



# 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

## Integrated Power, Avionics, and Software (iPAS)

- Environment to mature and demonstrate technologies
- Three elements of iPAS

- The Iron Bird: Mission Systems (Vehicle, *Power, Avionics, and Software*)
  - Support the development of a *common avionics, power, and software architecture* that supports a variety of various missions
- The Iron Nest: Testbed Systems



... a *common testbed framework* that supports integrated hardware/software testing for a variety of applications  
...: Improving SE&I techniques and assessments



## 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

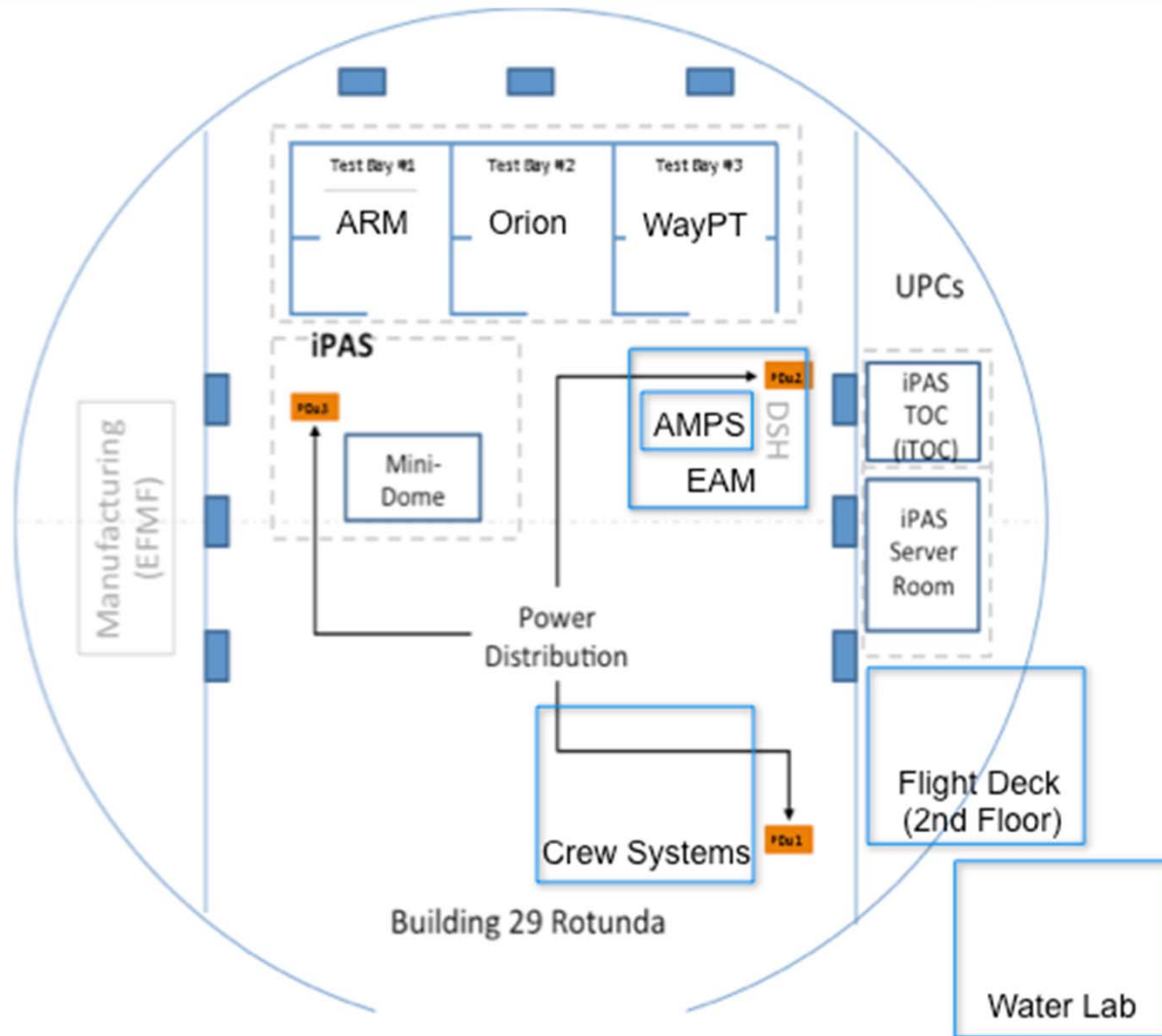
- Hardware and software products
  - Engineering Units, and eventually flight units as well
  - System Analogs (battery emulators, cold gas jets)
- Current Components
  - Hardware: AAE
    - Processors, Networks, Comm
    - Power, Propulsion, Crew Life Support
  - Software: CFS
    - Framework-independent 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



