



A Versatile Robotic Manipulator for Performing Assembly and Payload Handling Operations on Planetary Surfaces



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Vision: To Establish a Permanent Presence on the Lunar Surface

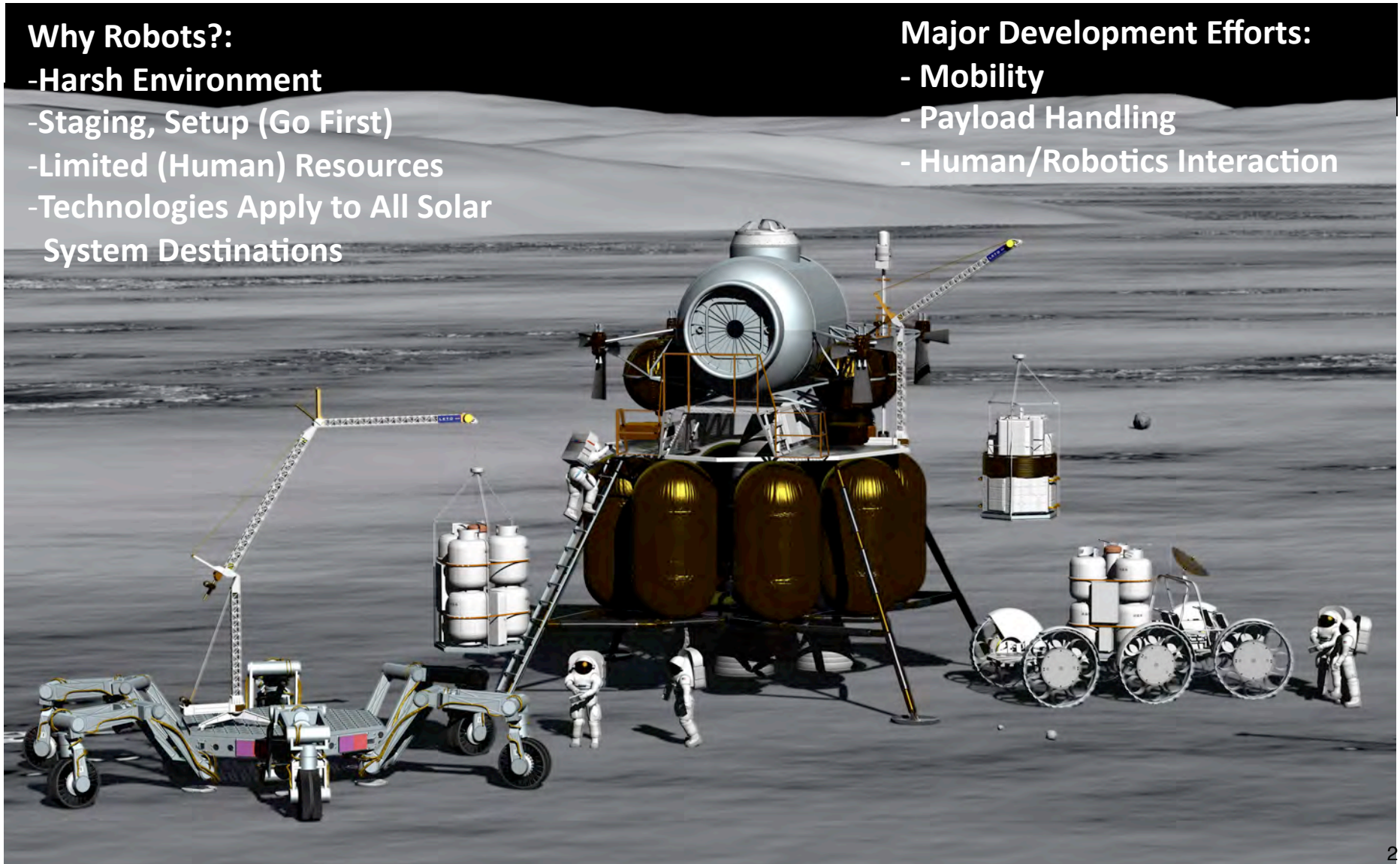
Robots Aid In: Transport, Payload Off Loading, Cargo Handling, Assembly, Maintenance, Etc.

