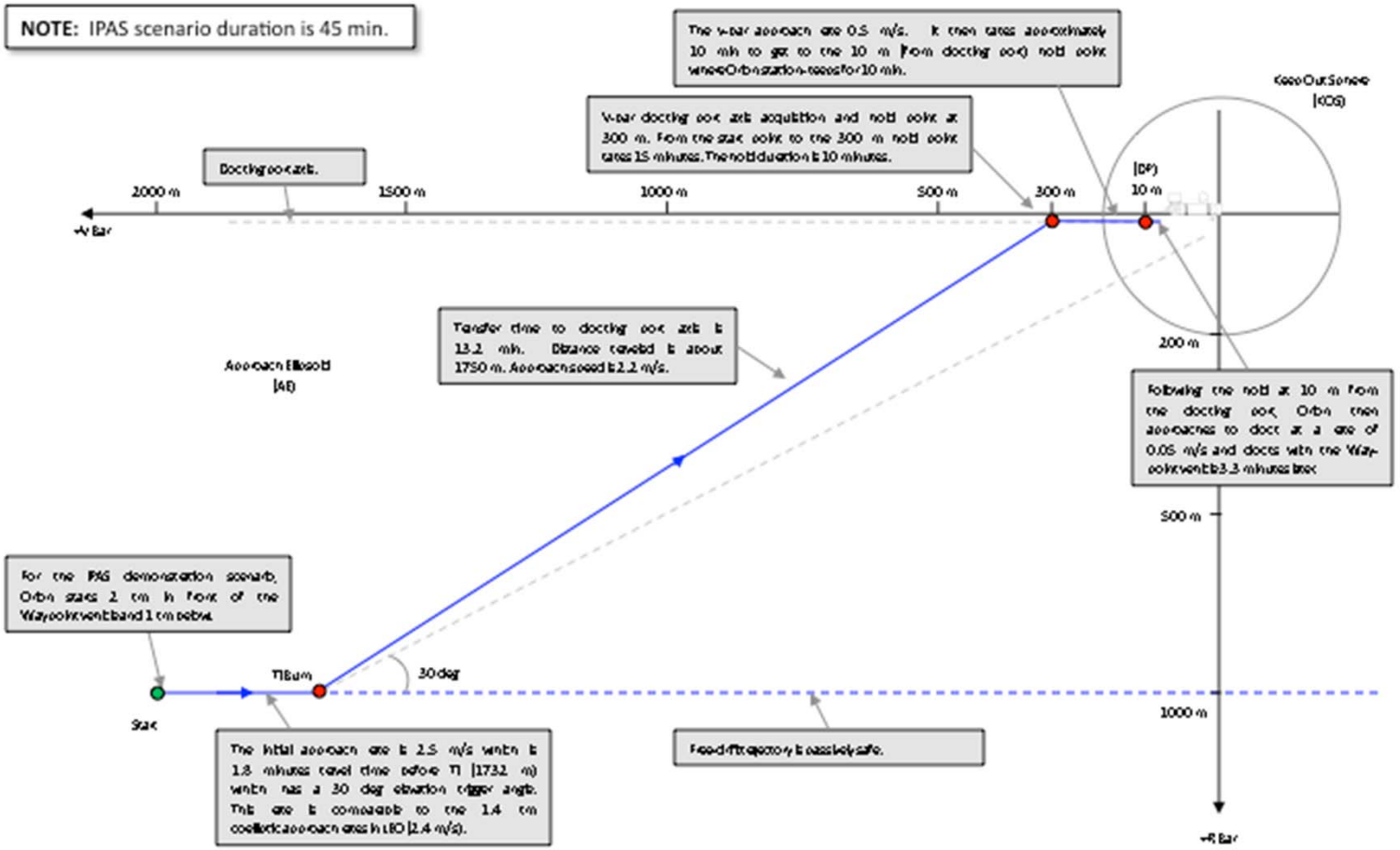


Proximity Operations

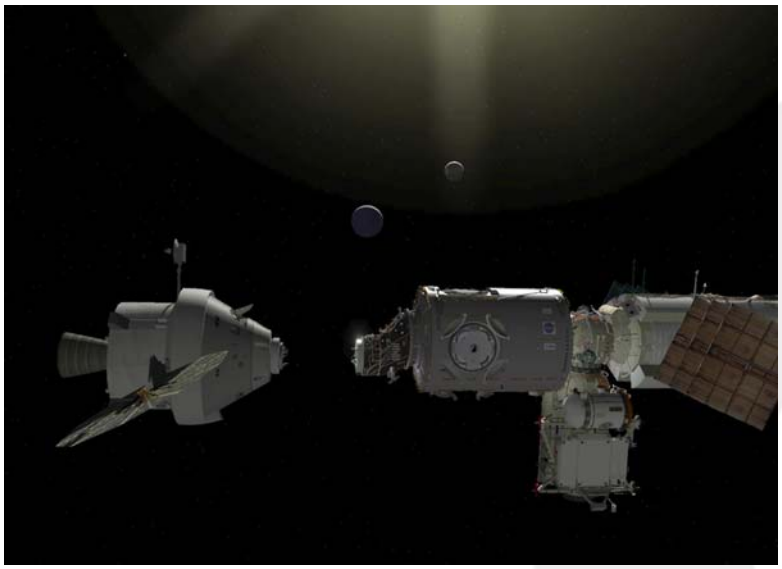


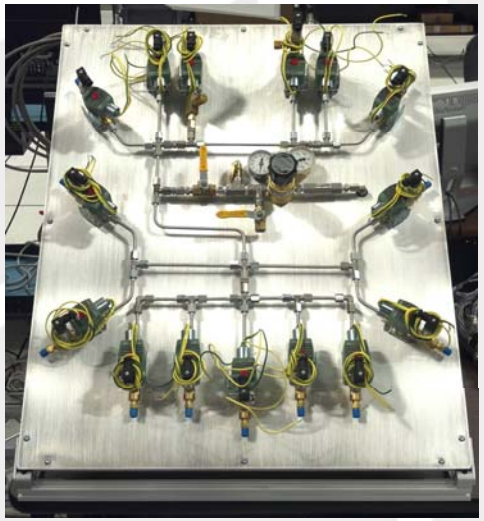
Dock

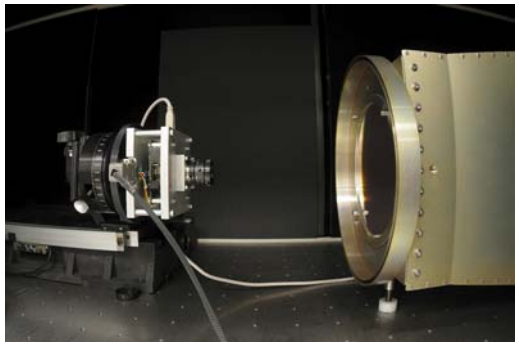
AR&D Trajectory



