Distributed Simulation for Space Exploration

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Overview

- Simulation of Space Based Systems
- Integrated Modeling and Simulation (IM&S)
- Distributed Simulation at NASA
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- The DSES Project
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- Looking Ahead
- Questions
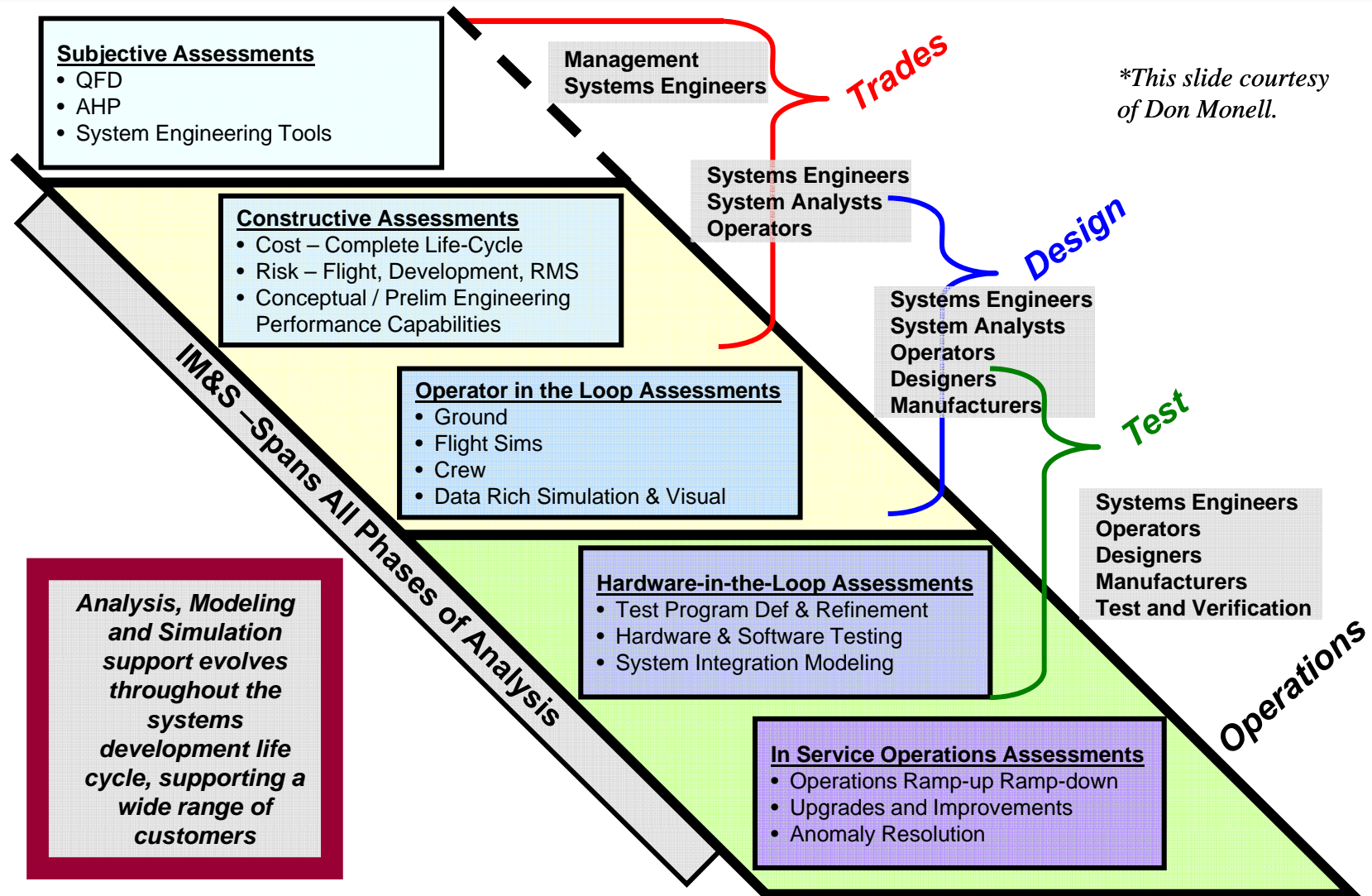
Simulation of Space Based Systems

- Space flight and its associated sciences, technologies, systems and operations are complex and often dangerous.
- Simulation is a potent method that NASA uses to:
  - investigate complex systems
  - reduce risk
  - reduce cost
  - train personnel in complex and dangerous tasks
  - and more . . .
- Every organization at NASA depends on simulation in one form or another.
- NASA employs many different types of simulation.
- The Exploration Systems Mission Directorate's (EMSD) Integrated Modeling and Simulation (IM&S) team is tasked to coordinate the simulation activities for NASA's Exploration Initiatives.

