

Progressive Autonomy for Optimized Mission Design and Operations

**Considerations for the
International Space Station
and Future Programs**

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Presentation Overview

- Overarching Autonomous Systems Goals
- High-level Decision Points
- Technical Obstacles
- Selected Trade Study Highlights
- Validating Technologies and Approaches
- Cultural Challenges

For manned spaceflight programs



ISS Mission Control Operations



Overarching Autonomous Systems Goals

- **Optimized Human Roles**
 - **Optimized System Roles**
 - **Aligned Operations Concepts**
 - **Aligned Operations Culture**
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- **Autonomy decisions are fundamental to overall mission design. Leveraging the capabilities that intelligent systems match or surpass over humans enables optimized human and system performance, drives (and in some cases restricts) the operations paradigm, and helps mold the Program's culture.**



High-level Decision Points

- **Reaction time versus communication latency**
- **Subject Matter Expert required for other tasks**
- **Autonomy lifecycle costs versus more personnel**
- **Engineering or structural barriers**
- **Human control inherently unsafe**
- **Crew availability to execute task**



High-level Decision Points continued

- **Reliability of Current Systems**

- **Program Descope**

- **Initial Design**

Late autonomy infusion can have an extensive impact on mission design, affecting a wide range of mission resources including

- **People, processes, procedures, tools**
- **Hardware, software, communications, ConOps**
- **Certifications, training, planning/scheduling**



Technical Obstacles

- **Data overload**
- **Highly dynamic environment**
 - Physical configuration changes (ISS construction, docked Shuttle or Progress, etc.)
 - Physical parameter changes (attitude, Russian or US systems in use, SSRMS in motion, etc.)
 - Crew effects (# of crew, crew changeover, exercise, etc.)
- **Current system limitations**
 - Required data not available due to bandwidth or onboard storage limitations, lack of dynamic downlist
 - Absence of sensors in critical locations