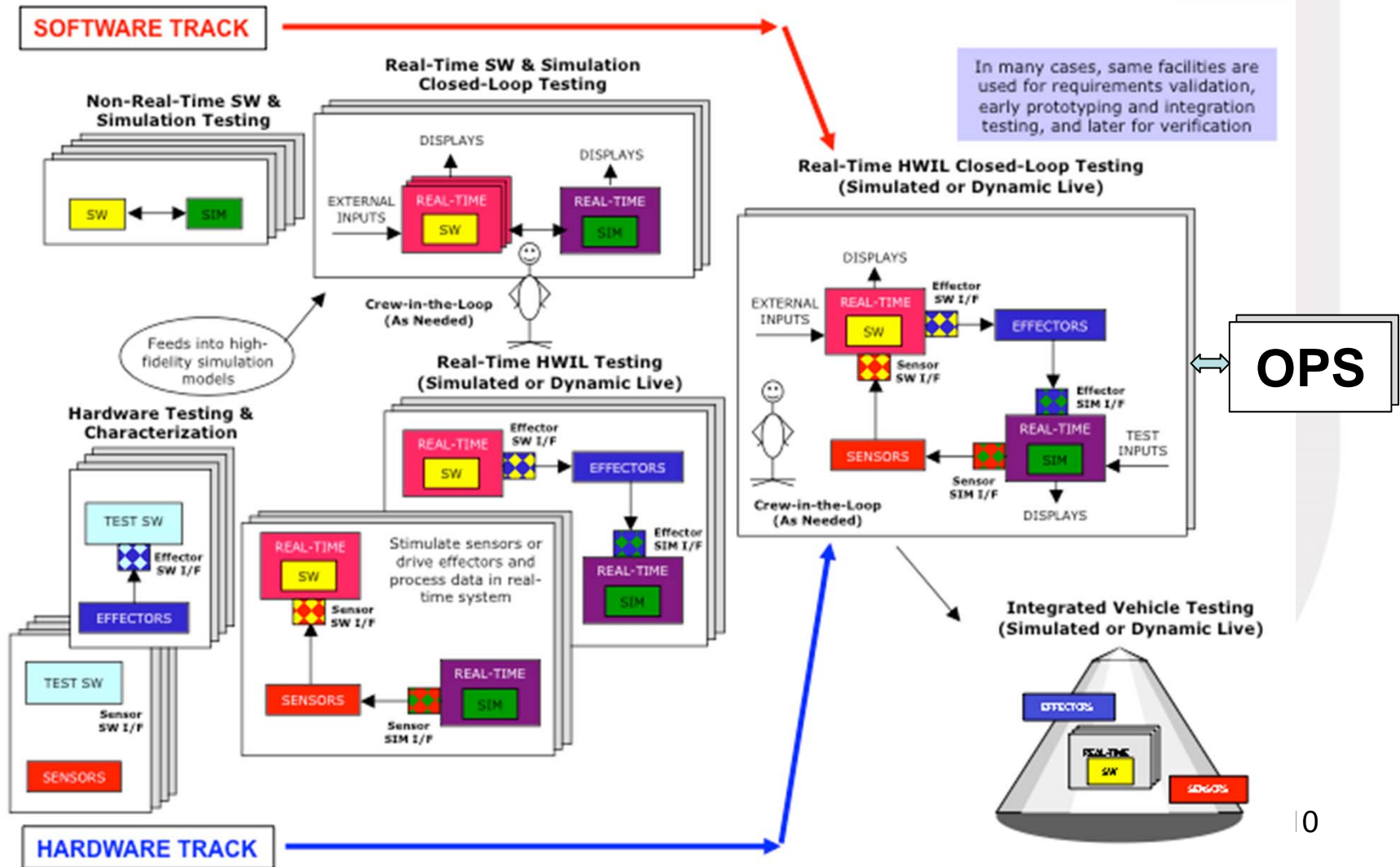
The Bird



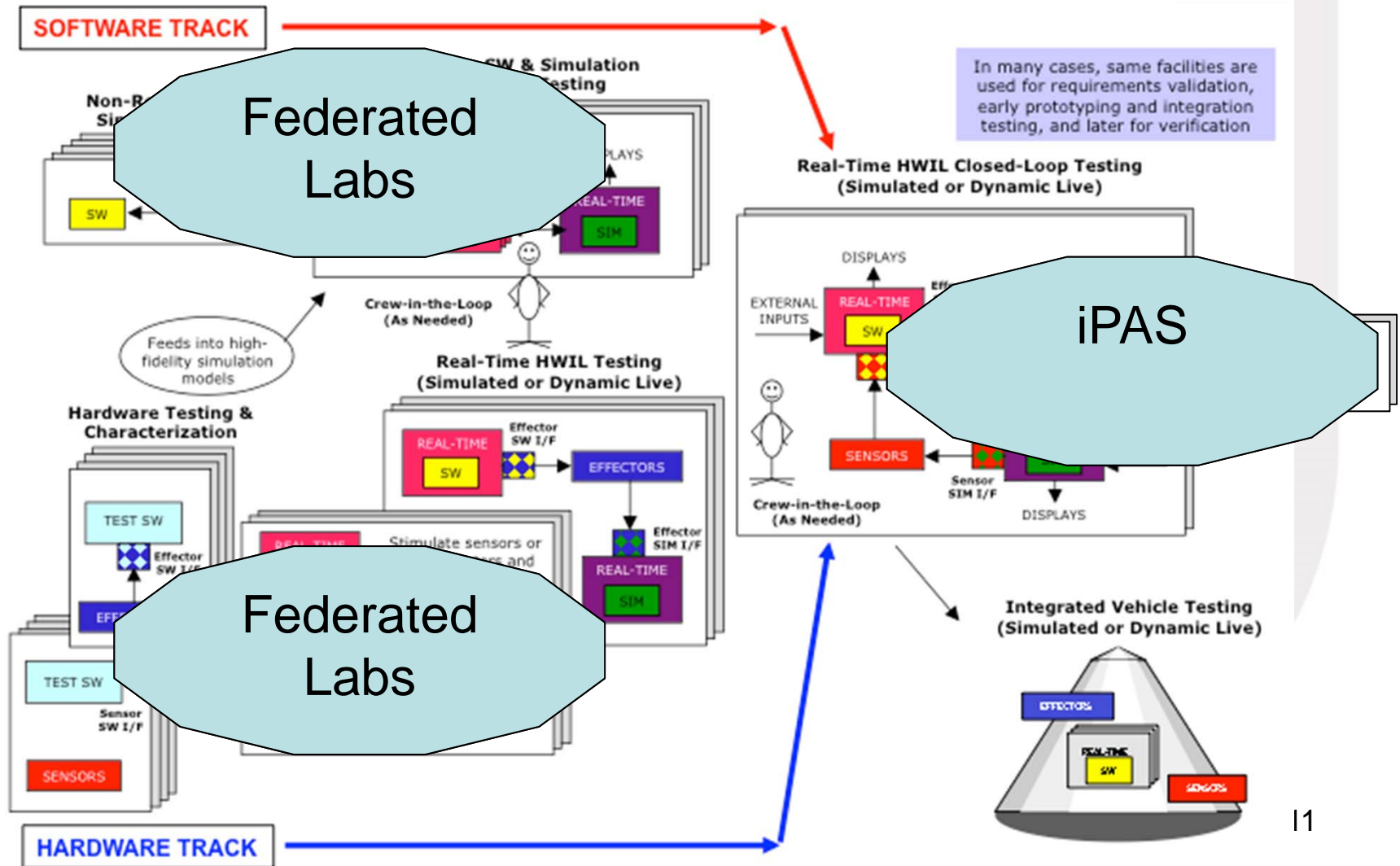
## iPAS Floorplan : Multiple, Parallel Development Teams



# 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

## B16 – GNC/Dome

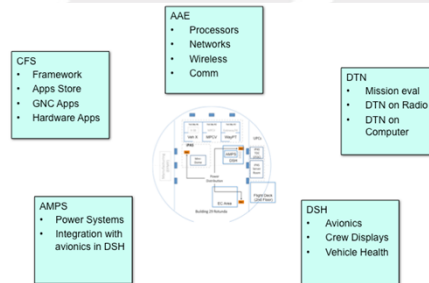
- Star Tracker
- Star Field
- Cockpits
- Dome