Simulation of Space Based Systems
The Systems Development Life Cycle

Subjective Assessments
- QFD
- AHP
- System Engineering Tools

Constructive Assessments
- Cost – Complete Life-Cycle
- Risk – Flight, Development, RMS
- Conceptual / Prelim Engineering Performance Capabilities

Operator in the Loop Assessments
- Ground
- Flight Sims
- Crew
- Data Rich Simulation & Visual

Hardware-in-the-Loop Assessments
- Test Program Def & Refinement
- Hardware & Software Testing
- System Integration Modeling

In Service Operations Assessments
- Operations Ramp-up Ramp-down
- Upgrades and Improvements
- Anomaly Resolution

Management
Systems Engineers

Trades

Systems Engineers
System Analysts
Operators

Design

Systems Engineers
System Analysts
Operators
Designers
Manufacturers

Test

Systems Engineers
Operators
Designers
Manufacturers
Test and Verification

Operations

This slide courtesy of Don Monell.

IM&S –Spans All Phases of Analysis

Analysis, Modeling and Simulation support evolves throughout the systems development life cycle, supporting a wide range of customers
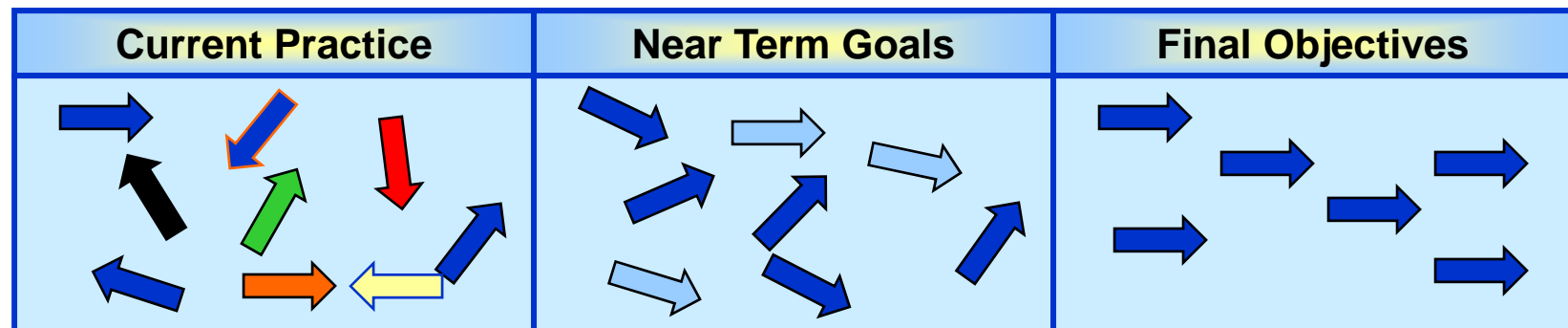
Integrated Modeling and Simulation

- The Exploration Systems Mission Directorate (EMSD) Integrated Modeling and Simulation (IM&S) team is tasked to coordinate the simulation activities for NASA's Exploration Initiatives.

- NASA is developing an Integrated Modeling and Simulation strategy to coordinate the simulation developers and simulation customers with Exploration objectives.

Current Practice	Near Term Goals	Final Objectives

Integrated Modeling and Simulation
(Continued)

- The IM&S strategy encompasses a wide spectrum of simulation and modeling policies and technologies.
- One prominent policy is collaboration through simulation exchange and model sharing:
  - Simulation exchange: Projects are encouraged to seek out and use applicable simulations from other projects and centers before creating new simulations.
  - Model sharing: Standards and processes are being specified to encourage the exchange of models between projects and centers.
- One prominent technology is distributed simulation
  - While this does not have to be collaborative, collaboration is encouraged.