Why Robots?:

- Harsh Environment
- Staging, Setup (Go First)
- Limited (Human) Resources
- Technologies Apply to All Solar System Destinations

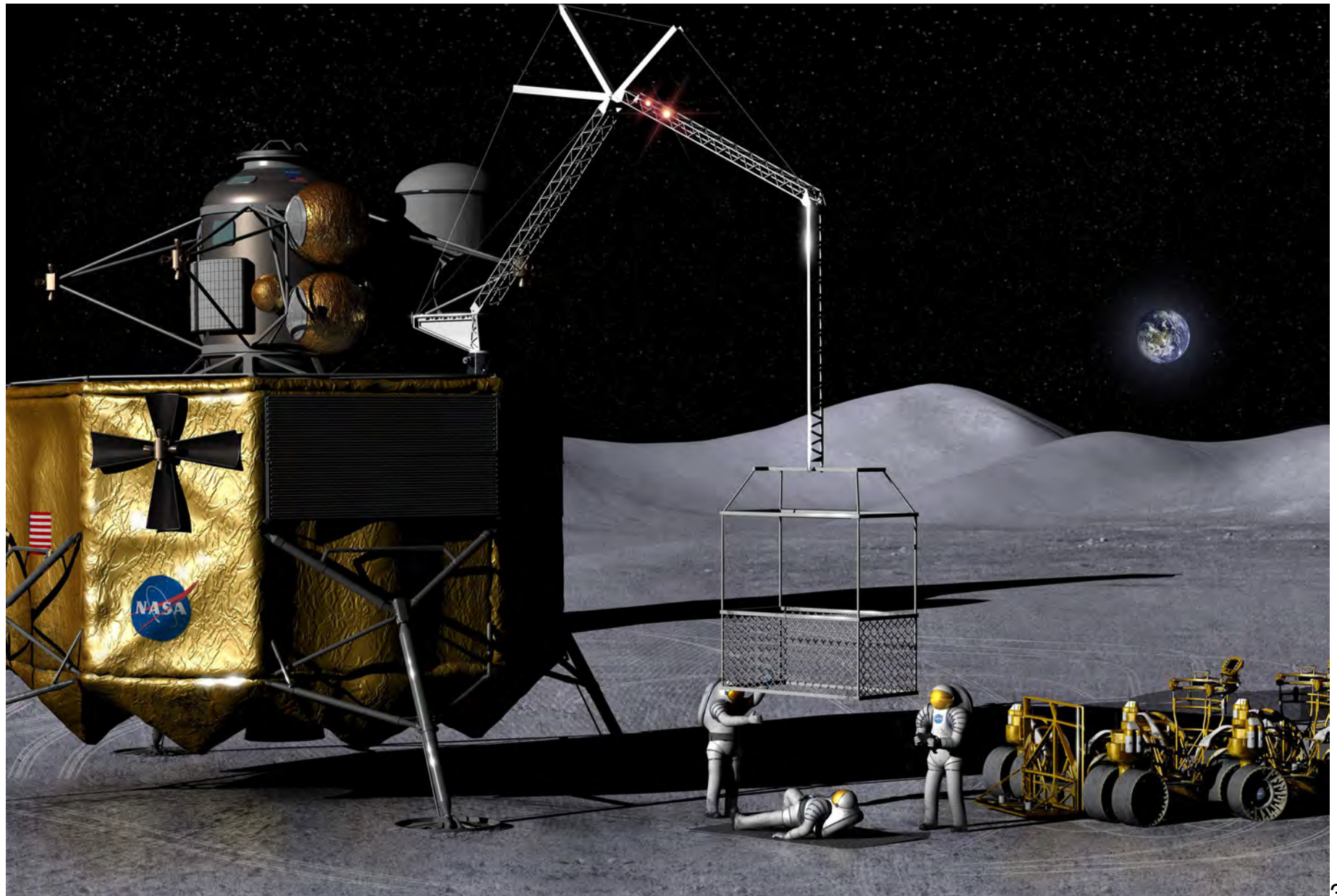
Major Development Efforts:

- Mobility
- Payload Handling
- Human/Robotics Interaction





Example of Single-Link Manipulator Being Used For Incapacitated Crew Rescue Operations