## B30 – Mission Ops

- MCC emulator
- SNRF interface
- Telemetry and commanding

## B44 – Comm

- Channel simulator
- TDRSS
- Comm architecture



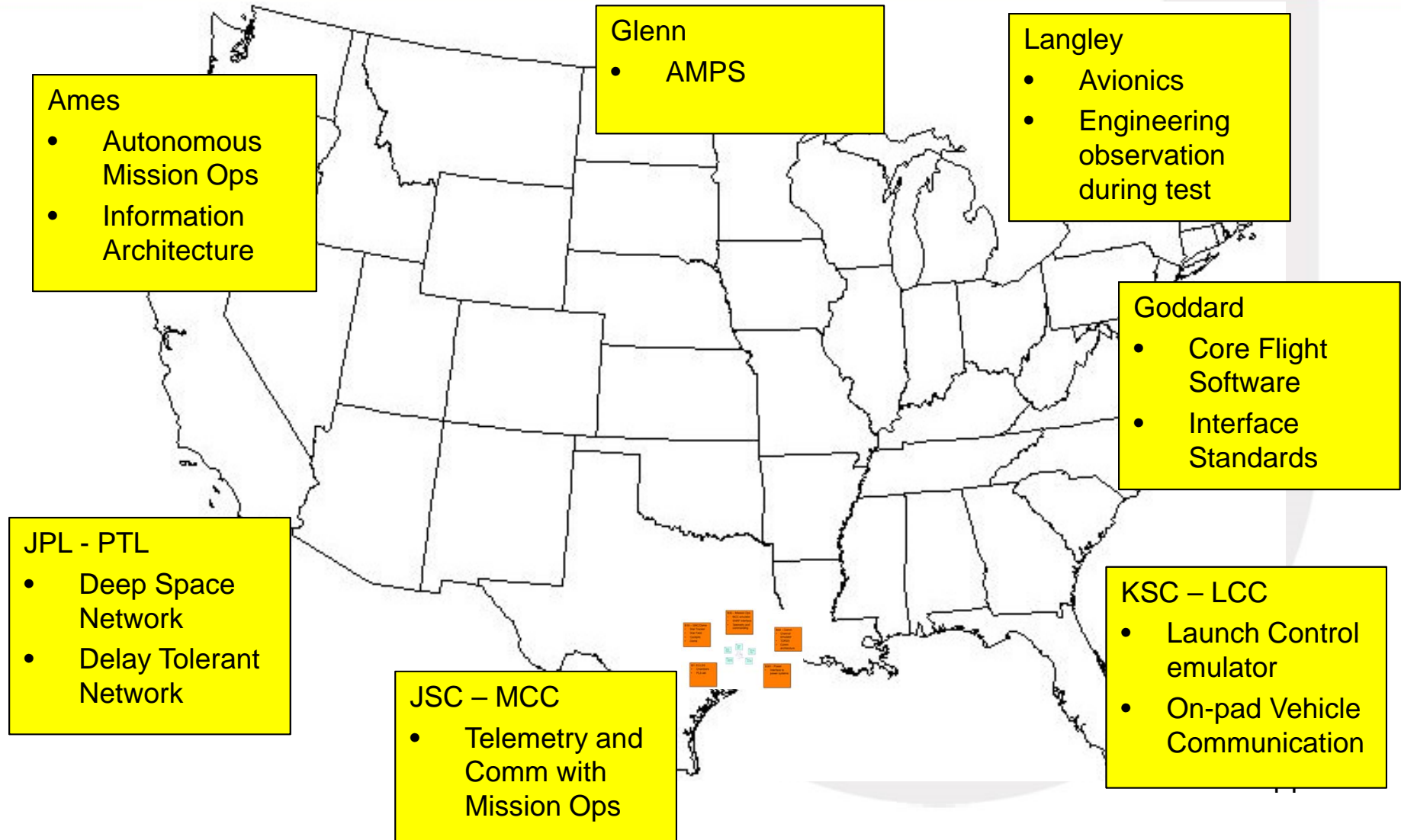
## B7- ECLSS

- Chambers
- PLS lab

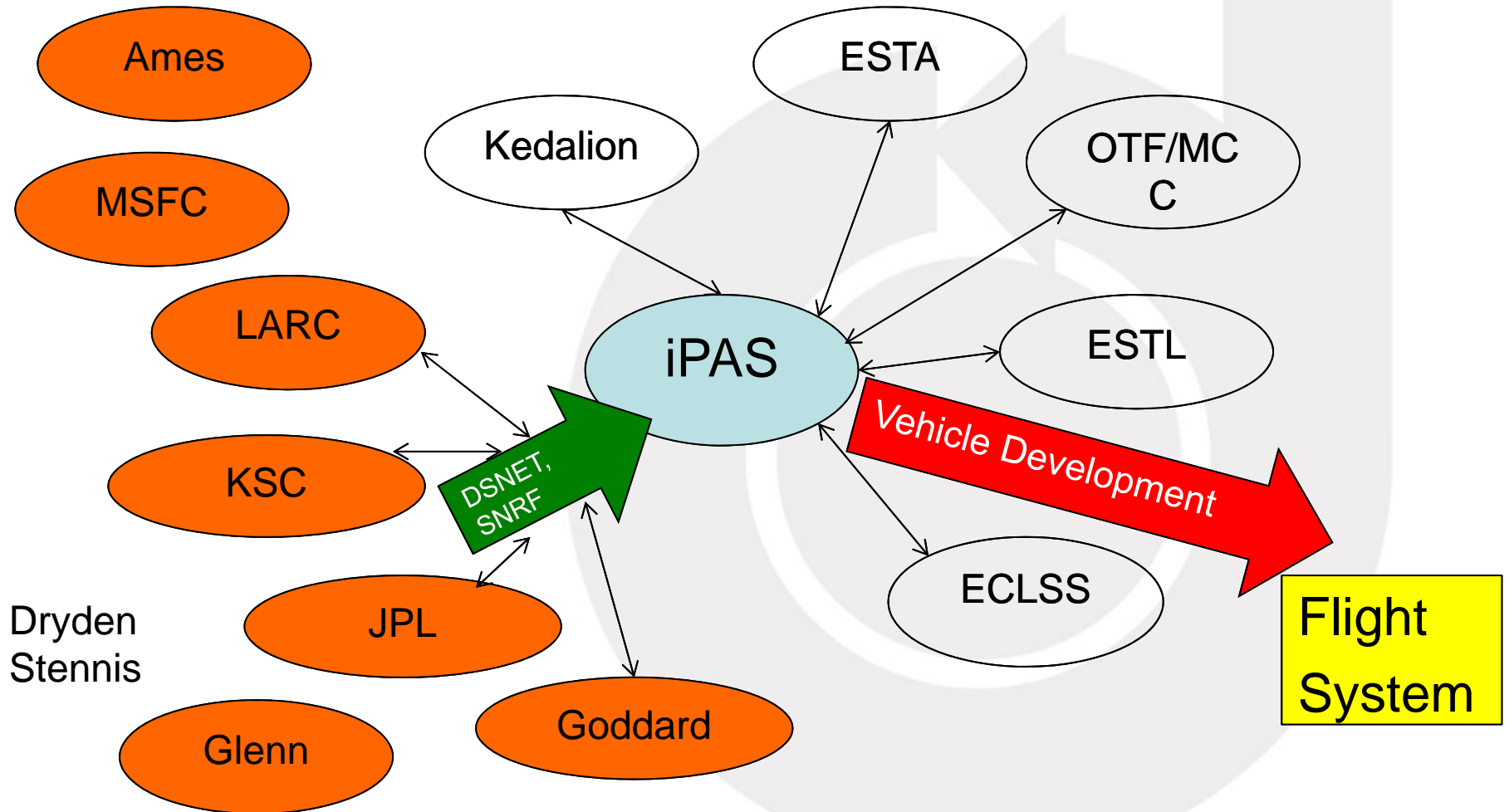
## B361 - Power

- 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)

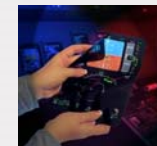
- Develop Technology for Human/System Interfaces
- Goals
  - Develop and mature next-generation human interfaces
  - Infuse HSI methodology earlier in the design process
  - Support technical communication across disciplines (integration)
  - Create partnerships with Industry and Academia
- Critical 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



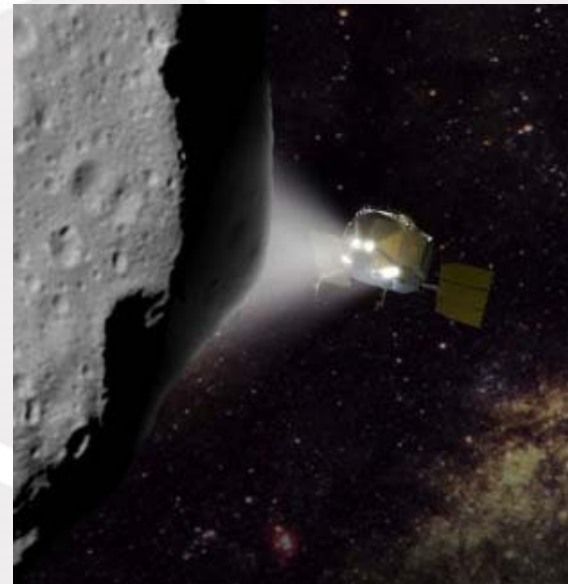
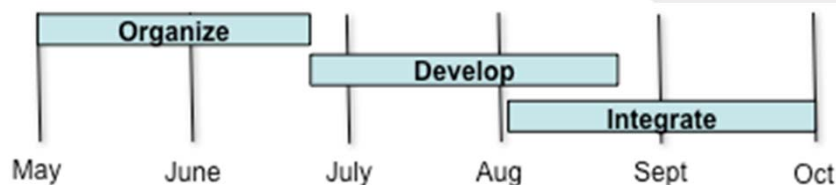
Gesture-Driven Input

## AES Technology Maturation for Human Spaceflight

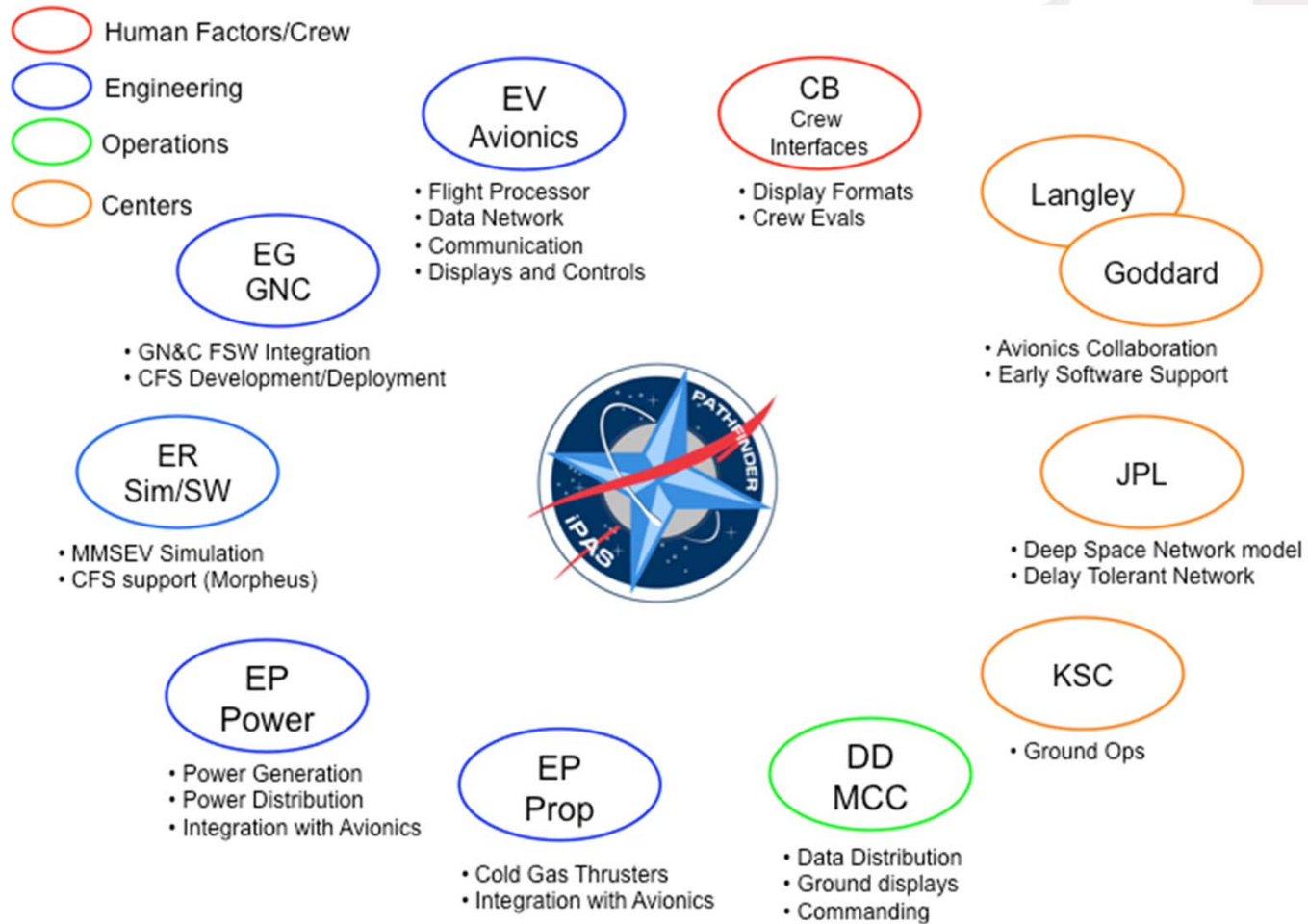
- 2011: Asteroid Visitation Mission
- 2012: L2 Waypoint Mission
- 2013: Asteroid Redirect Mission

