National Aeronautics and Space Administration

On-orbit Servicing Assembly and Manufacturing (OSAM) Workshop

Technologies, Partnerships, and Opportunities

ENABLING SPACE INFRASTRUCTURE

LaRC Modeling and Simulation Developments for OSAM

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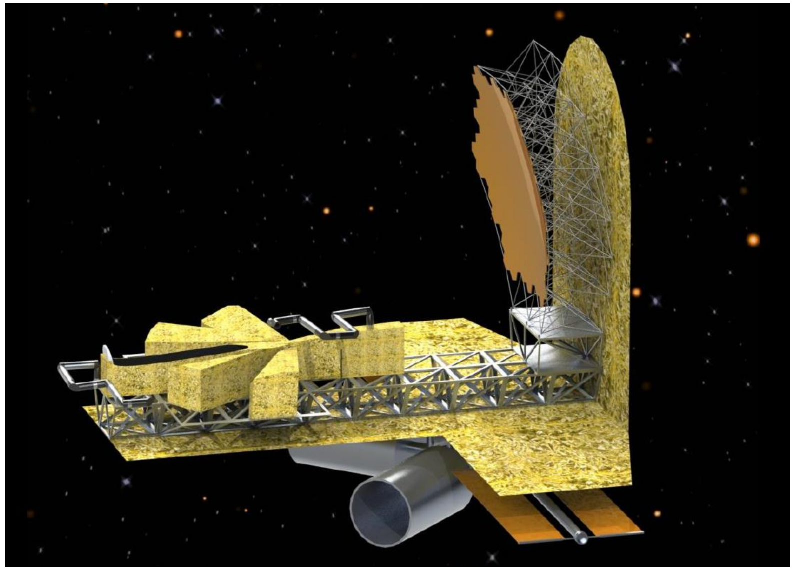
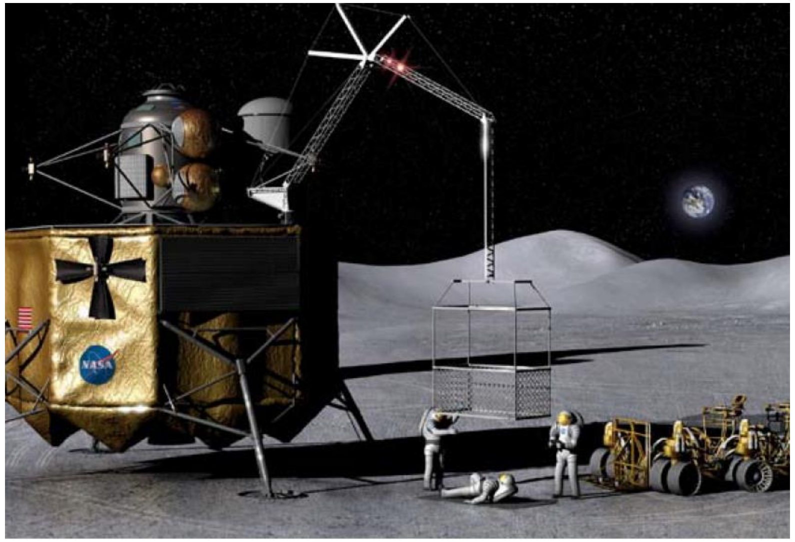
ON-ORBIT SERVICING, ASSEMBLY, AND MANUFACTURING

Objectives of LaRC Modeling and Simulation for OSAM

ON-ORBIT SERVICING, ASSEMBLY, AND MANUFACTURING

- Predict performance of spacecraft in the space environment
  - Performance changes to spacecraft over lifespan (e.g. including past original plans for persistent assets)
- Verification and Validation of Concepts, Designs, and Orbital Performance
  - Assembly concepts
  - Autonomy algorithms
  - Structural performance (including joining mechanisms)
  - Metrology system performance
  - GNC performance (e.g. spacecraft mass properties changes over lifespan)
- Develop a toolbox of modular and reusable validated software components
  - Individually validated with laboratory and in-space testing
    - Continuous models updates based on data from laboratory and in-space hardware tests
  - Combine components to predictively simulate larger structures, alternative algorithms, etc.
- Target applications of modeling and simulation for OSAM
  - Overall spacecraft performance (predictive validation or digital twin)
  - Concept simulations for early design phases
  - Assembly supervisory simulation
    - E.g. presenting assembly progress information and status to a human supervisor