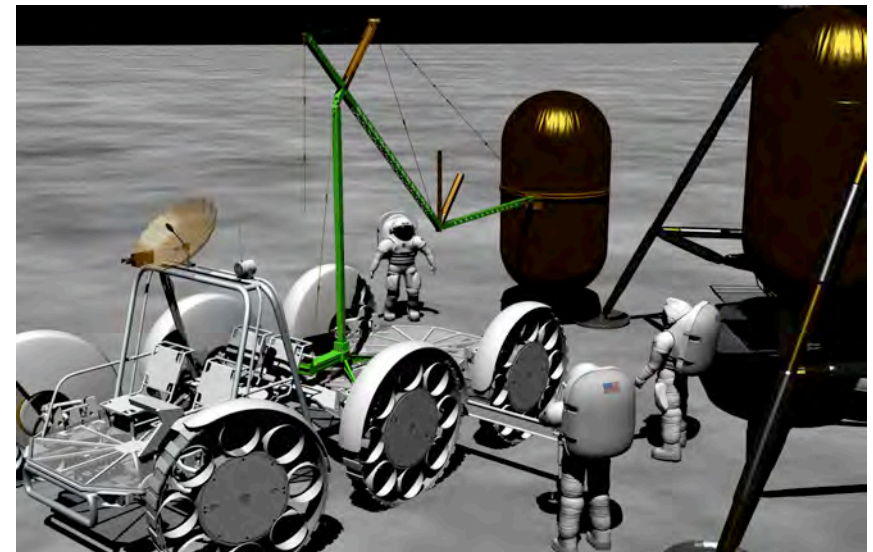
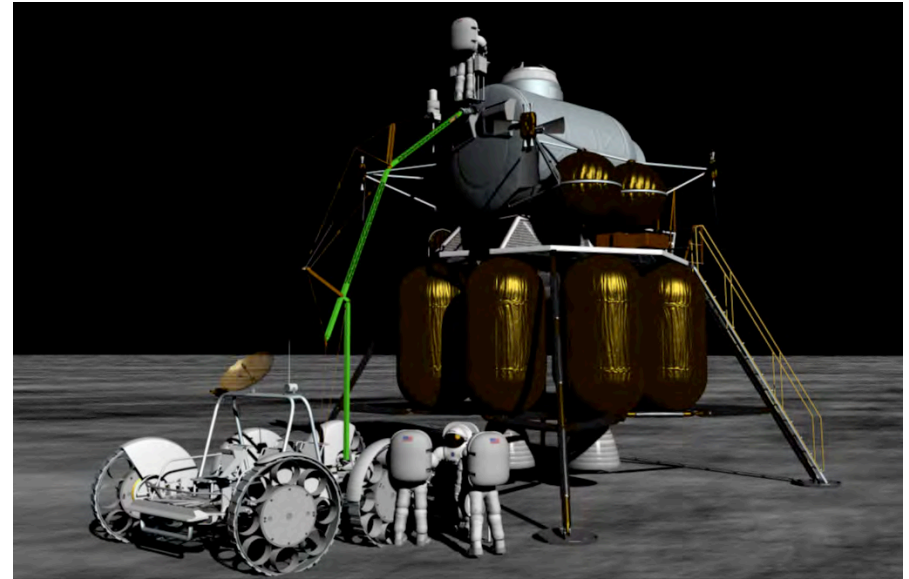




Langley Research Center Team's Assignment: Develop Robotic Capability for Payload and Cargo Handling