## Asteroid Visitation Mission

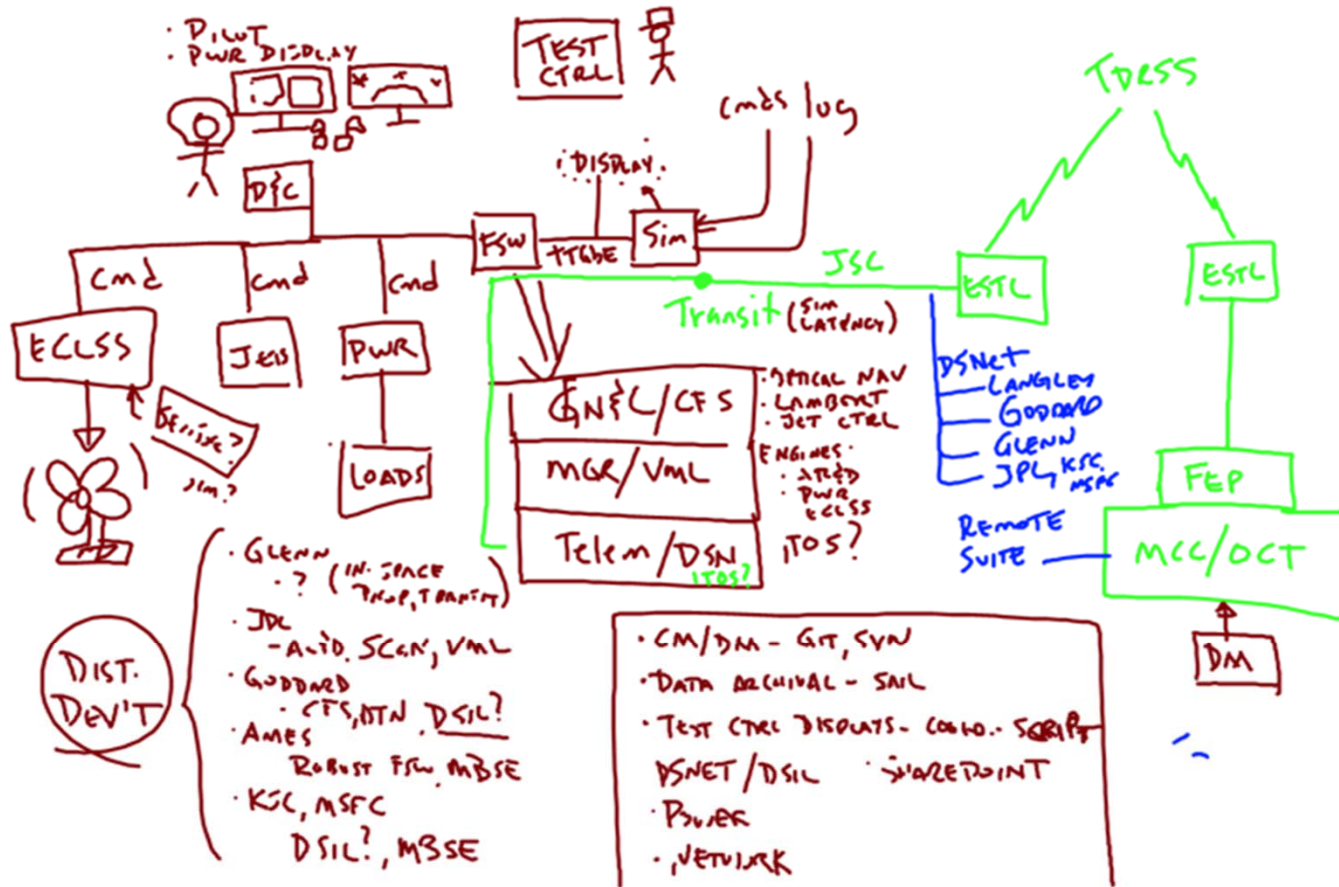
- Mission: Demonstrate a Crewed Mission to Asteroid
  - *Meaningful, organizing vision for integration*
  - But consider the products and integration independent of mission
  - Be prepared to apply capabilities to different missions
- May 2011: Authority to Proceed
- Organized the Pathfinder team
  -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