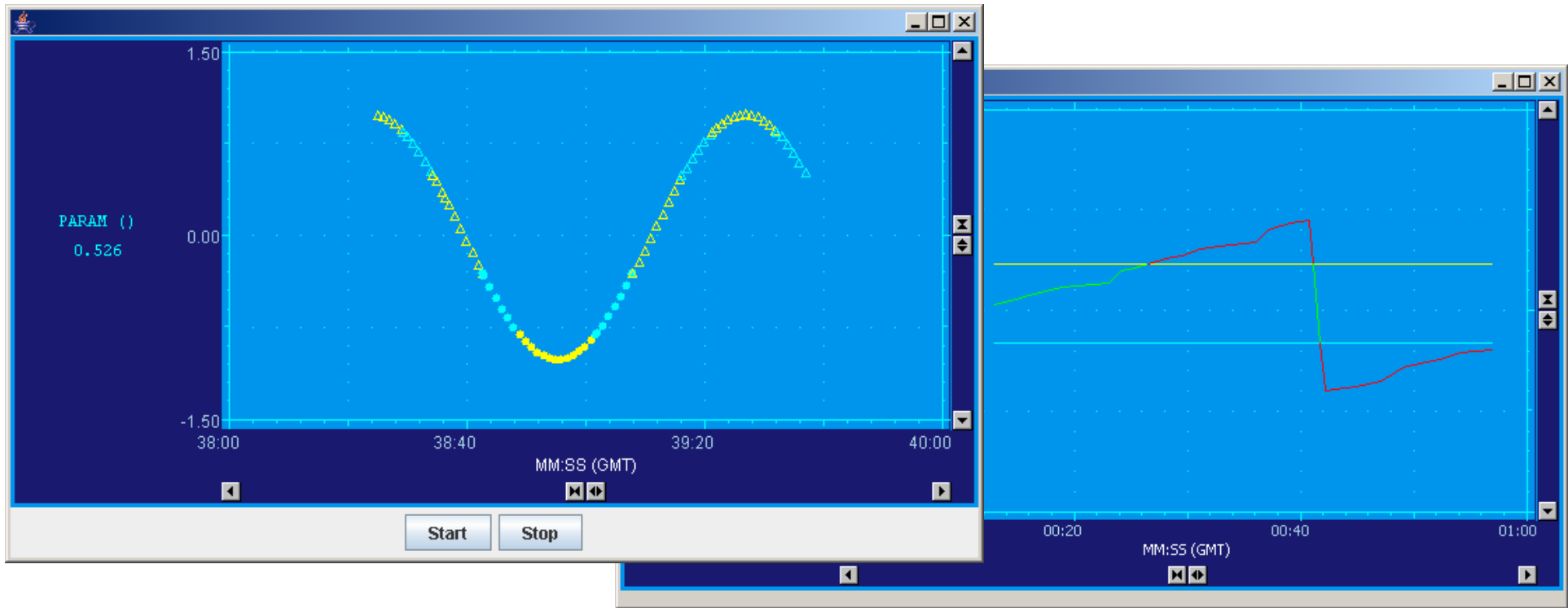
Selected Trade Study Highlights

- **FDIR (all Systems, many items)**
 - **Electrical Power Systems (loadshed)**
 - **GN&C (attitude maneuvers)**
- **Automated Commanding**
- **Onboard Crew Planning**
- **Flight Controller Training Systems**
- **Automated Rendezvous/Proximity Operations/Separation**



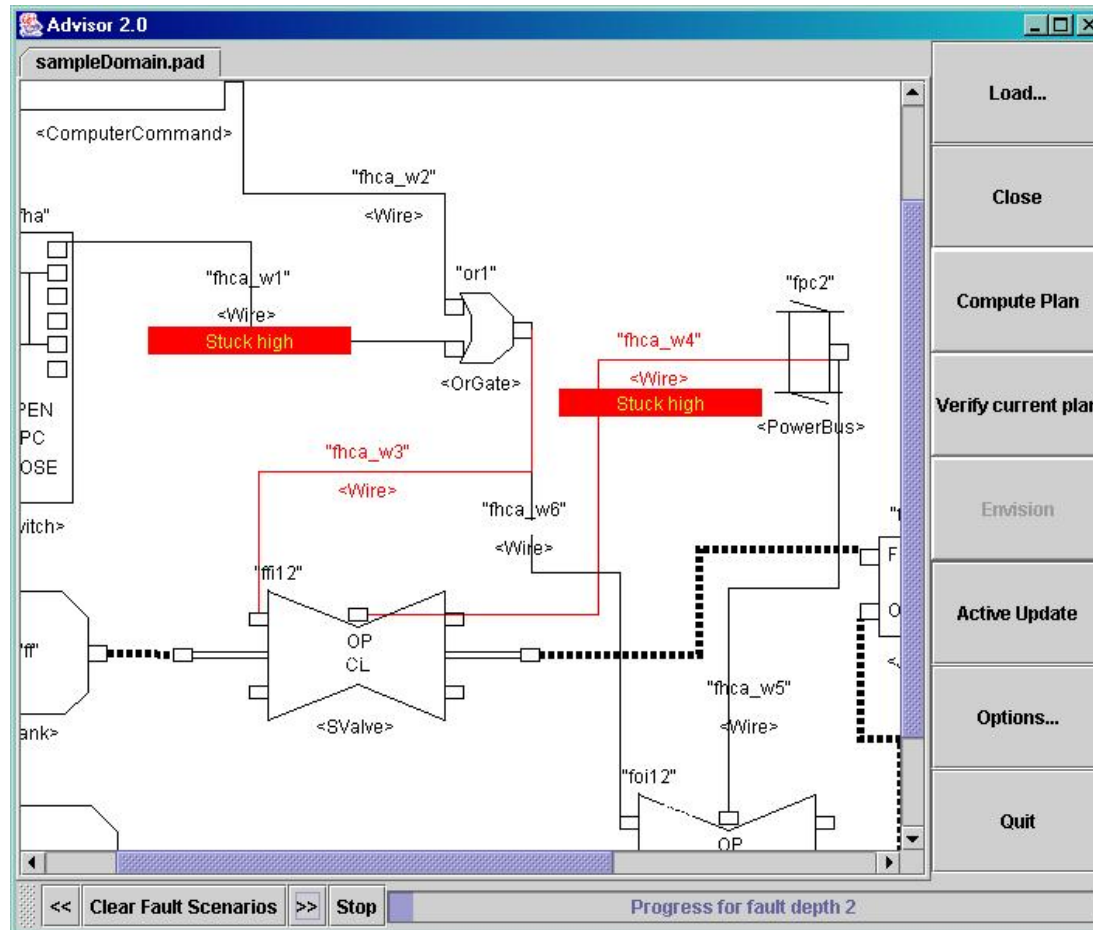
Validating Technologies and Approaches I