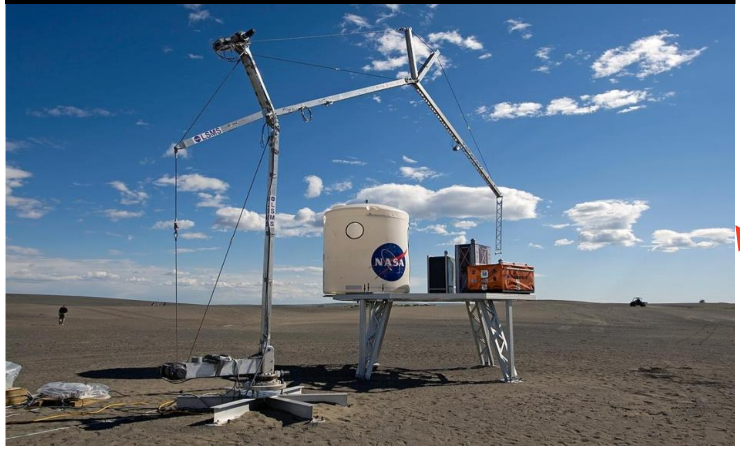




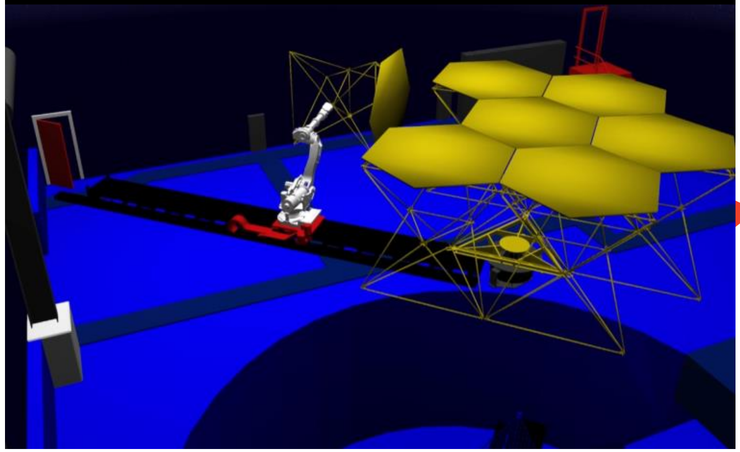
OSAM Collaboration at Langley

ON-ORBIT SERVICING, ASSEMBLY, AND MANUFACTURING

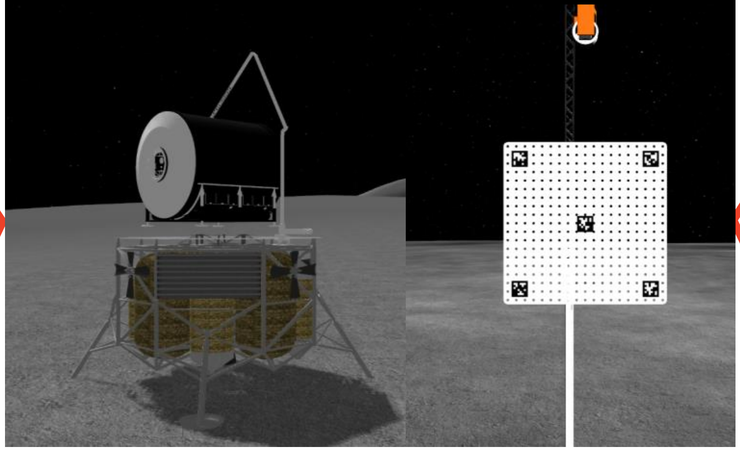
STRUCTURES AND MECHANISMS



AUTONOMY

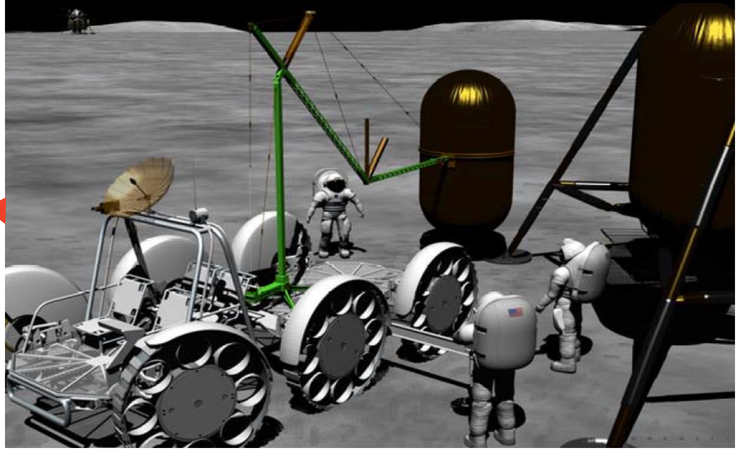


MODELING AND SIMULATION



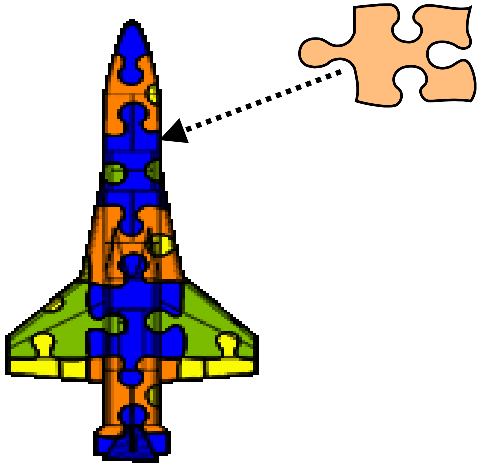
MATERIALS

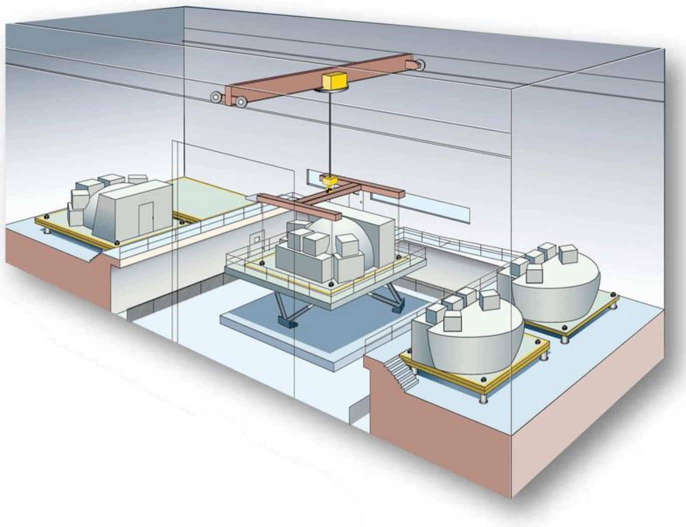
SYSTEMS ANALYSIS



Langley Standard Real-time Simulation in C++ (LaSRS++)

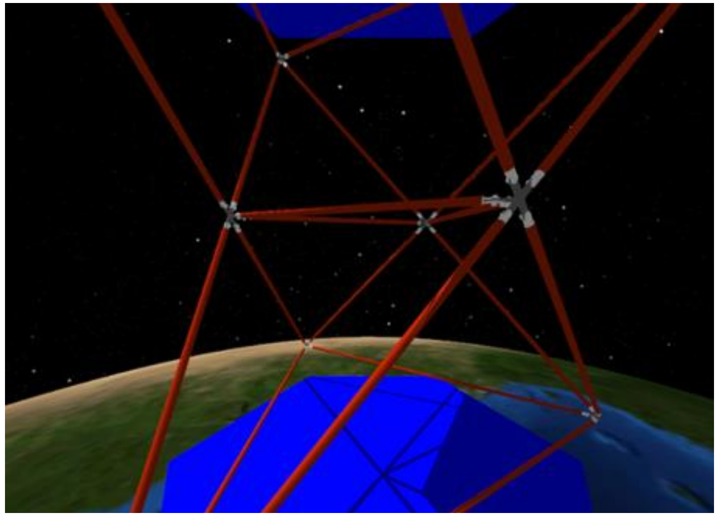
- Used at NASA Langley for over 20 years
- Adapted from previous LaSRS framework with a focus on object-oriented design to increase modularity and re-usability of code
- Capable of hard real-time operation with hardware-in-the-loop, desktop, and fast-time simulations
  - Designed with Sim-to-Flight philosophy where software components work within simulations and on ship systems (flight hardware).
- Prior six degree-of-freedom dynamics-based spacecraft simulations include: Ares I-X, Sierra Nevada Dream Chaser, HL-20, Orion Crew Capsule, Mars airplane, Apollo, Altair, and Spacecraft Handling Qualities Studies
  - Currently simulating HLS Lunar Landers for lunar operations