Distributed Simulation at NASA

- Distributed Research Locations
  - 10 NASA Centers
  - International Partners
- Distributed Human Resources
  - Science and engineering domain expertise
  - Software engineering and programming expertise
  - Computer and network engineering expertise
- Distributed Computer Resources
  - Thousands of Computers
  - Dedicated High Speed Computer Networks
- Distributable Problems
 - Systems with well defined interfaces
  - Simulation domains with separable dynamics
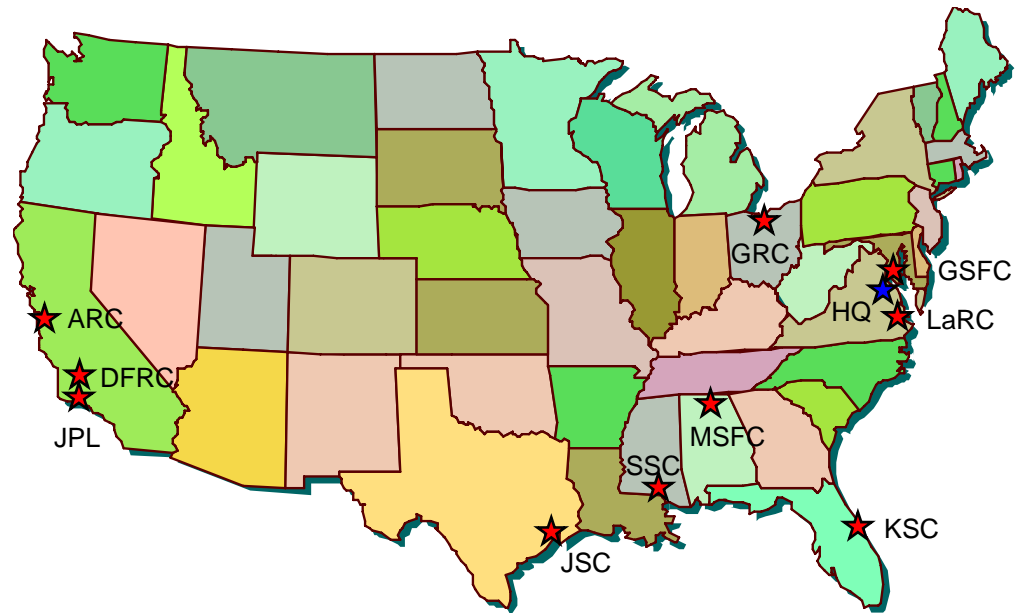
|	
ARC - Ames Research Center	JSC - Johnson Space Center
DFRC - Dryden Flight Research Center	KSC - Kennedy Space Center
GRC - Glenn Research Center	LaRC - Langley Research Center
GSFC - Goddard Space Flight Center	MSFC - Marshall Space Flight Center
JPL - Jet Propulsion Laboratory	SSC - Stennis Space Center

Distributed Simulation in Action

- The DIstributed Simulation (DIS)* is a collaborative simulation project with international participation (US and Japan).
  - The DIS simulation consists of two principal components:
    - International Space Station (ISS) which runs in Houston, Texas, and
    - HII Transfer Vehicle (HTV) which runs in Tsukuba, Japan.
- This simulation will support flight controller procedure development and training.
- This simulation has been successfully demonstrated and is in the final phases of development. It is scheduled for deployment in late 2007 or early 2008.