- Novelty Detection
- Failures Within Limits
- Detecting Nominal Change



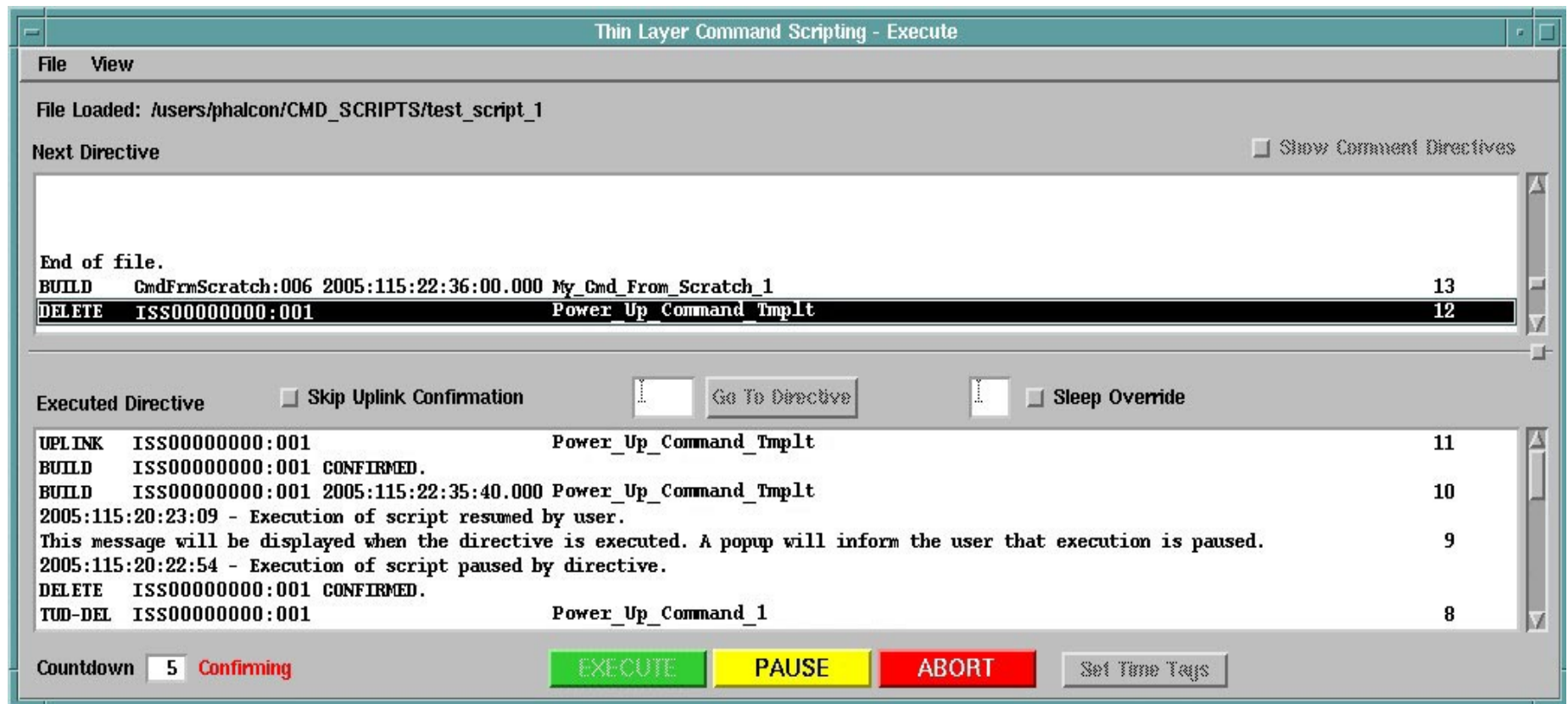
Validating Technologies and Approaches II