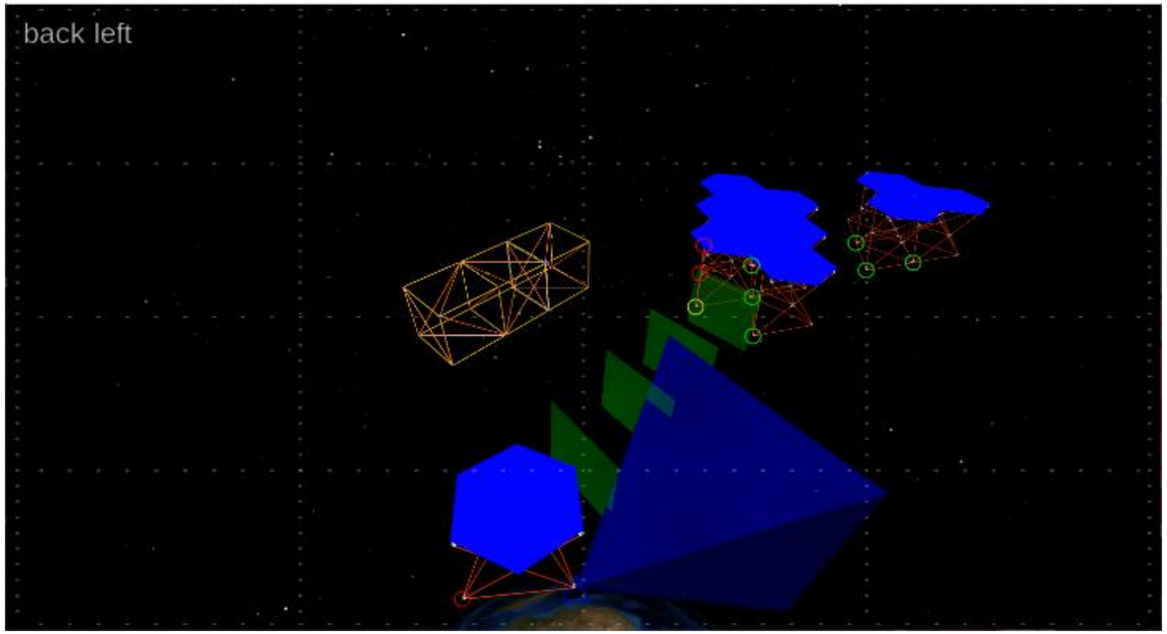


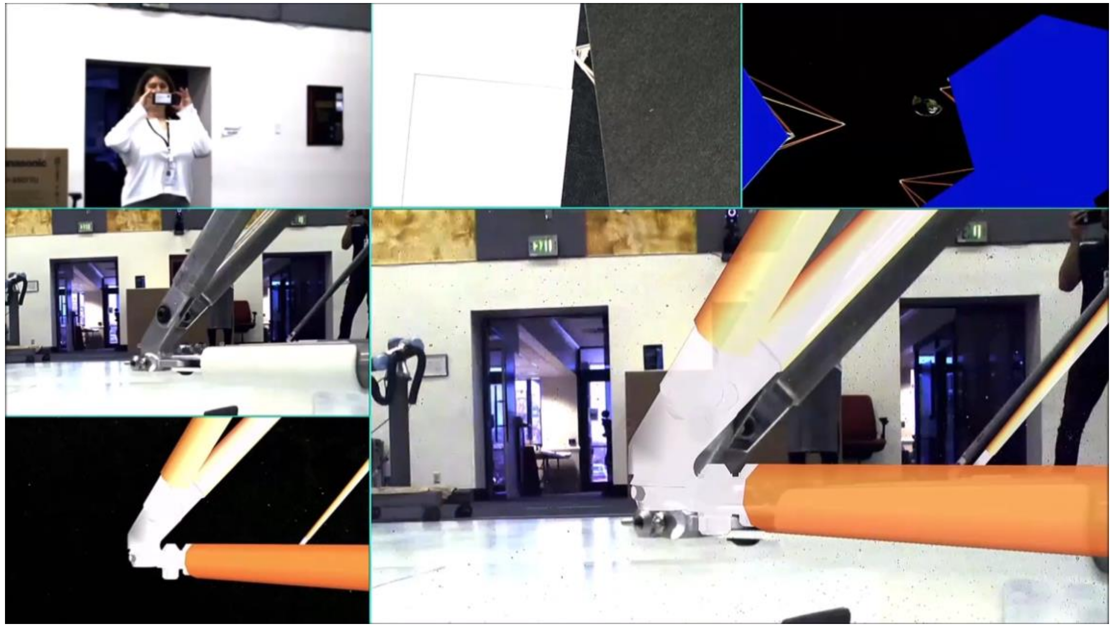


Robotic Assembly of Modular Space Exploration Systems (RAMSES)

- Sensor/fiducial modeling and data visualization
- Trajectory visualization
- Visual sensor simulations
- Data sharing between Mod/Sim and Autonomy Frameworks
  - Multiple spacecraft component state data
  - Data Distribution Service (DDS)