JAPAN

JAXA/Tsukuba

JSC/Houston
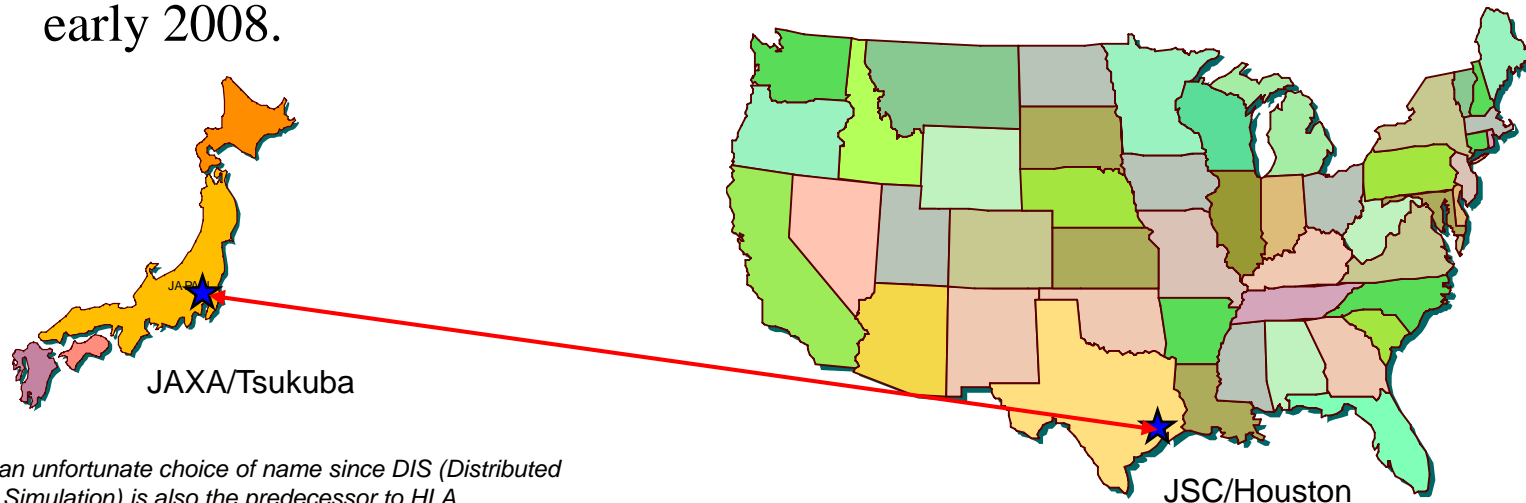
DIS was an unfortunate choice of name since DIS (Distributed Interactive Simulation) is also the predecessor to HLA.
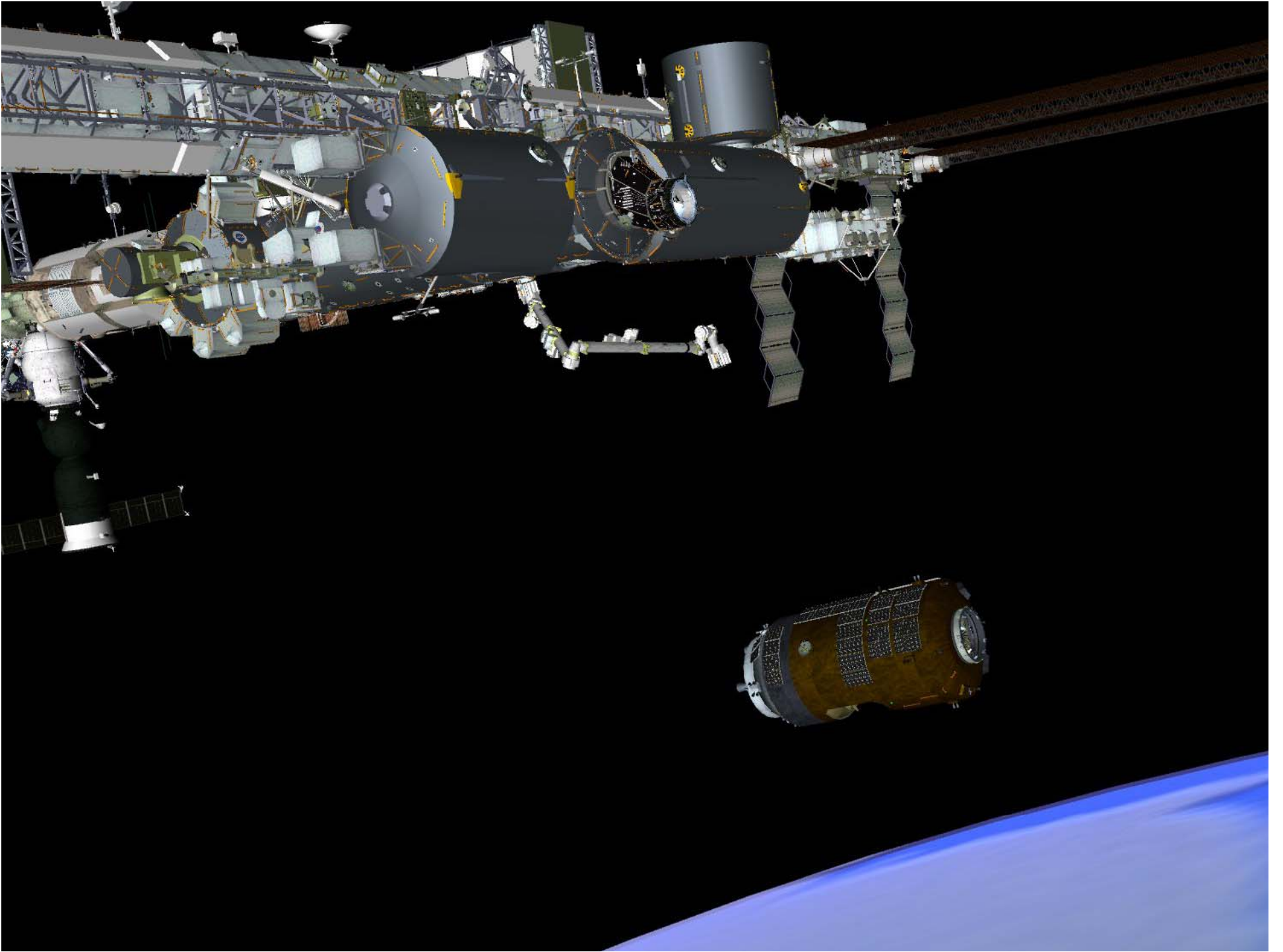
Distributed Simulation in Action
## *(Continued)*