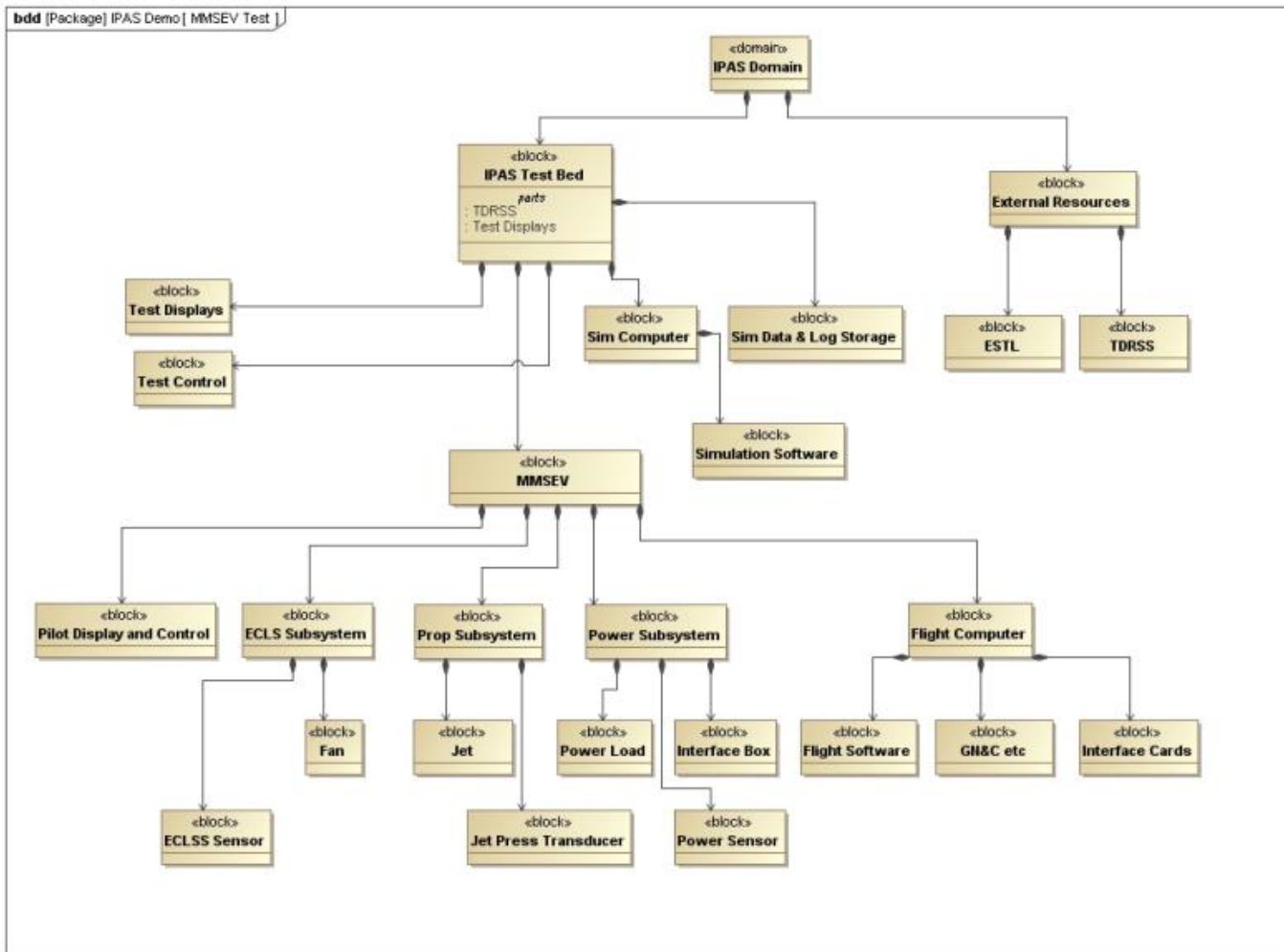
# iPAS Pathfinder Team



# Whiteboard Project Formulation

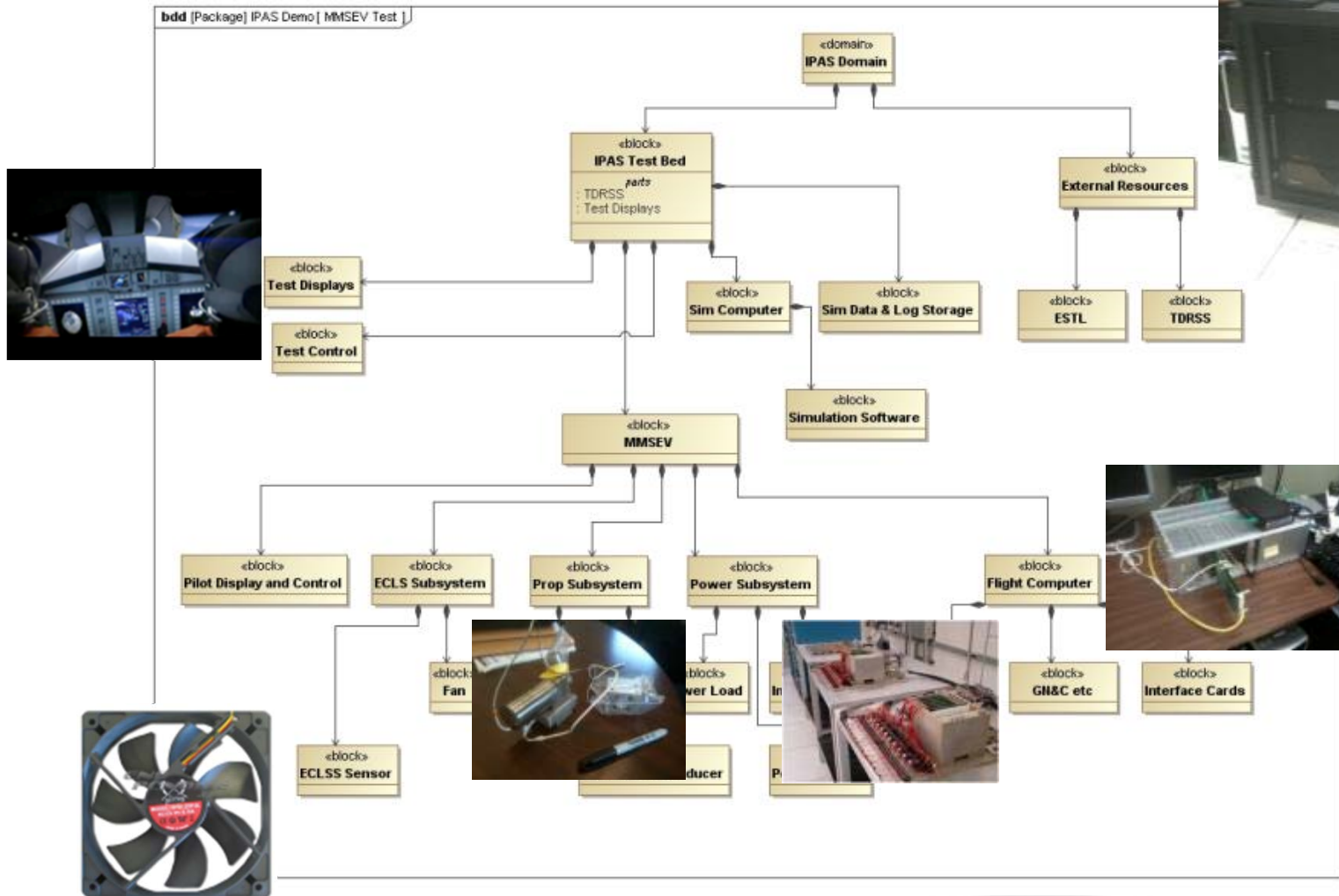


# Model Based System Engineering (MBSE)



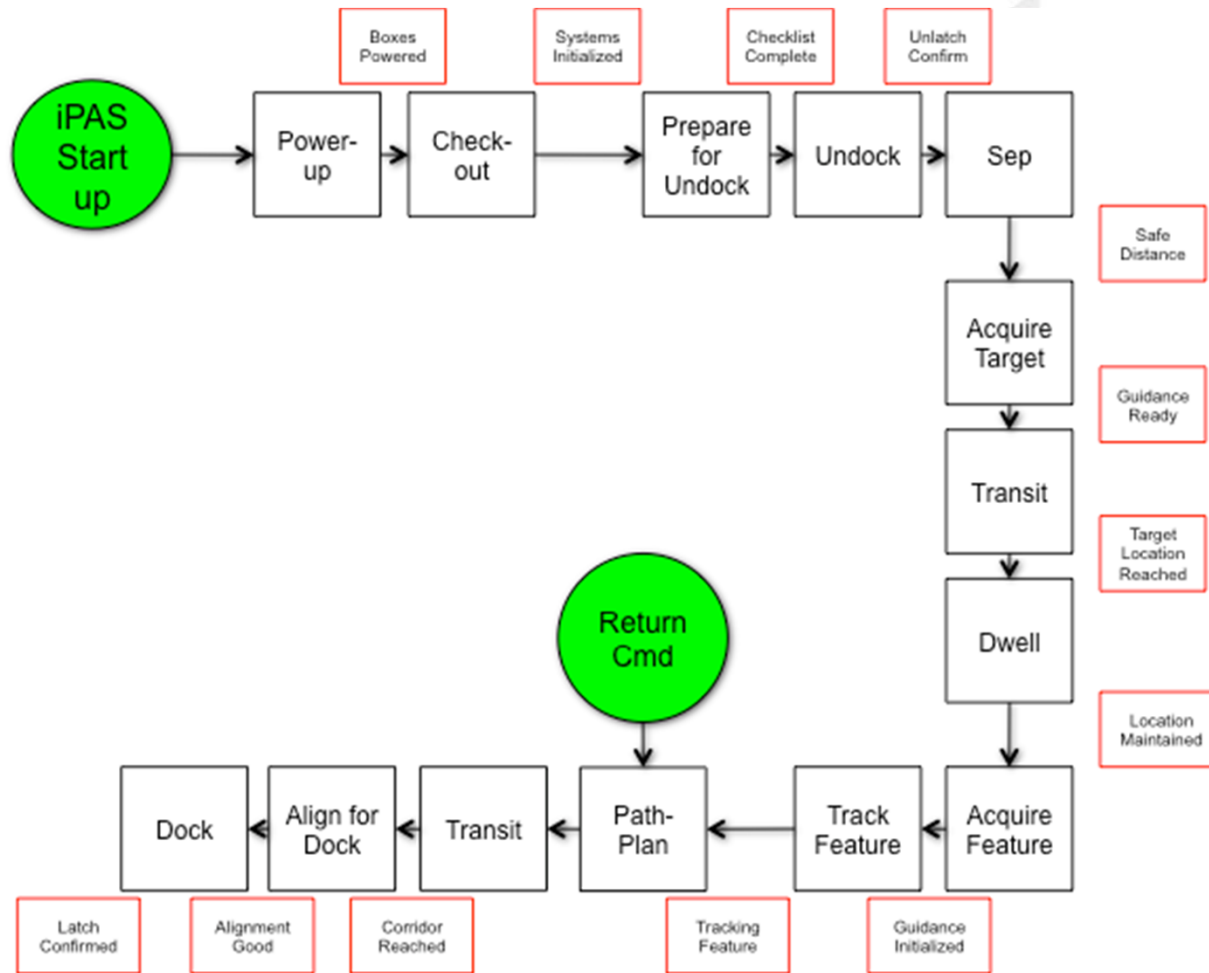


# Model Based System Engineering (MBSE)





# Mission Context: Develop Concept of Operations



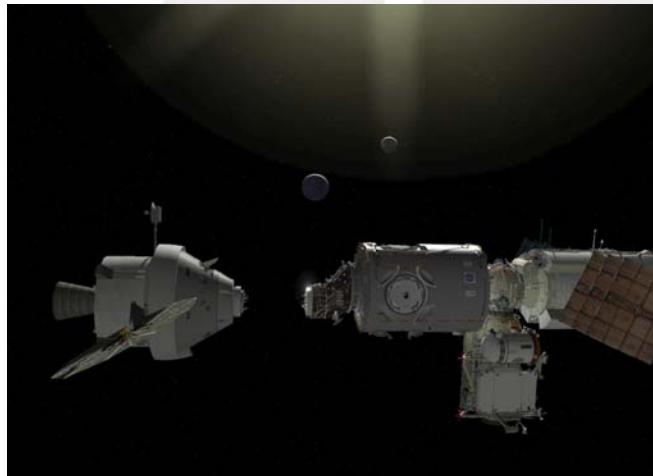
## First Integrated Test: September 2011