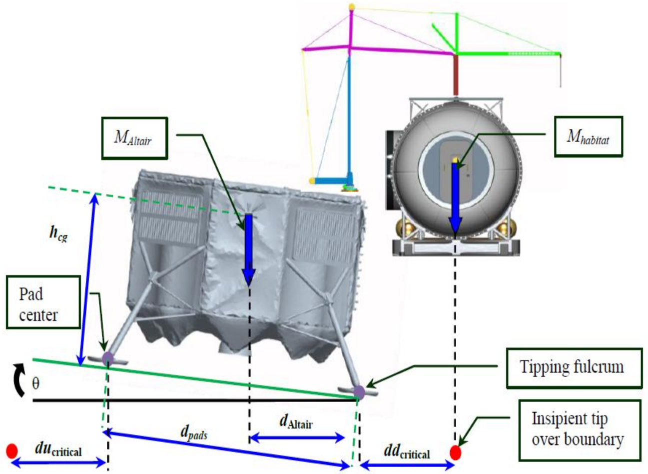


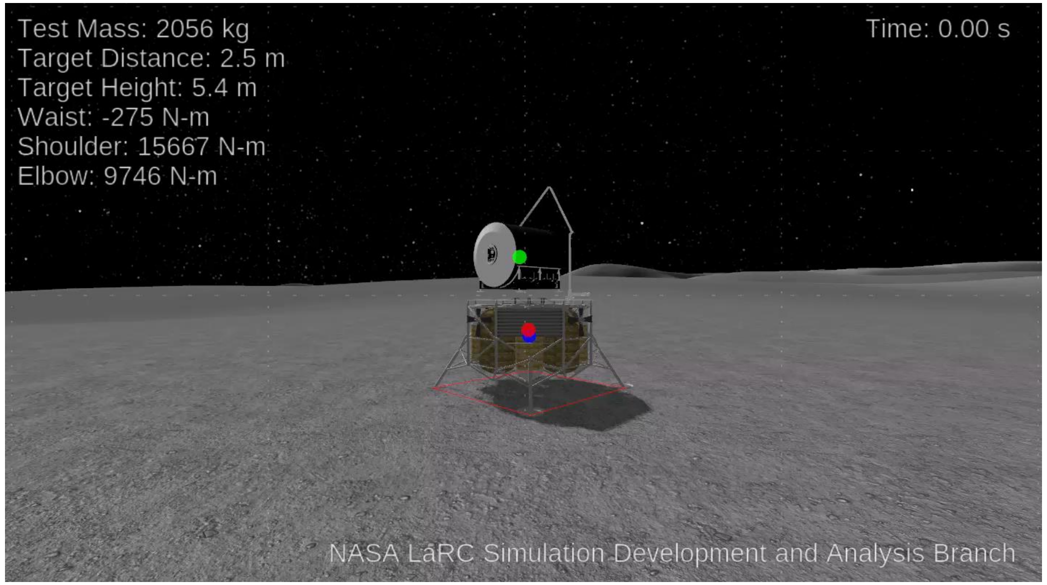


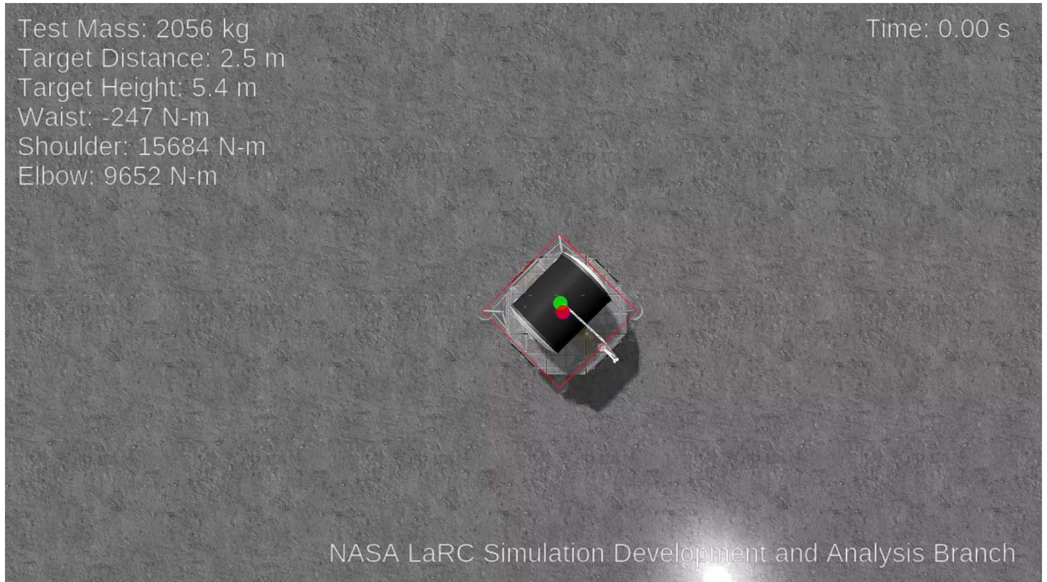


RAMSES: Lightweight Surface Manipulator System (LSMS)

- Rigid multibody full dynamics EOM using:
  - 5 body problem including lander
  - Simplified model of LSMS with moments applied at joints
    - Waist, shoulder, elbow joints
    - Translational DOF added to raise/lower test mass
  - Control law drives moments at joints to achieve desired test mass positions
- Visualization
  - Center of mass locations
  - Tip over hazards
  - Joint motor performance