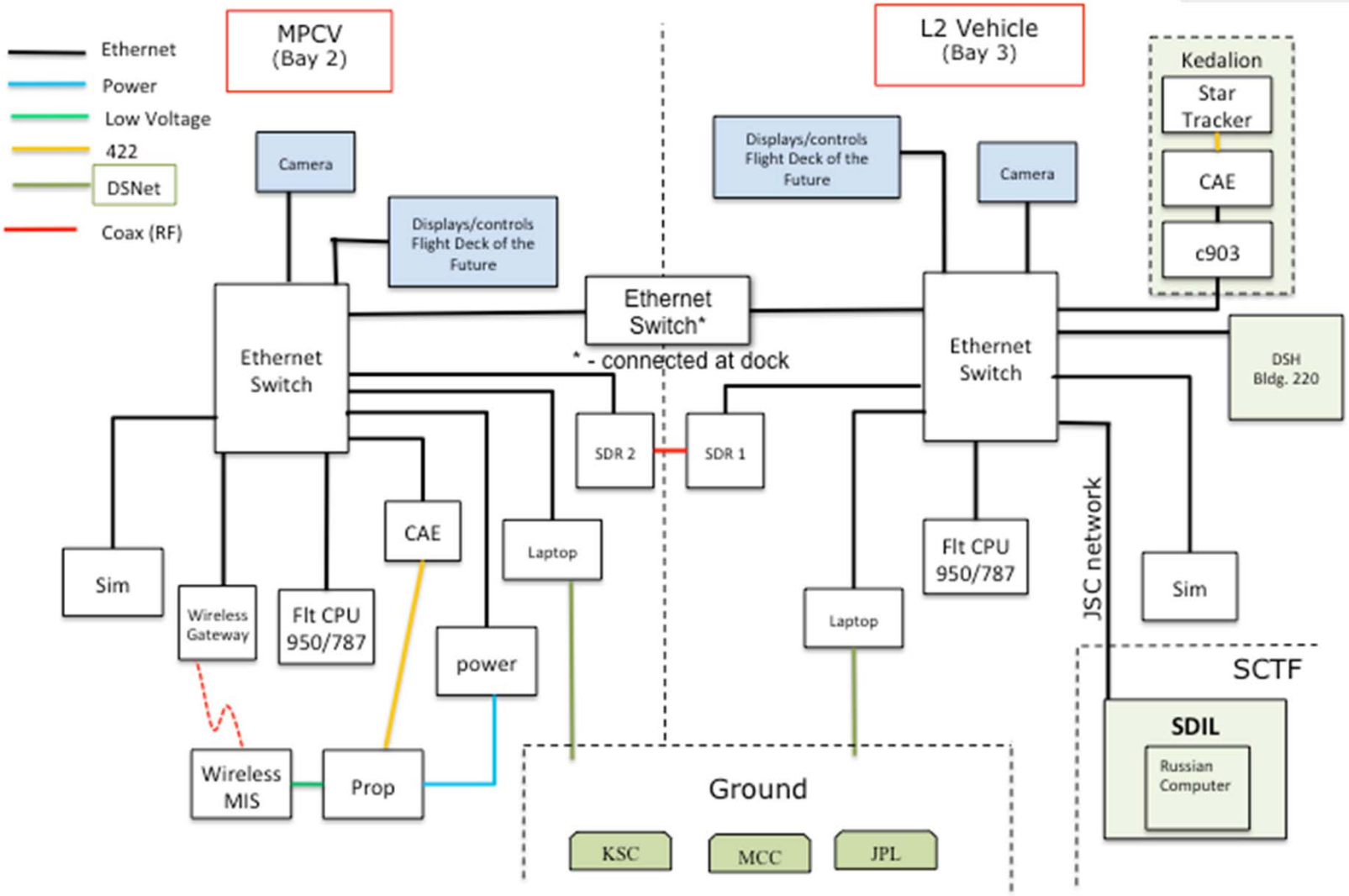
MPCV AR&D with vehicle at L2





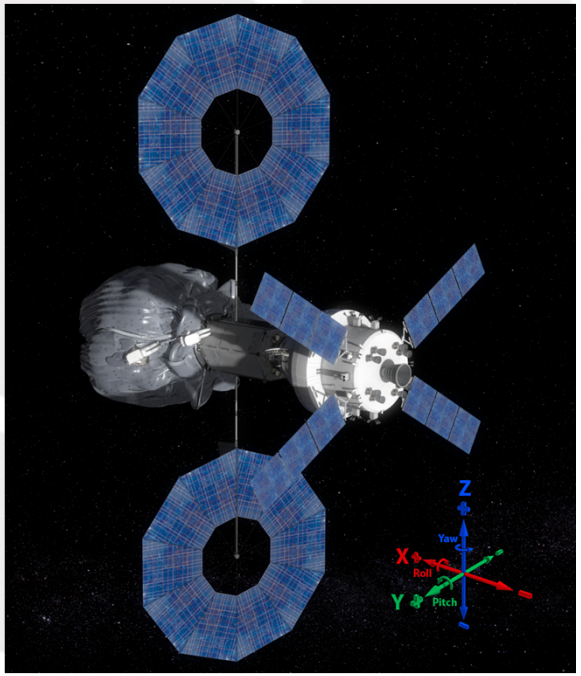


Test Architecture



Third Test: Asteroid Return Mission

- Apply tools and software to Asteroid Return Mission
- Added: Orion EM1 Absolute Navigation
- Leveraged off existing CFS and other infrastructure
- Capability applied to support early trades
  - Stack attitude control
  - Docking dynamics