- The preceding image and the two images below are scenes generated from the DIS simulation.

  – In these images, the ISS state is being propagated in Houston, Texas and the HTV state is being propagated in Japan.

  – These simulations are connected via HLA over an ISDN line.

  – This simulation supports high rate contact interactions with the SSRMS using the HLA ownership transfer mechanism.

- The Distributed Space Exploration Simulation (DSES) is a research and development collaboration between NASA centers which focuses on the technologies and processes related to the collaborative (and in this case, distributed) simulation of complex space systems in support of NASA's Exploration Initiative.
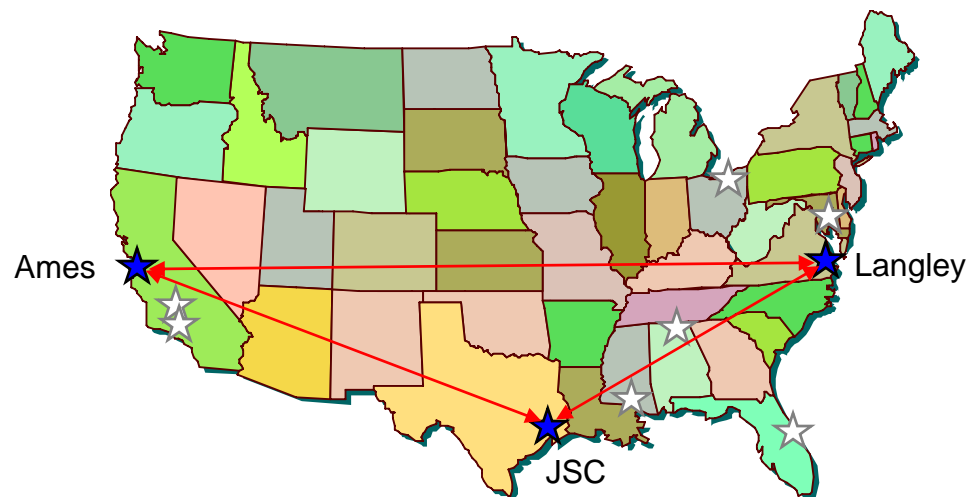
The DSES Project
NASA Center Collaboration

- A number of NASA centers are actively participating in DSES:
  - Ames Research Center (ARC): *Mike Blum*
  - Johnson Space Center (JSC): *Edwin Z. Crues*
  - Langley Research Center (LaRC): *Victoria Chung*
- The project would like to include other interested organizations as our development and investigations progress
  - NASA centers like JPL, Marshall, Goddard, etc.
  - Exploration Initiative team members