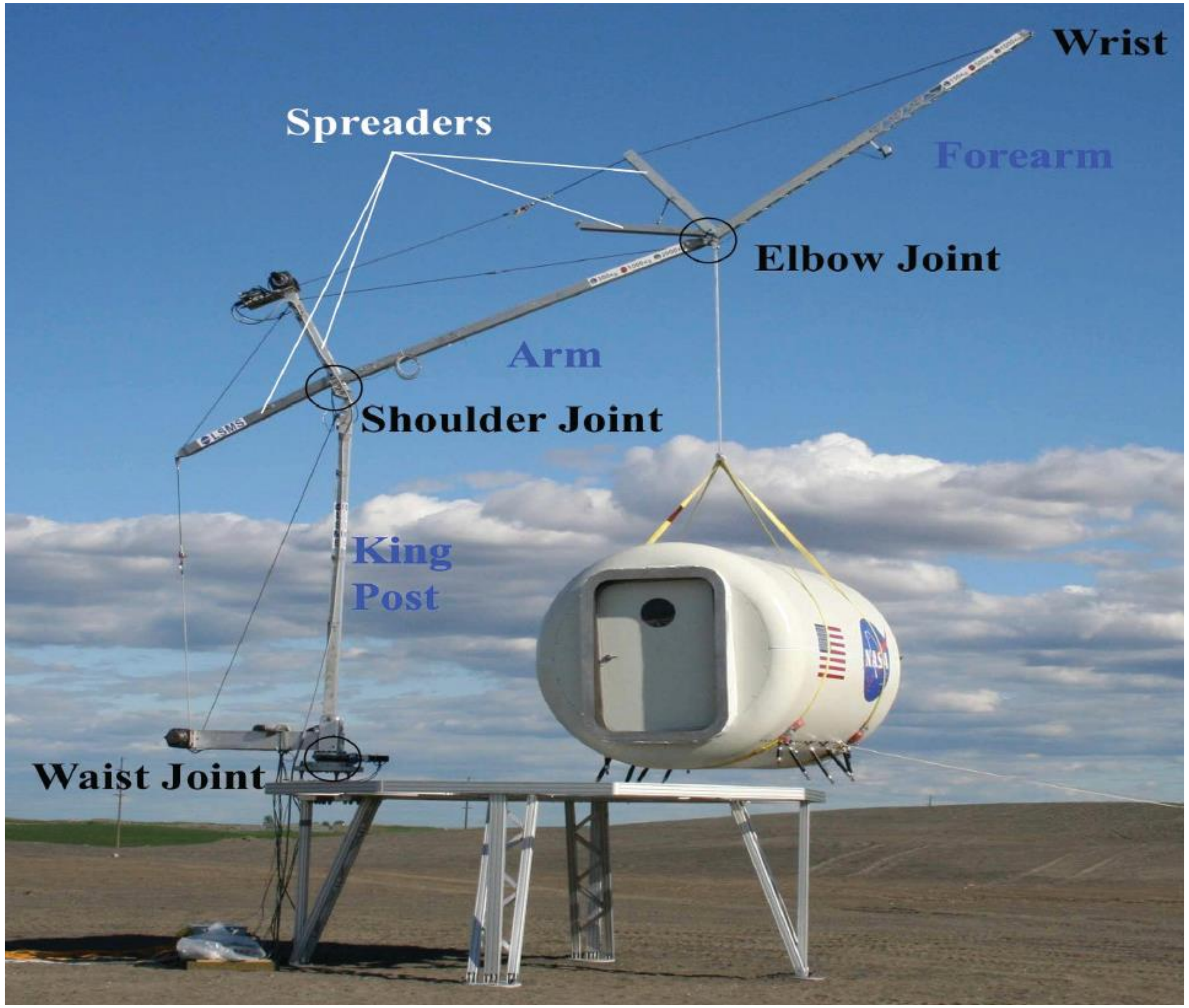






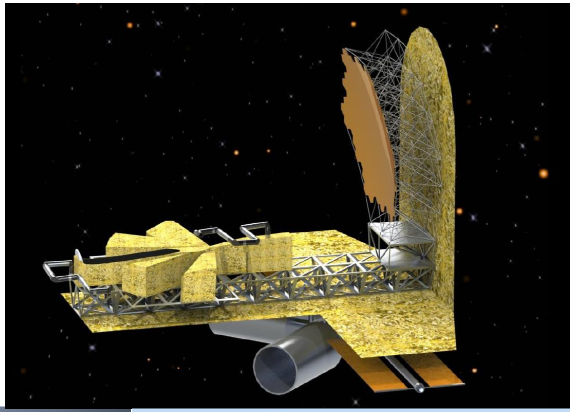
RAMSES: Flexible Multibody Modeling

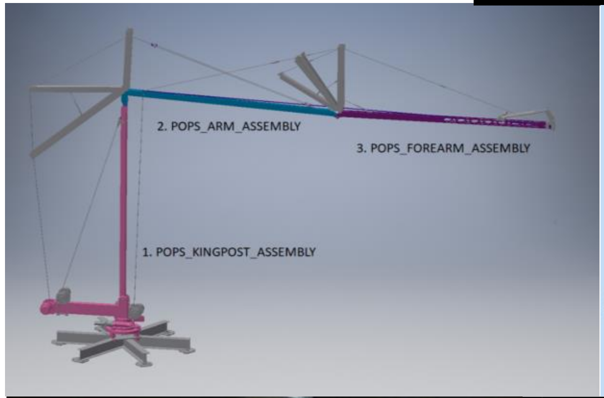
- [Dymore]()
  - Finite element based multibody dynamics code
  - Developed by Dr. Olivier Bauchau and students at the University of Maryland
  - Currently collaborating with University of Maryland on integration with existing tools and processes
- Goals:
  - Model vehicles (e.g. Persistent Platform, LSMS, etc.) using flexible multibody structures
  - Provide increased accuracy/fidelity in simulations
  - Facilitate a path towards verification & validation of OSAM technology designs
    - Provides direct insight to situational differences caused by materials and structure design

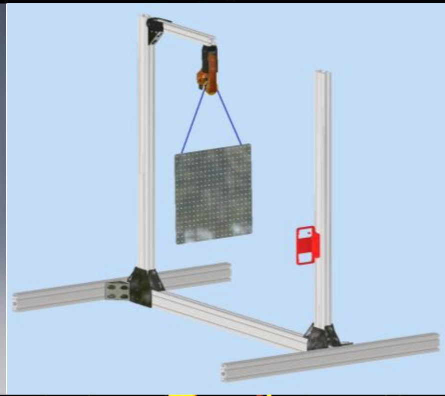


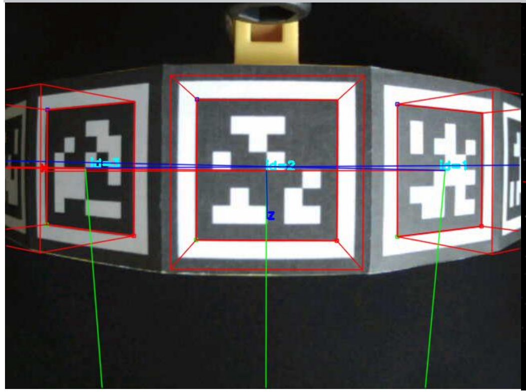
OSAM Architecture Simulation System (OASiS)