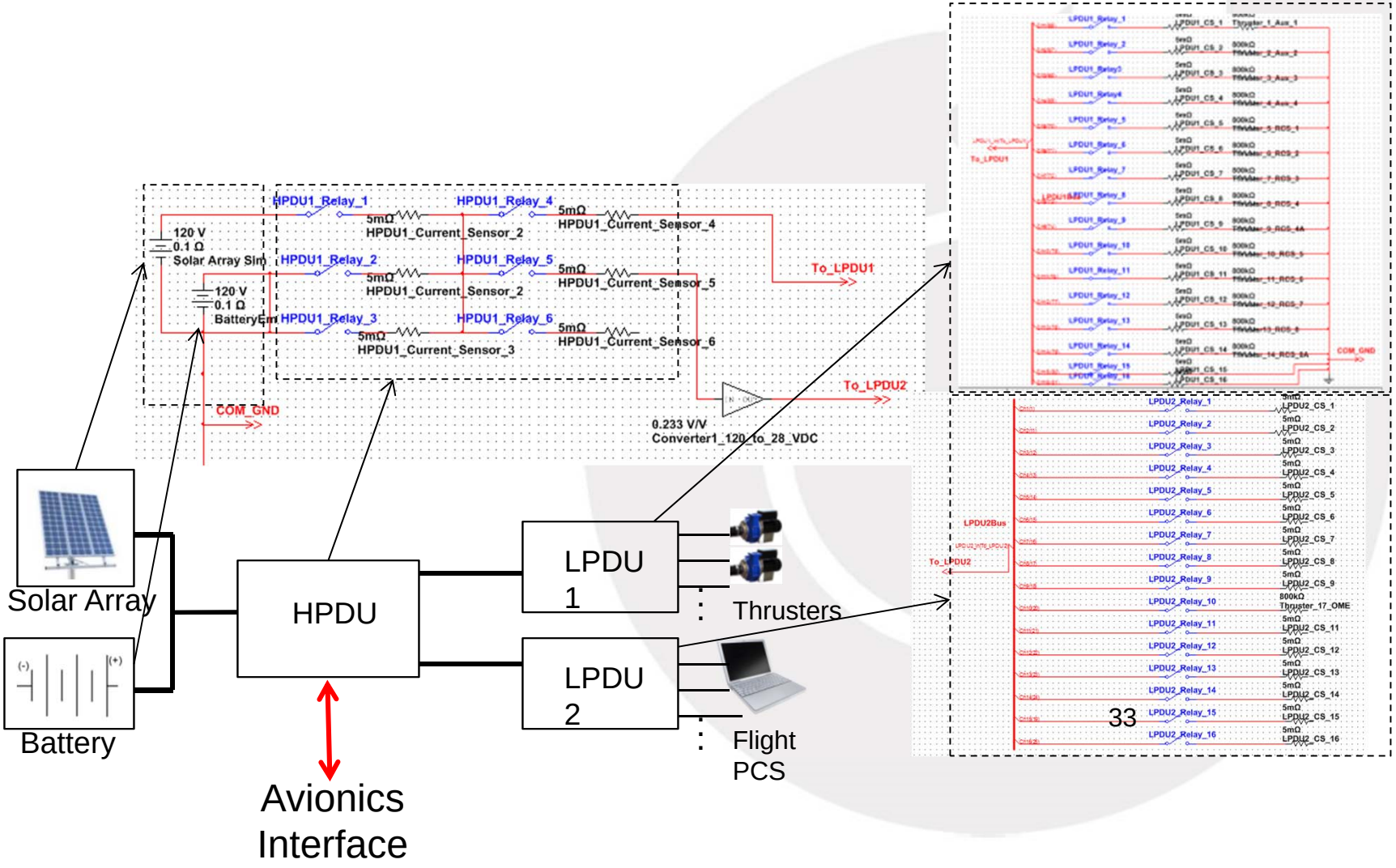


New Methods for System Engineering and Integration

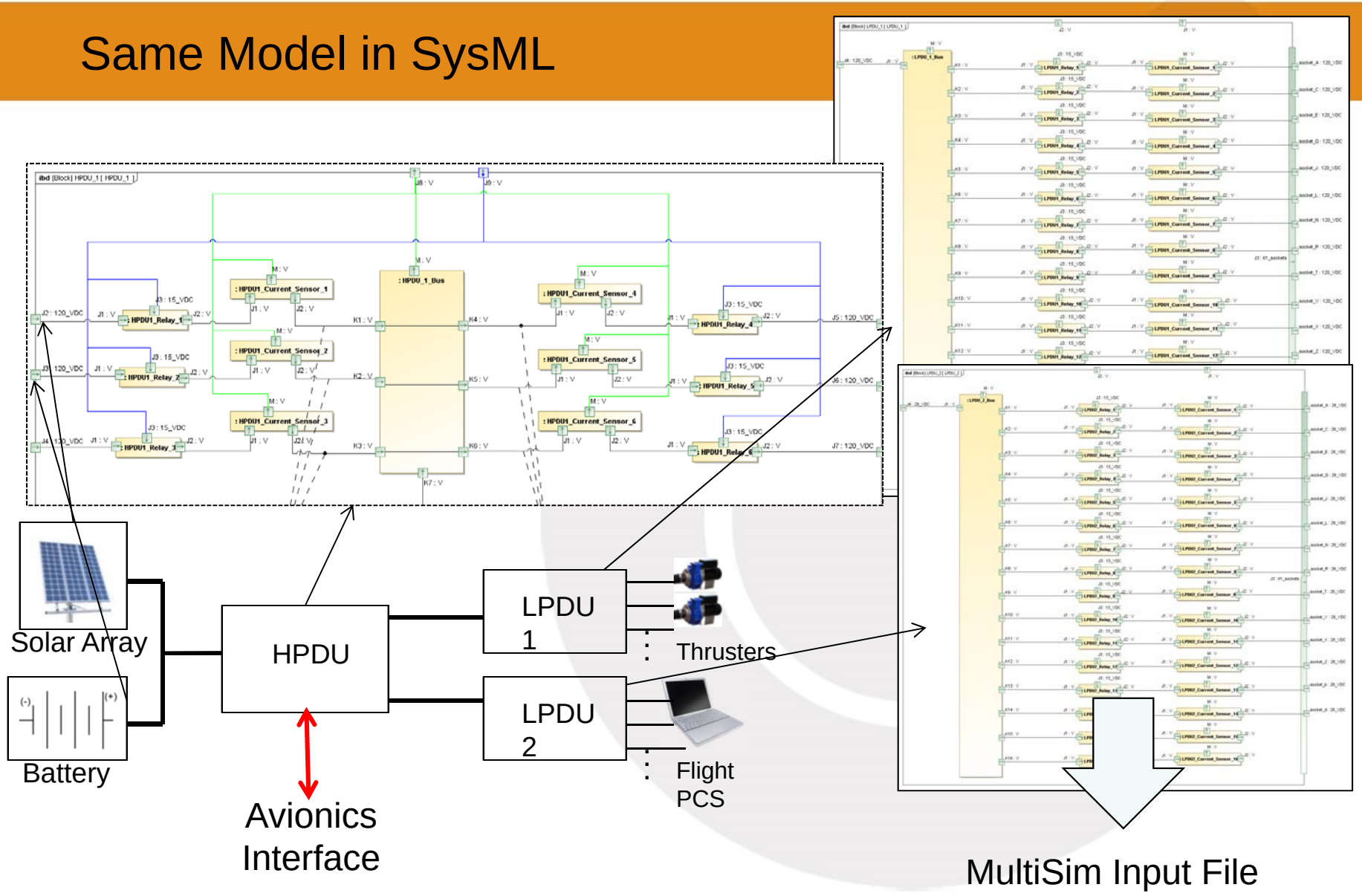
- Model Based Engineering
  - Analysis tools that support design and development
- Model Based System Engineering
  - Environment that supports analysis of multi-discipline integration
- Model Application
  - Requirements and sizing: Mission Planning
  - Design and Development: Describe systems
  - Analysis: Generate inputs files for analysis tools
  - Test: Generate test procedures for iPAS
  - Operations: Deliver product to crew/operators