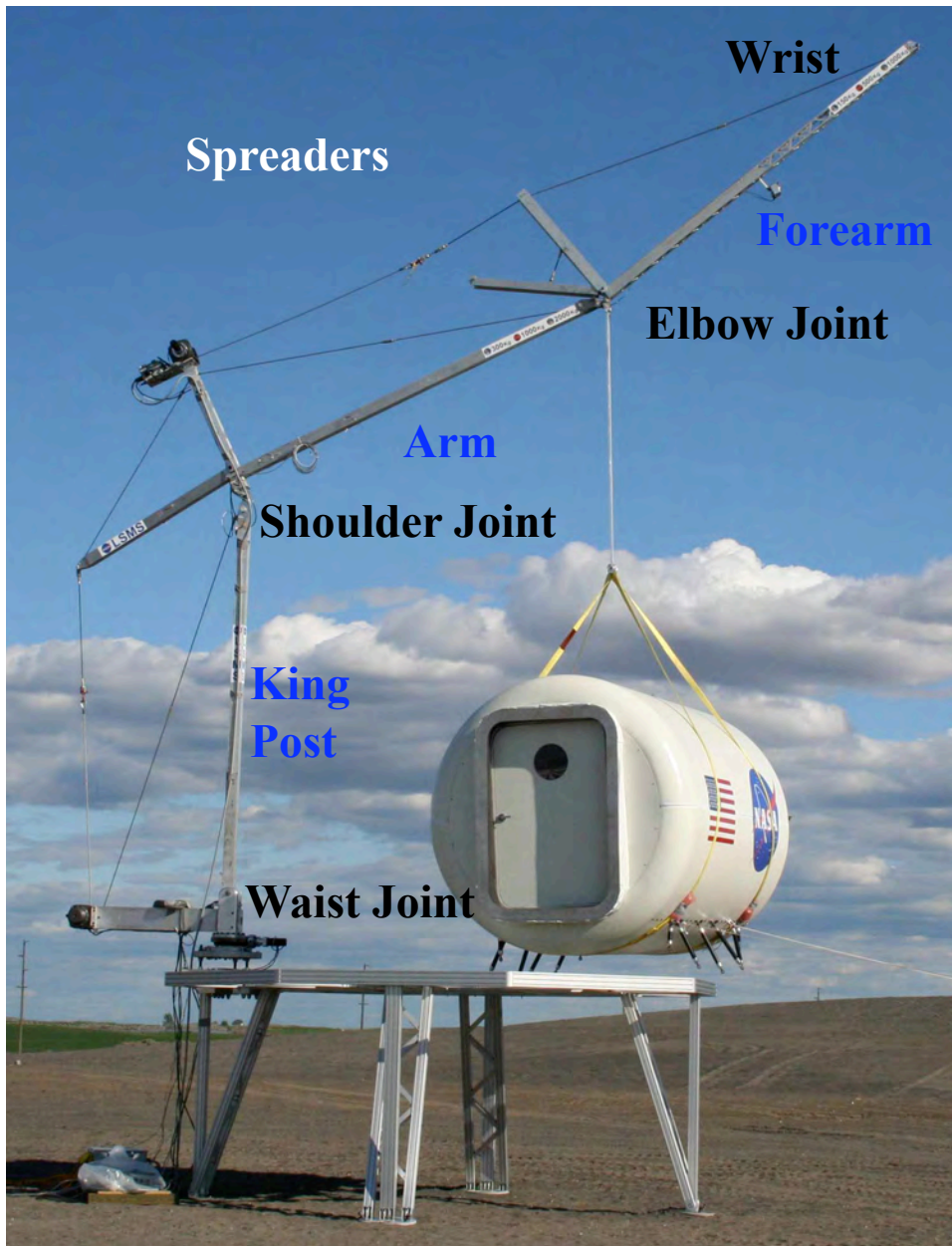
Design and Operational Needs:

- Reach (Surface to Lander Deck)
- Payload Weight
- Packaging and Deployment
- Robot Weight
- Autonomous
- Remotely Operated
- Simplicity (Reliability)
- Modularity
- Versatility
- Limited Mobility
- Standard Interfaces





First Generation LSMS: Full Scale, 3 Degree-of-Freedom Manipulator



Design and Operational Needs:

- Reach (Surface to Lander Deck): **3.75 m links, 9.55 m at +45 degrees**
- Payload Weight: **1000kg (Lunar), 500kg (Mars), 150kg (Earth)**
- Packaging and Deployment: **Joint offsets, Nesting members**
- Robot Weight: **Innovative Architecture, 3% of Lunar Payload (Adv. Tech.)**
- Autonomy: **Tele-operated now, Autonomous this year**
- Remotely Operated: **On-board cameras, Internet link to JPL, Simulation models**
- Simplicity (Reliability): **3 degrees of freedom, links, actuators**
- Modularity: **Link lengths & number**
- Versatility: **End effectors, forklift mode, digging mode**
- Limited Mobility: **Self offload (inchworm)**
- Standard Interfaces: **Quick change at wrist**