- 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

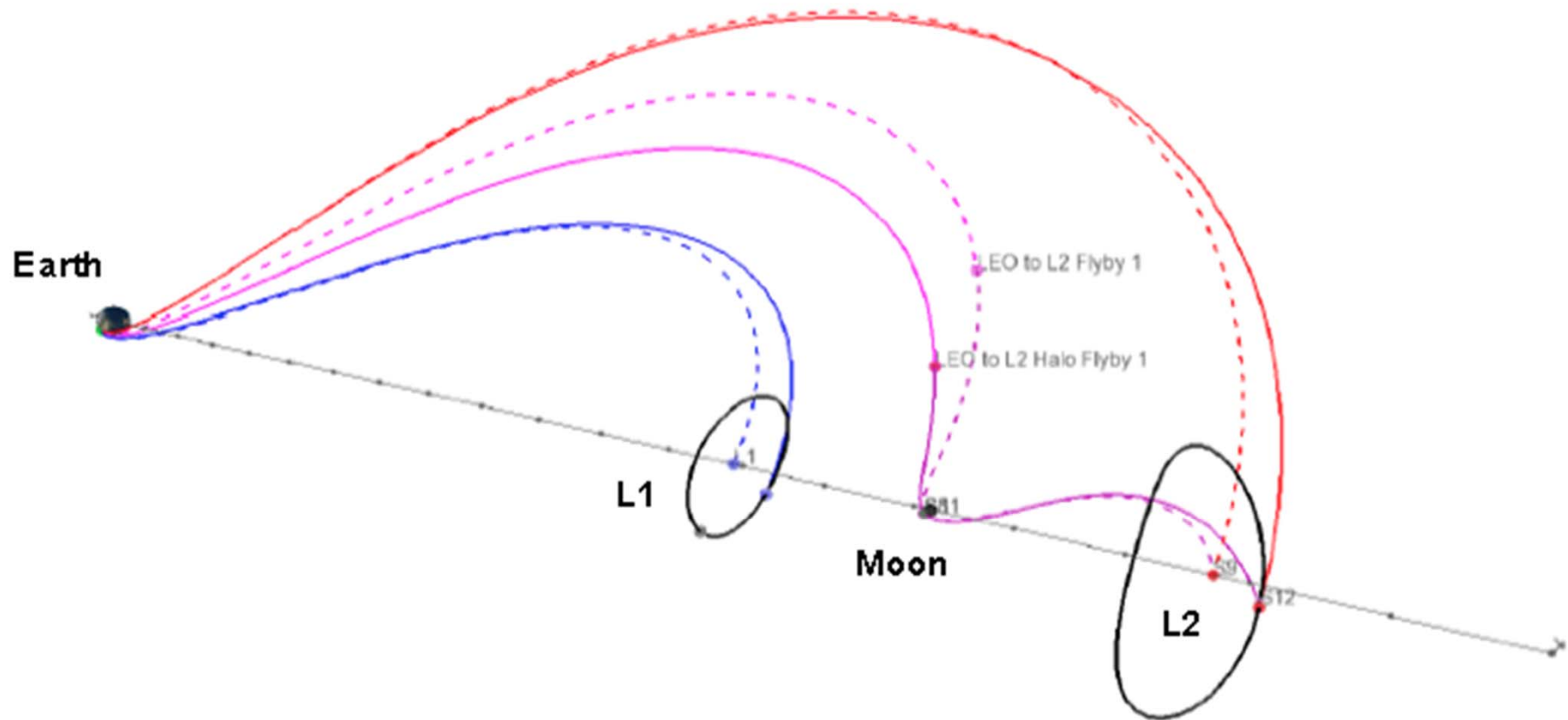


## Second Test: L2 Waypoint Mission

- 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

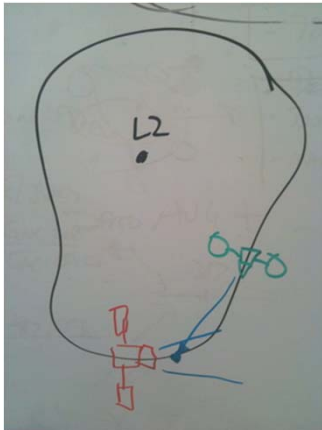


# Waypoint Scenario Development

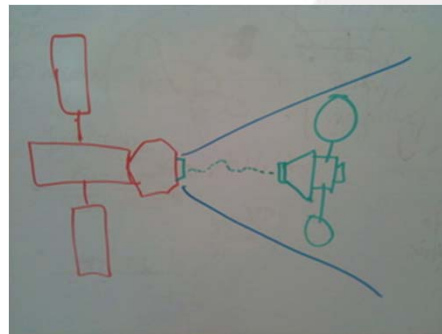


test\_9\_flyby.ideck

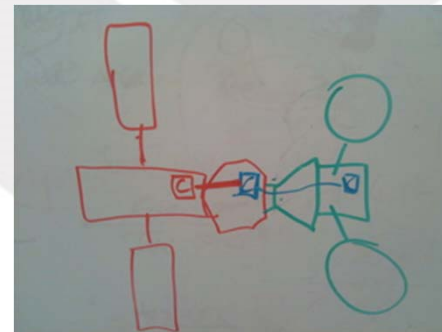
## Orion AR&D with Vehicle at Earth/Moon L2



Rendezvous in L2 Halo Orbit

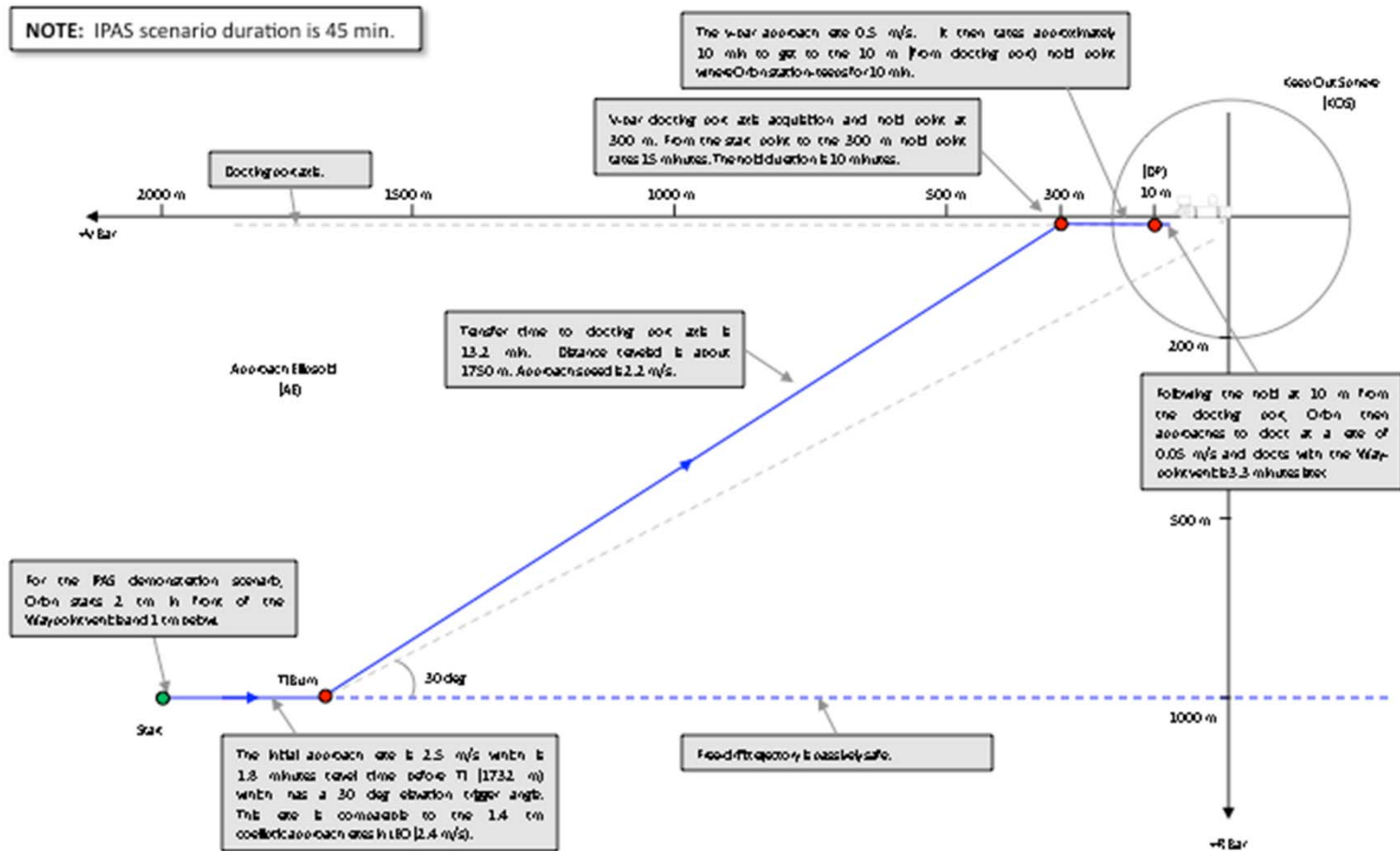


Proximity Operations

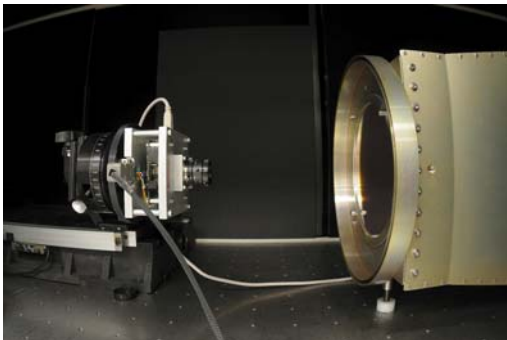
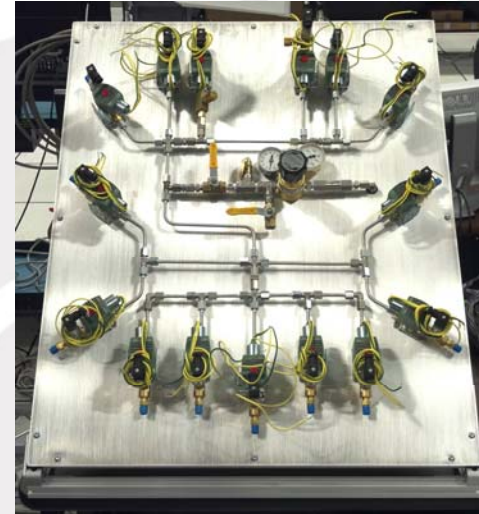
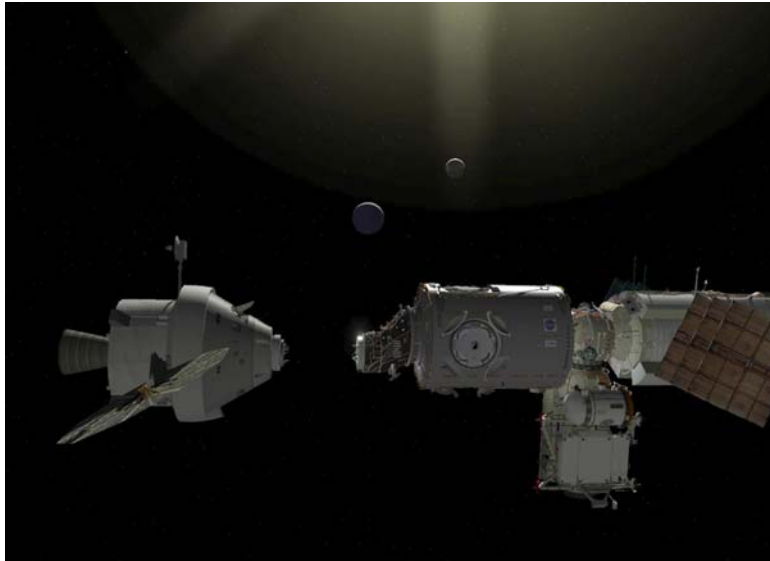