- Reasoning & Planning w/ Multiple Failures



Validating Technologies and Approaches III

- Automated Commanding



Validating Technologies and Approaches IV

- Automated Commanding

Template Create (from Command Inventory)

CIPUI: ISS000000 Ops Name: Power_Up_Device

| SPUI | Parameter Name | Value | Units | Range |
|--------------|----------------|-----------------|--------------------------|----------|
| | | | | Picklist |
| ISS000000_01 | ID | 0 | | |
| ISS000000_02 | Location | 1 - See CDHF | Command Bus Identificati | Picklist |
| ISS000000_03 | Sequence | 25 | N/A | 1 to 30 |
| ISS000000_04 | Type | 1 - RT Transmit | Transmit/Receive | Picklist |
| ISS000000_05 | Mode | 0 | N/A | |
| ISS000000_06 | Count | 2 | N/A | 0 to 31 |

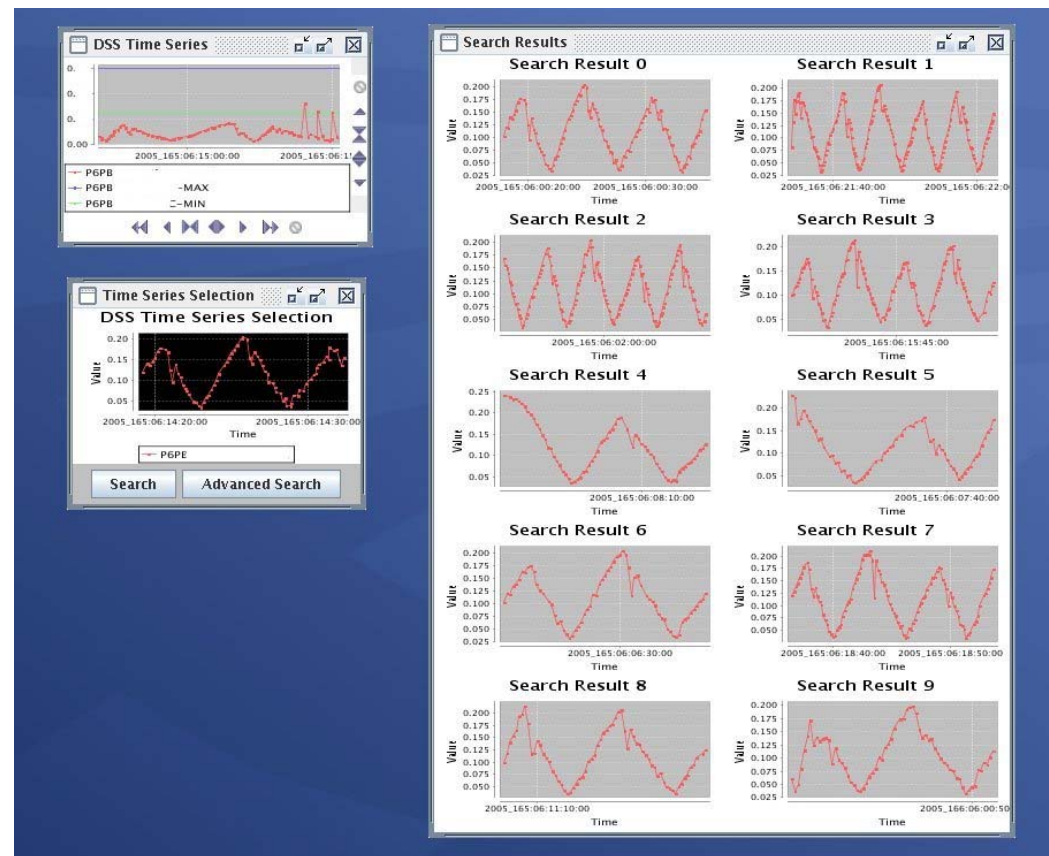
Replace Instance Create New Instance Exit Help