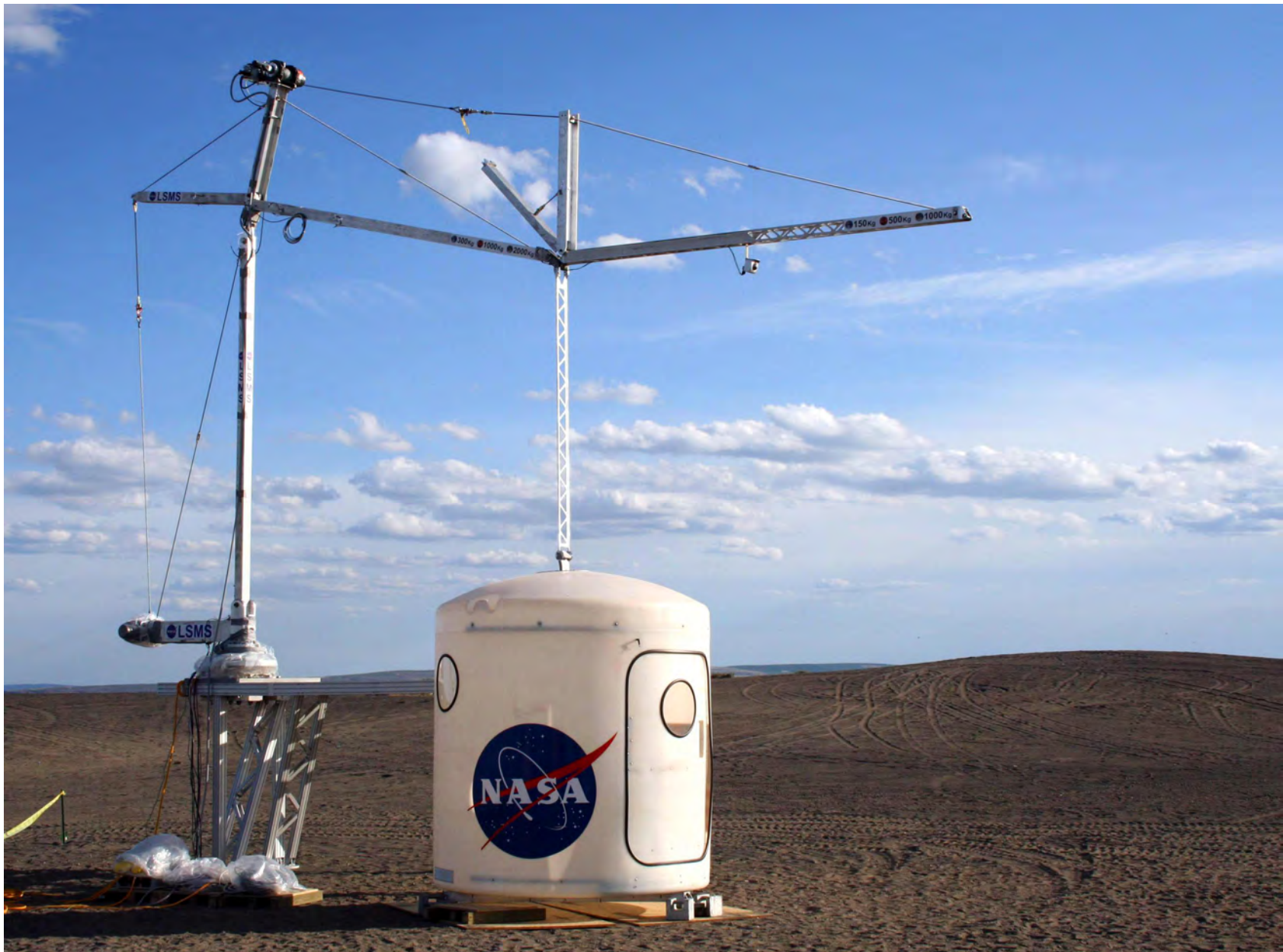
Videos and Animations:

- Deployment**
- Moses Lake Operations**
- Fork Lift Mode**
- Digging Mode**
- Payload Handling/Latching**

