iPAS: AES Flight System Technology Maturation for Human Spaceflight

Bill Othon
NASA/Johnson Space Center

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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
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
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  - The Process: 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
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
iPAS Floorplan: Multiple, Parallel Development Teams

- Test Day #1: ARM
- Test Day #2: Orion
- Test Day #3: WayPT

- iPAS
  - Mini-Dome
  - AMPS
  - EAM

- Power Distribution
- Manufacturing (EFMF)
- Building 29 Rotunda

- Flight Deck (2nd Floor)
- Water Lab

- UPCs
  - iPAS TOC (ITOC)
  - iPAS Server Room
Design, Development, Test, and Evaluation (DDTE)
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Federated Labs

iPAS

Federated Labs
Co-located Technology Maturation

Avionics
- Processors
- Networks
- Wireless
- Comm

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

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

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

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

- **Ames**
  - Autonomous Mission Ops
  - Information Architecture

- **Glenn**
  - AMPS

- **Langley**
  - Avionics
  - Engineering observation during test

- **JPL - PTL**
  - Deep Space Network
  - Delay Tolerant Network

- **Goddard**
  - Core Flight Software
  - Interface Standards

- **JSC - MCC**
  - Telemetry and Comm with Mission Ops

- **KSC - LCC**
  - Launch Control emulator
  - On-pad Vehicle Communication
Federation of Labs: Integrated, Distributed Testing

iPAS

Kedalion

ESTA

OTF/MC C

ESTL

ECLSS

Flight System

Vehicle Development

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
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, Centers

- **Developed 4 Month Sprint**
  - Identify elements in hand (McGyver)
  - Incrementally add hardware and software
  - Show integrated test
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
Orion AR&D with Vehicle at Earth/Moon L2

Rendezvous in L2 Halo Orbit

Proximity Operations

Dock
AR&D Trajectory

**NOTE:** IPAS scenario duration is 45 min.

- The initial approach rate is 2.5 m/s which is 1.8 minutes total time before T1 (173.2 m) which has a 30 deg elevation edge angle. This rate is comparable to the 1.4 cm conic trajectory rate in 1/6G (5.4 m/s).
- The transfer time to docking port is 13.2 min. Distance traveled is about 1750 m. Approach speed 2.2 m/s.
- Following the node at 30 m from the docking port, Orbin then approaches to dock at a rate of 0.05 m/s and docks in the Waypoint at 0.3 minutes after.
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

Solar Array

Battery

Avionics Interface

HPDU

LPDU 1

LPDU 2

Thrusters

Flight PCS

To_LPDU1

120 V 0.1 Ω Solar Array Sim

120 V 0.1 Ω Battery Sim

0.233 VV Converter1_120_to_28_VDC

Avionics Interface
Same Model in SysML

Solar Array

Battery

Avionics Interface

HPDU

LPDU 1

LPDU 2

Thrusters

Flight PCS

MultiSim Input File
Test Demonstration in iPAS

Expected Results

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Modeled Results

Actual Results
Establish iterative loop between Models and Products