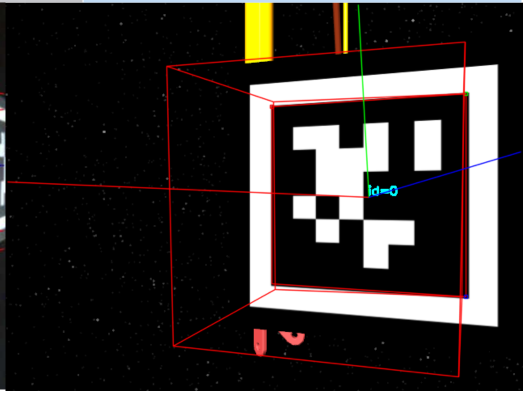
- Project Goal:
  - Provide mission developers with modular, high-fidelity simulation capabilities to rapidly prototype and evaluate OSAM technologies and operational concepts, enabling the verification and validation of large-scale OSAM mission architectures prior to launch
- Key OASiS Project Tasks:
  - Enhance existing OSAM modeling and simulation capabilities within LaSRS++ (building off previous RAMSES developments)
  - Demonstrate the simulation of a key OSAM operation with new capabilities, and
  - Compare accuracy of simulation against analog hardware setup using metrology system data
- Current Developments:
  - Modeling generic robotic guidance, navigation, and control laws for multibody systems using LSMS as a test case
  - Optical metrology system analysis using Aruco and DiamondVisionics image generation system
  - Comparison of POSE data between hardware and simulation images









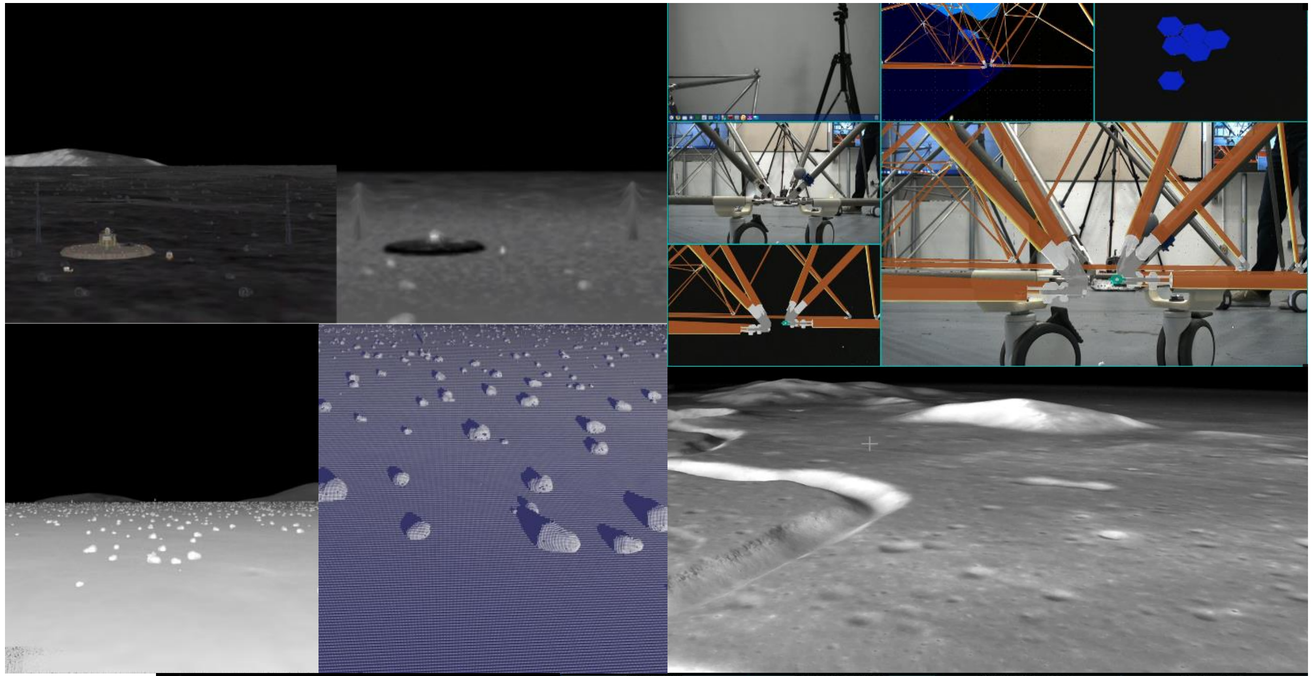


OSAM Architecture Simulation System (OASiS)

- Hardware/Simulation Testing:
  - Hardware Configuration:
    - Two-point cable-capstan system attached at the end of the forearm of the LSMS for payload offloading on uneven surfaces (e.g. on the Lunar surface)
    - Camera and IG system using same resolution and FOV
  - Initial Results:
    - Static image POSE analysis between simulation and hardware environments with plate at -15, 0, and +15 degrees
    - Varying eyepoint distance to analyze effect on POSE data
  - Next Steps:
    - Realtime dynamic POSE analysis of hardware and simulation tests (rotating plate)
    - Enhance multibody modeling capabilities for easier integration of unique robotic agent designs