Backup Graphics



LSMS Lifting Lander Airlock Module Mockup



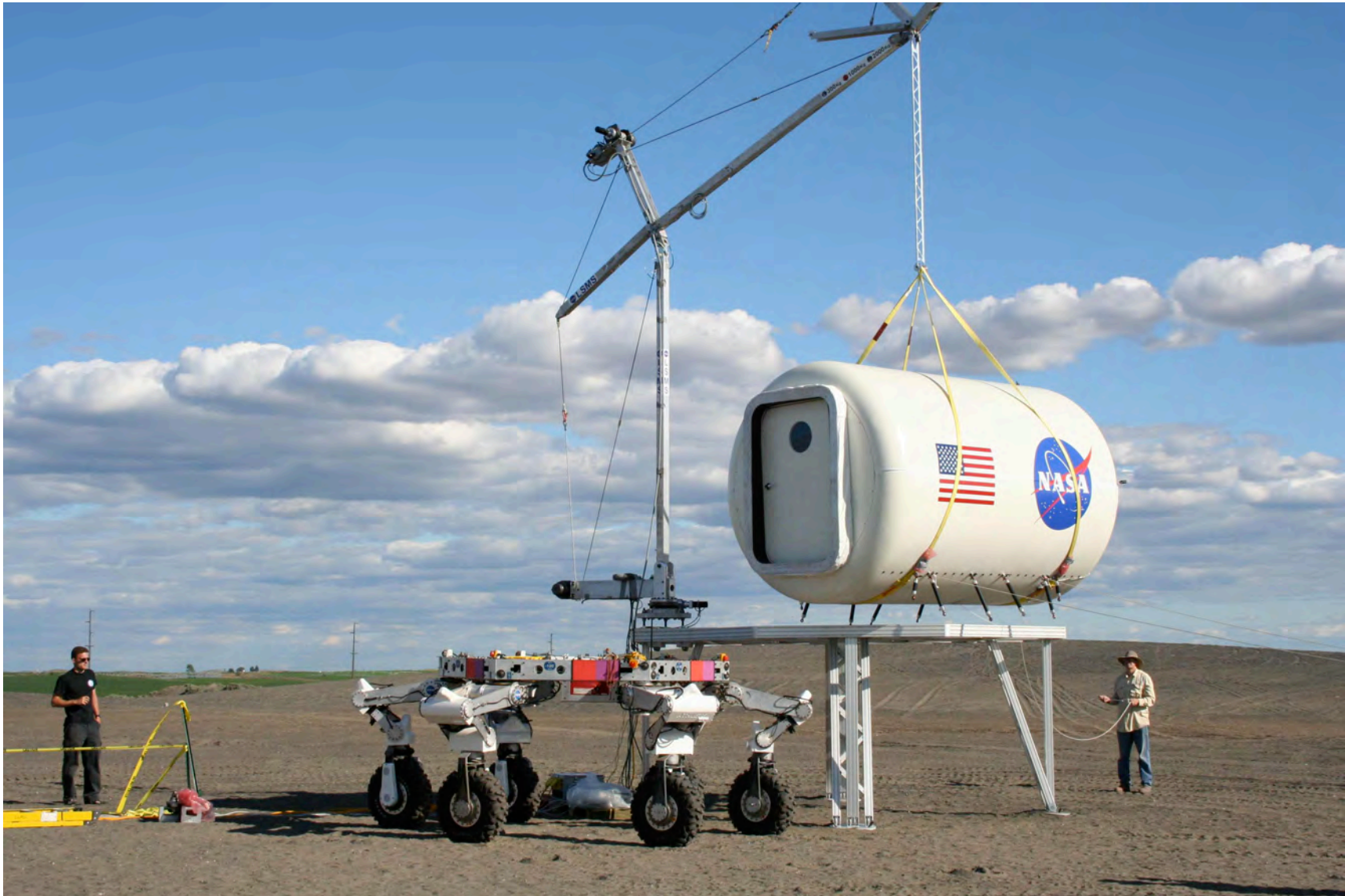


LSMS Performing ISRU Payload Operations From ATHLETE Mobile Base





LSMS Lifting JPL Hab Mockup On To ATHLETE