Dock

# AR&D Trajectory

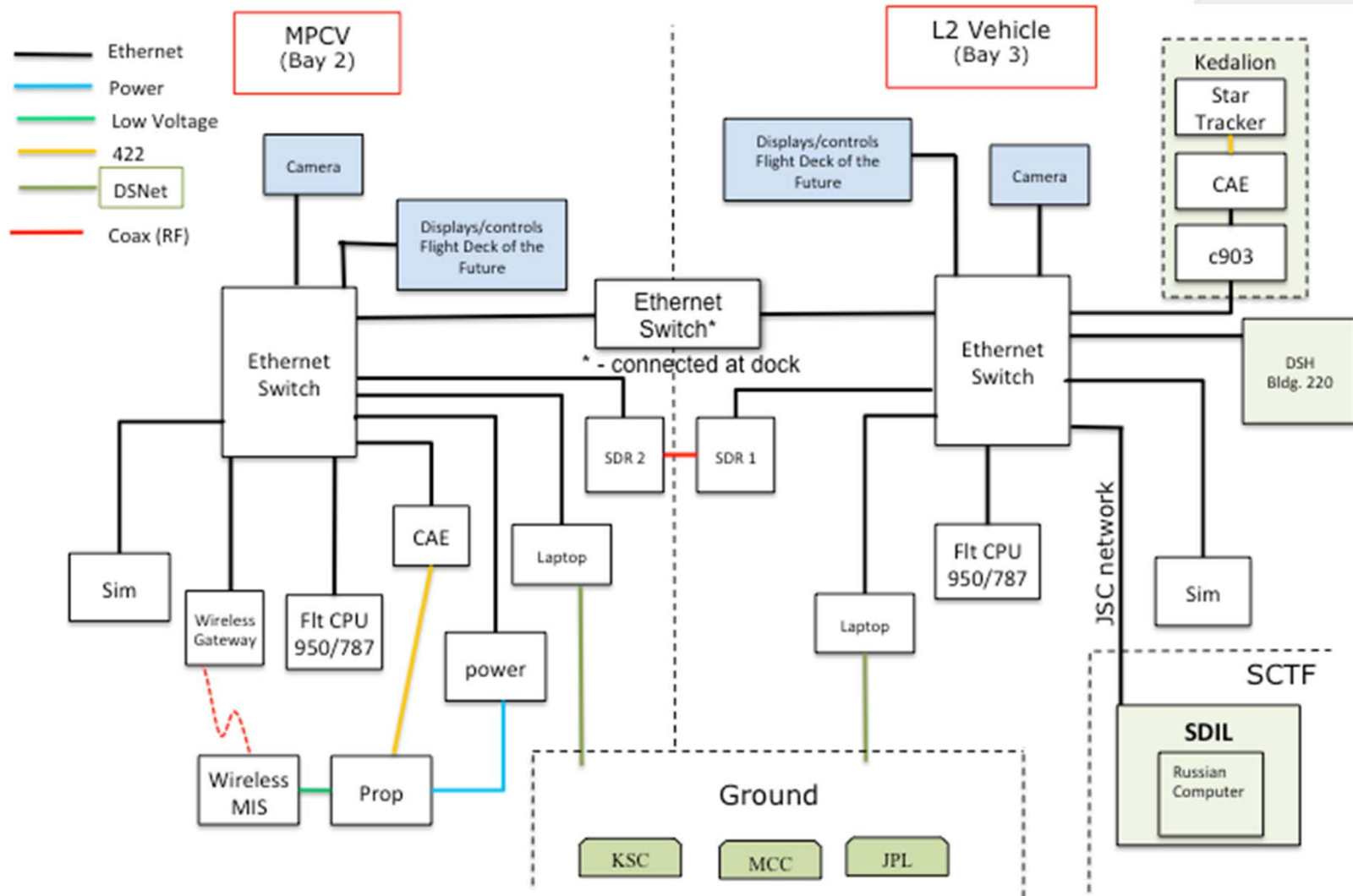


## MPCV AR&D with vehicle at L2



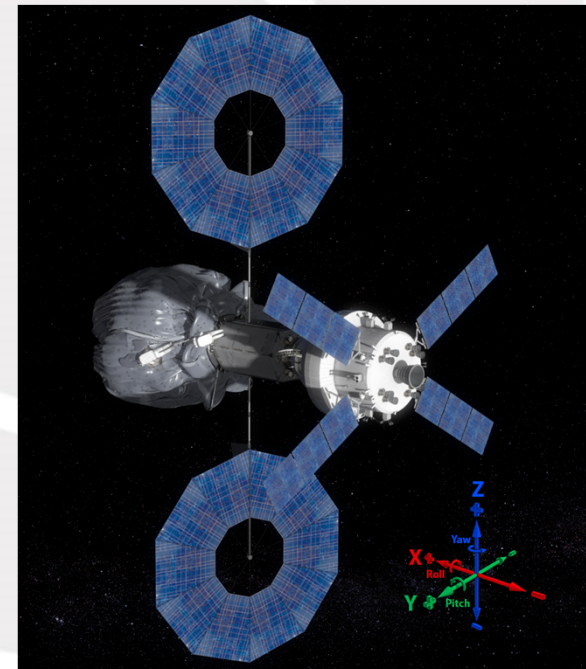


# Test Architecture



## 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

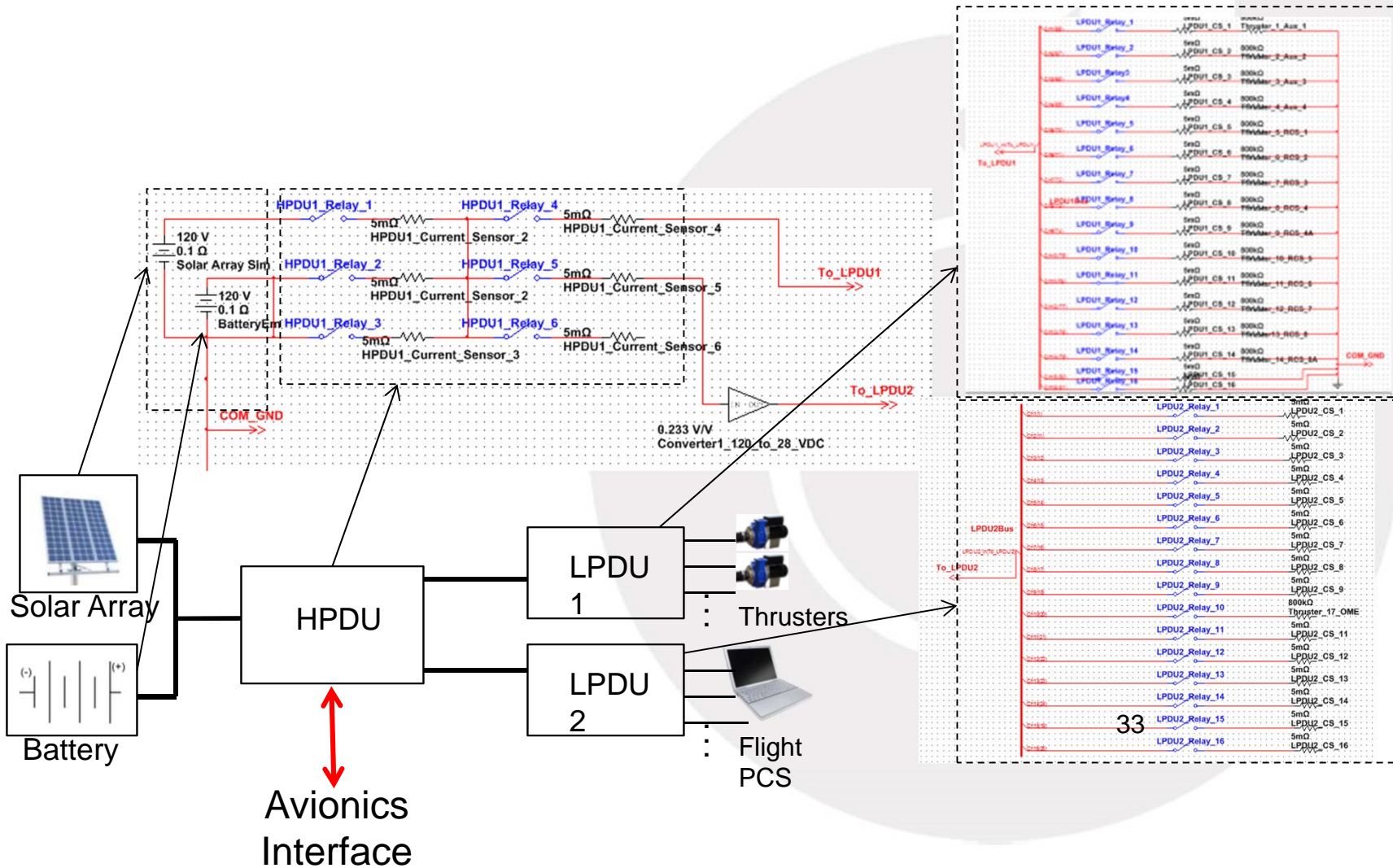


## New Methods for System Engineering and Integration

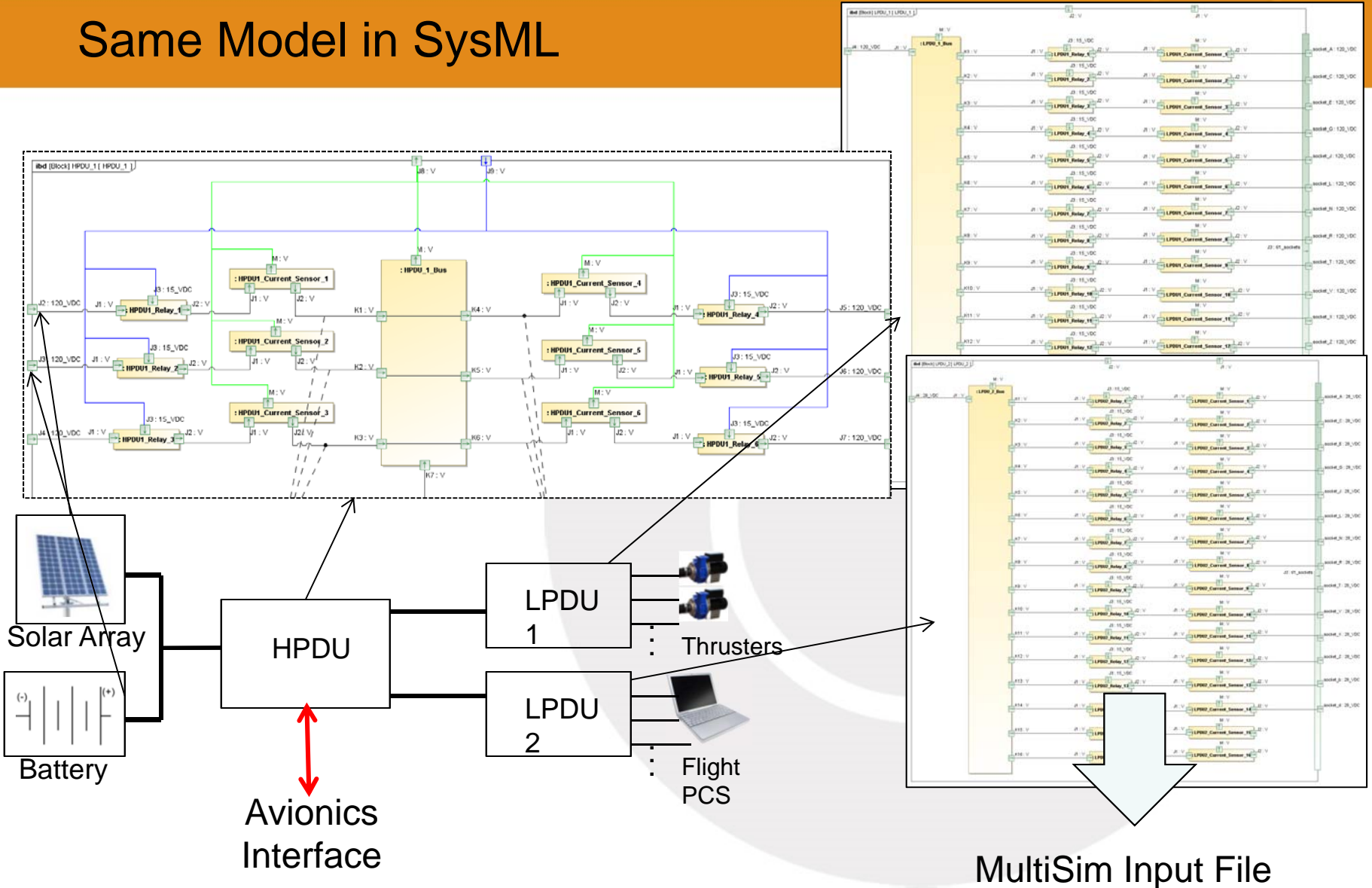
- Model Based Engineering
  - Analysis tools that support design and development
- Model Based System Engineering
  - Environment that supports analysis of multi-discipline integration
- Model Application