LaRC Modeling and Simulation Future Goals

- Verification and Validation
  - Laboratory testing
    - Precision Assembled Space Structures (PASS)
  - Simulate autonomous assembly with autonomy hardware in the loop
  - Identify how high-fidelity modeling and simulation could be applied to future certification processes for servicing, assembly, and manufacturing technologies
  - Simulation Comparisons (e.g. ADAMS, Dymore, Gazebo, etc.)
- Modeling
  - Integration of software to model structural mechanics
- Visualization
  - Applications of virtual and/or augmented reality, for example:
    - Autonomous assembly supervision by humans
    - Spacecraft concept development
  - Ray traced scenes for more realistic sensor scene generation
  - Applications of existing LaSRS++ physics-based sensor simulations
    - Millimeter Wave Radar (MMWR)
    - Forward Looking Infrared (FLIR)
    - Light Detection and Ranging (LIDAR)
    - Sensor fusion
- Integration with existing branch HLS simulations
  - Human machine teaming
  - Re-use of capabilities between HLS and OSAM simulations (e.g. LIDAR sensor modeling, lander modeling, etc.)
  - Multi-agent/system simulations



Questions?

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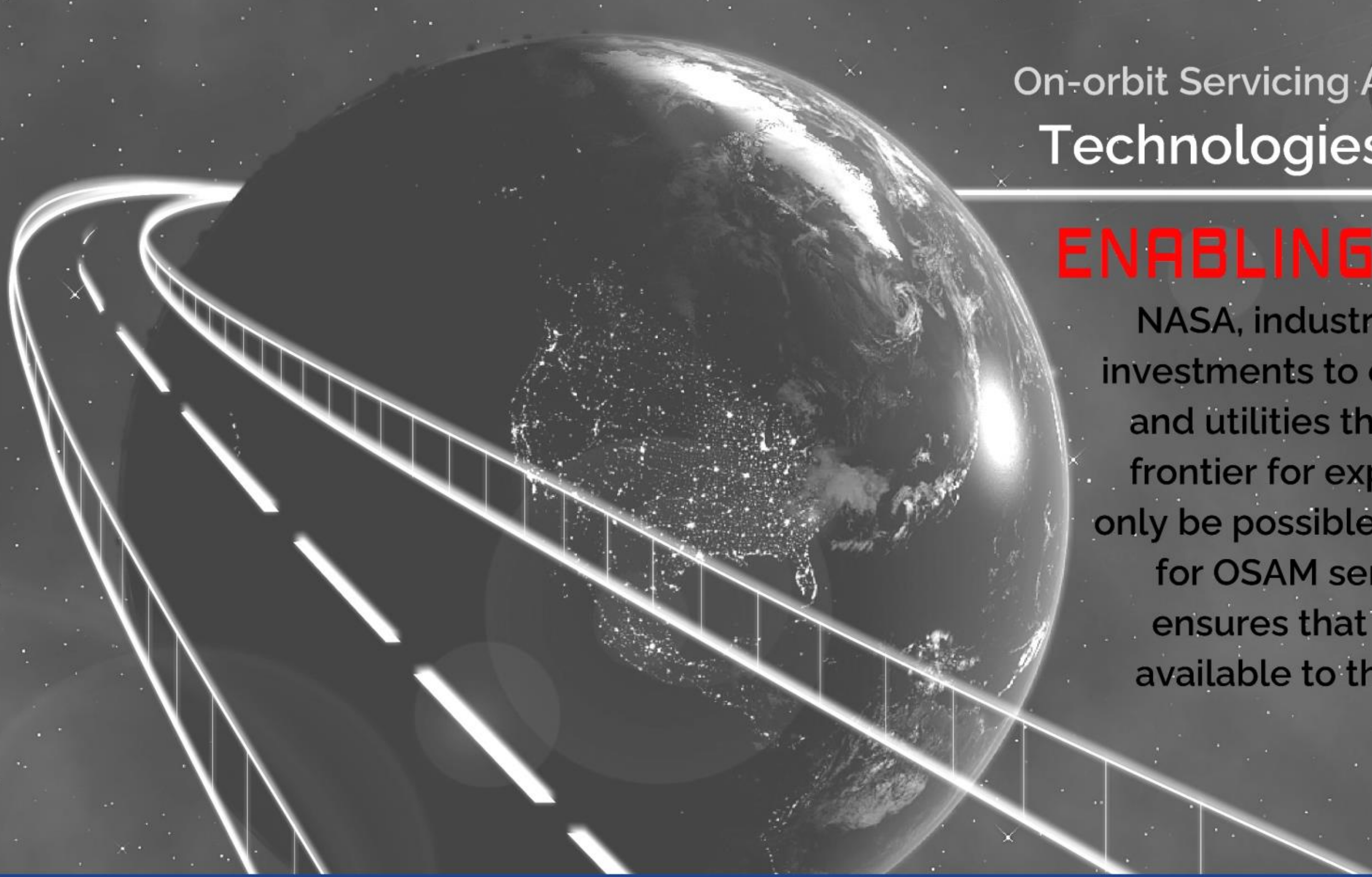

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NASA, industry, and other government agencies are making investments to establish the in-space infrastructure for services and utilities that extend satellite capabilities and expand the frontier for exploration and discovery. This shared vision will only be possible through an affordable commercial marketplace for OSAM services. NASA's Technology Transfer Program ensures that innovations for these capabilities are broadly available to the public, maximizing the benefit to the nation.

To arrange further discussion of OSAM technologies contact:

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OSAM
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