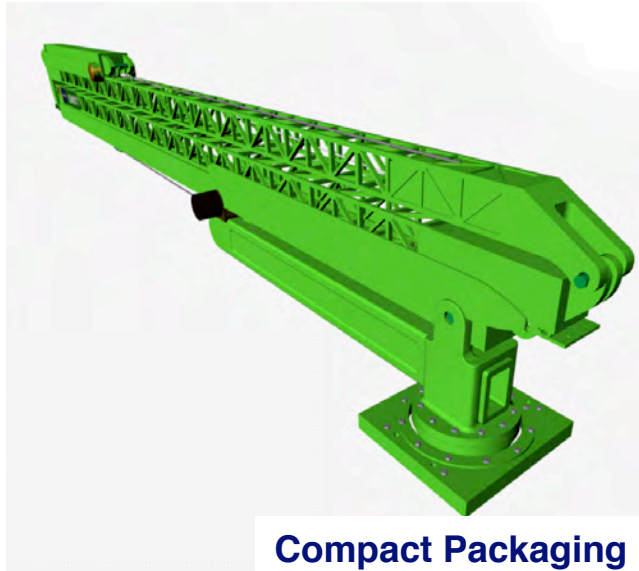


LSMS Placing Small ISRU Payload On Chariot

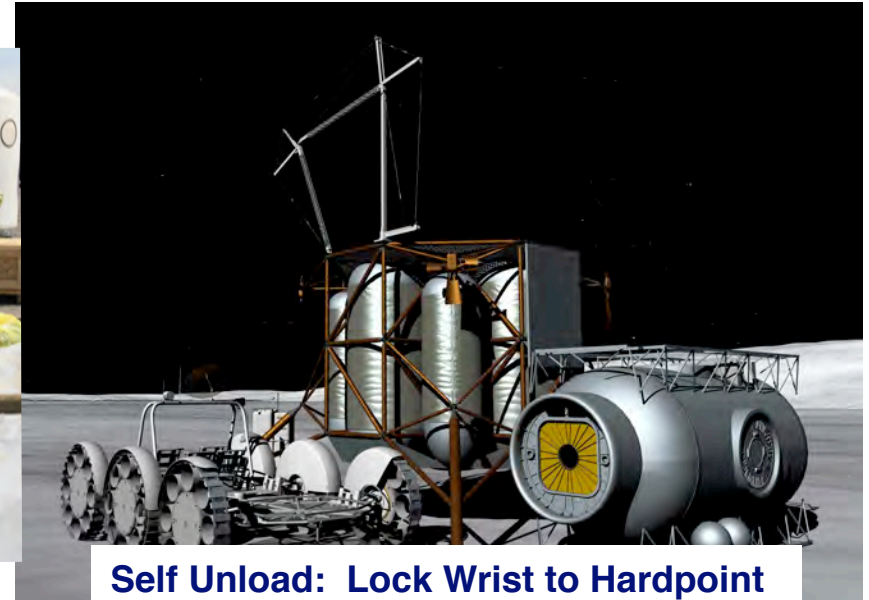




LSMS Test Bed: Compact Packaging and Self Mobility