Get Management Buy-In to
New Ways of Doing Business

iPAS Power System in MultiSim



Same Model in SysML

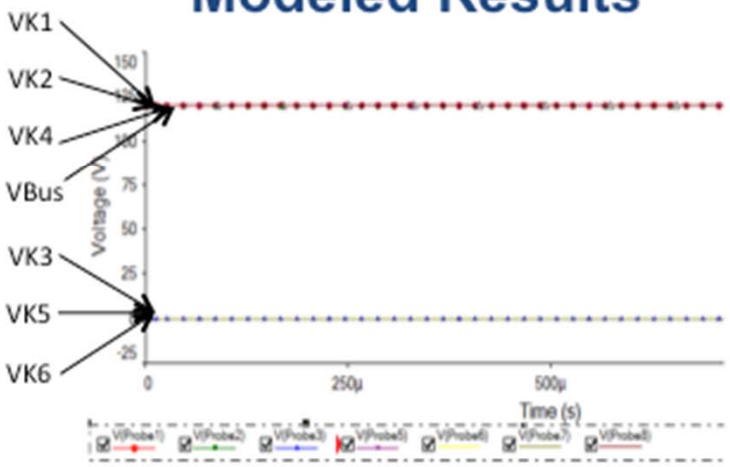


Test Demonstration in iPAS

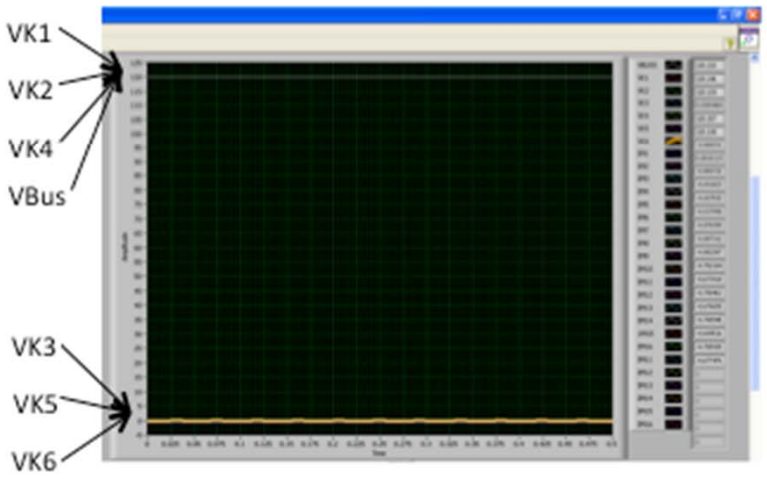
Expected Results

Channel	State	Voltage	Value	Current	Value
K1	Off	VK1	120	IK1	0
K2	On	VK2	120	IK2	0
K3	Off	VK3	0	IK3	0
K4	On	VK4	120	IK4	0
K5	Off	VK5	0	IK5	0
K6	Off	VK6	0	IK6	0
Vbus		VBUS	120		