The DSES Project
Establishing Network Connections

- In the process of establishing a NASA Distributed Simulation Network (NASA DSNet)
  - Have established moderate bandwidth network connectivity between participating centers
  - Have recently established a NASA Integrated Services Network (NISN) Private Virtual Circuit (PVC) between the participating NASA centers (10Mbs)
  - Collecting and developing tools for network analysis and testing for simulation execution preparation and support

The DSES Project
Building Computational Infrastructure

- Computational Hosts
  - Have successfully installed and configured a collection of computers at ARC, JSC and LaRC
- Using institutional simulation tools
  - Trick (JSC)
  - LaSRS++ (Langley)
- Using institutional simulation models
  - JSC EA Common Model Set (Trick based)
  - LaSRS++
- Using a commercial HLA Run Time Infrastructure
  - Pitch 1516 RTI
- Establishing a defined process and tolerances for matching orbital dynamic state propagation.

- Model Sharing
  - Ames incorporating JSC's gravity model
  - JSC incorporating Langley's aerodynamics model
- Successfully tested network connectivity and performance using the Iperf tool
  - Established three way NISN PVC connection: Ames, JSC, & Langley
  - Observed some performance issues
- Successfully tested initial HLA based distributed applications
  - Simple Pitch Chat Federation
  - Simple 6 DOF Space Vehicle Federation
- "Matched" orbital environment and dynamics modeling

Looking Ahead

- Still working DSNet performance issues with NISN
- Continue development of prototype simulation
  - Multi-vehicle (i.e. CLV, CEV, and ISS)
  - Realistic operational scenario (i.e. CLV launch, CEV rendezvous, approach and docking to ISS)
  - Further develop Space Vehicle Federation Object Model (SV-FOM)
- Characterize distributed simulation performance
- Developing more generalized HLA connectivity with Trick based simulations
- Investigate non-HLA distributed simulation technologies: TENA, Trick, XMPP, etc.
- Develop meaningful NExIOM interfaces
- Assess suitability for application to exploration class simulations
- Establish a suitable generalized distributed simulation architecture

Looking Ahead
Integrating Distributed Resources

Constellation Integration

Distributed simulation provides early integration capabilities that lead to early test and verification opportunities.
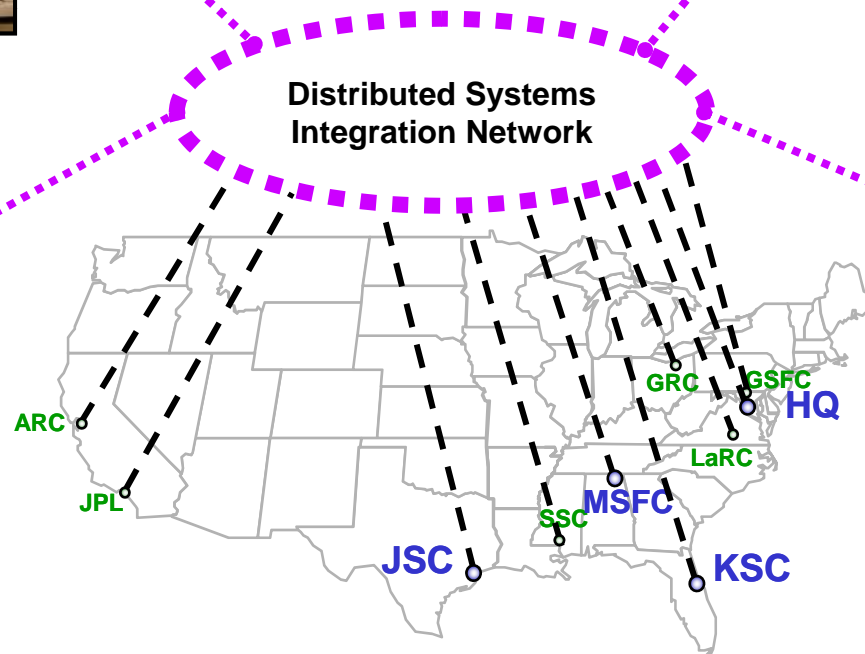
Lunar Segment

Distributed Systems Integration Network

In-Space Segment

Launch Segment

ARC
JPL
GRC
GSFC
HQ
LaRC
SSC
MSFC
JSC
KSC

Questions?

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