Validating Technologies and Approaches V

- **Knowledge Fusion Architecture:
Integrating Context with Data**

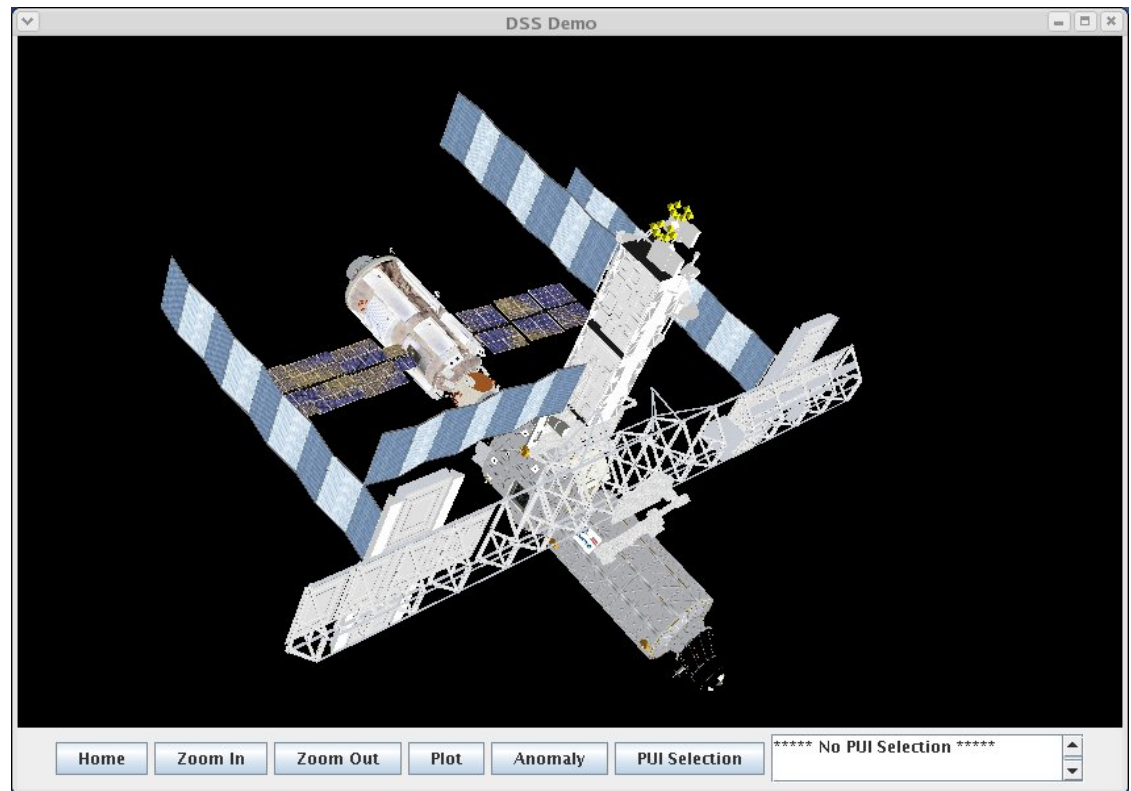
- **Ontological-Event
Driven Search**
- **Time Series Search
(JPL-led collaboration)**



Validating Technologies and Approaches VI

- **Data Summarization for Enhanced Operations Concepts**

- Overlaid, visual temporal and spatial information (JPL-led collaboration)
- Dimensionality reduction techniques



Cultural Challenges (onboard and ground)

- Fear of loss of expertise in systems
- Fear of over-reliance on tools
- Team communication and behavior changes
- Loss of status or sense of accomplishment
- Trust hierarchy: human or system?



Progressive Autonomy to Effect Change

- For future mission designs
- For emerging operations concepts
- To support the Vision for Exploration