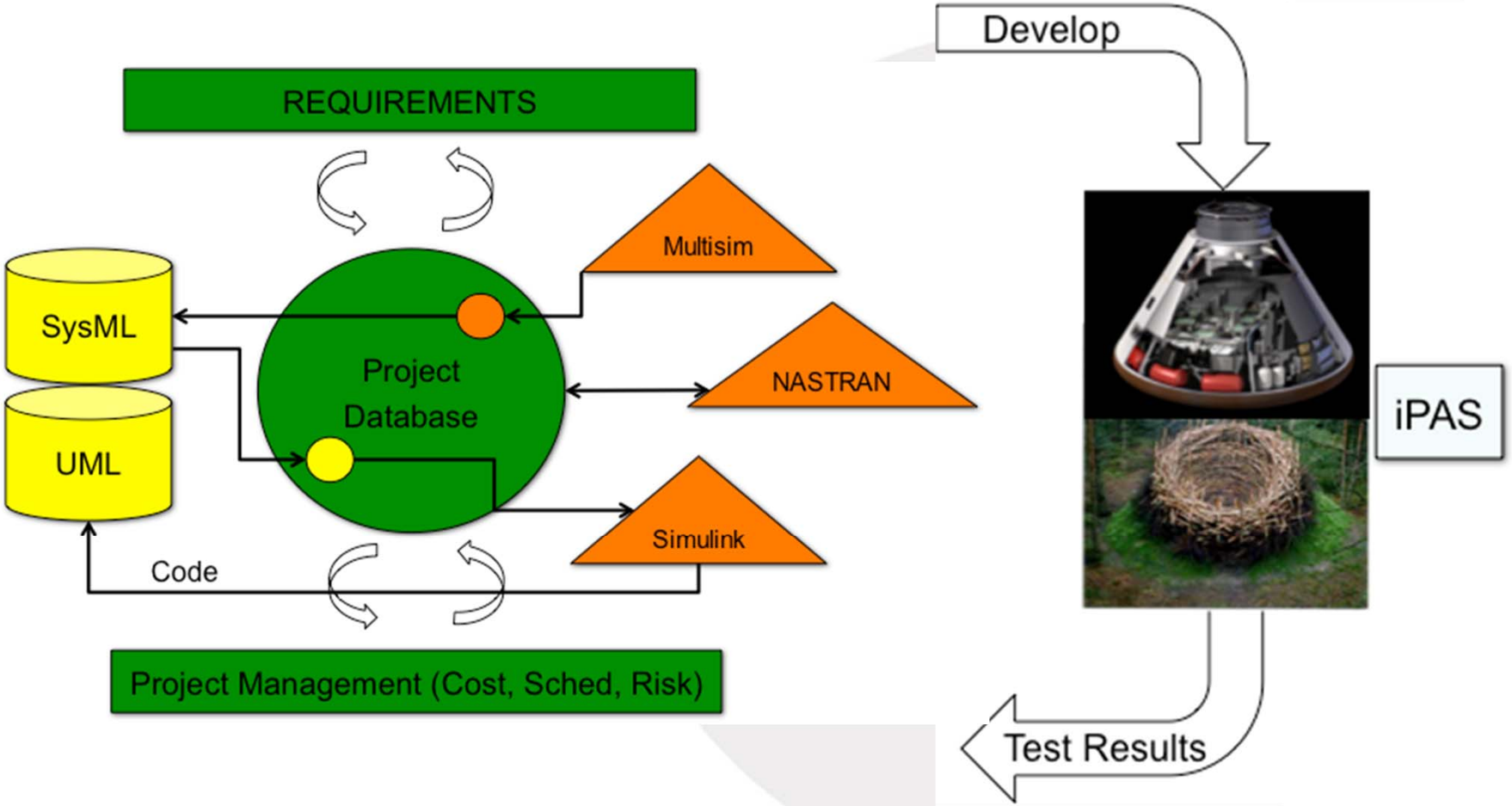
Modeled Results



Actual Results



Product Development and Test



Establish iterative loop between Models and Products

The World's Forum for Aerospace Leadership