  - Requirements and sizing: Mission Planning
  - Design and Development: Describe systems
  - Analysis: 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





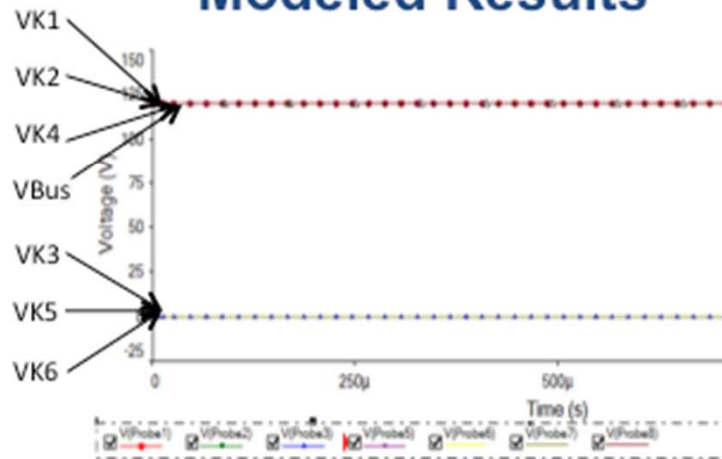
# Test Demonstration in iPAS



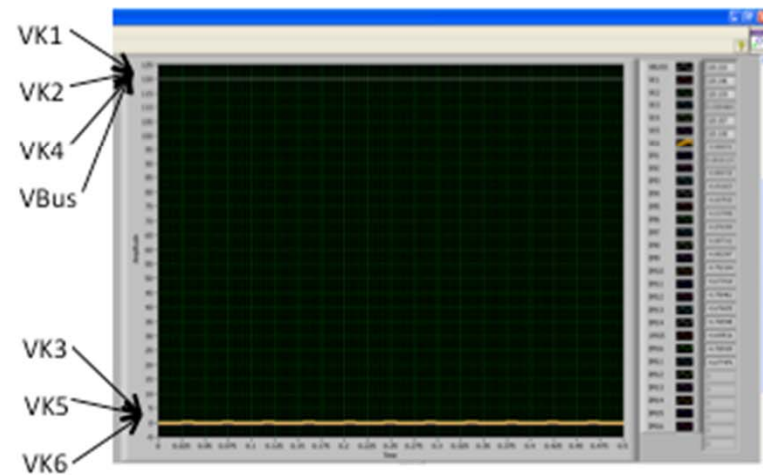
## Expected Results

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		

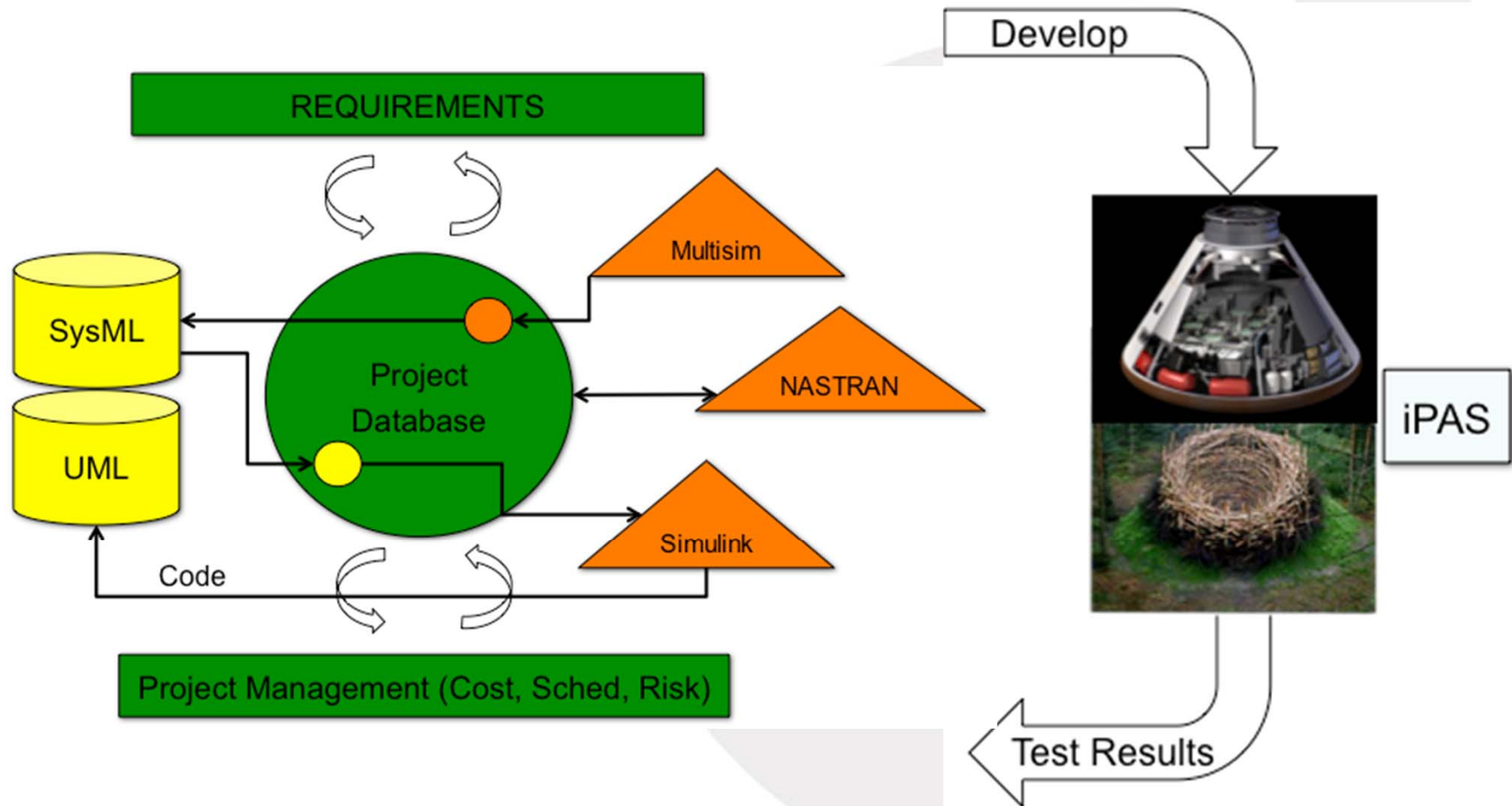
## Modeled Results



## Actual Results



# Product Development and Test



Establish iterative loop between Models and Products





*The World's Forum for Aerospace Leadership*