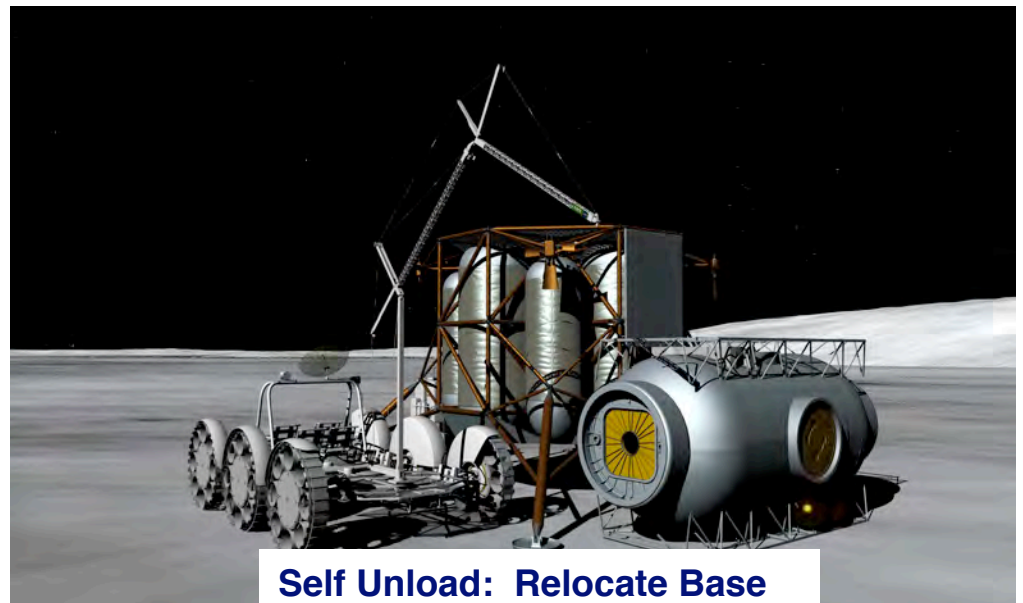
Compact Packaging



Self Unload: Lock Wrist to Hardpoint



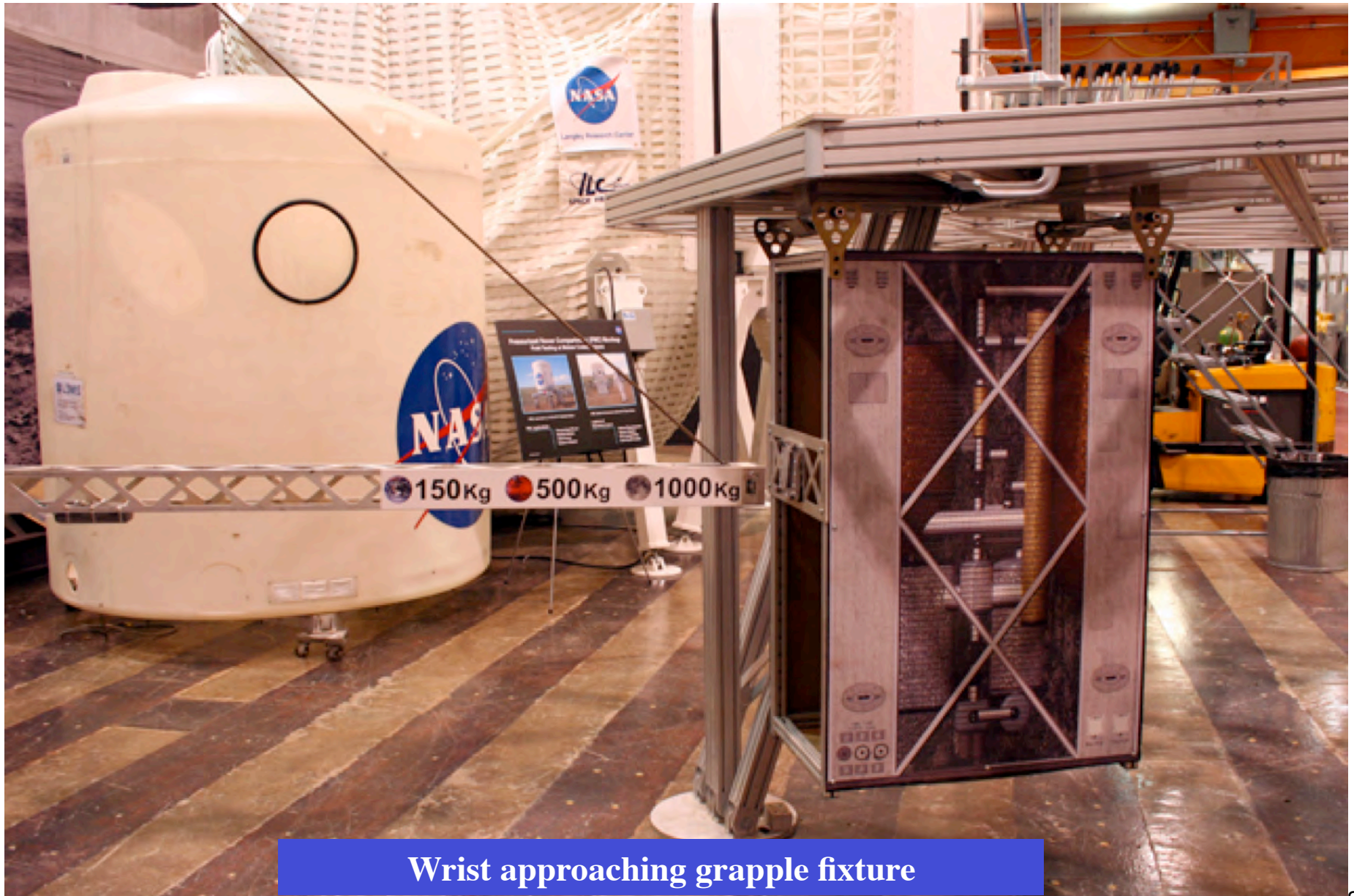
Self Unload: Lift Base



Self Unload: Relocate Base

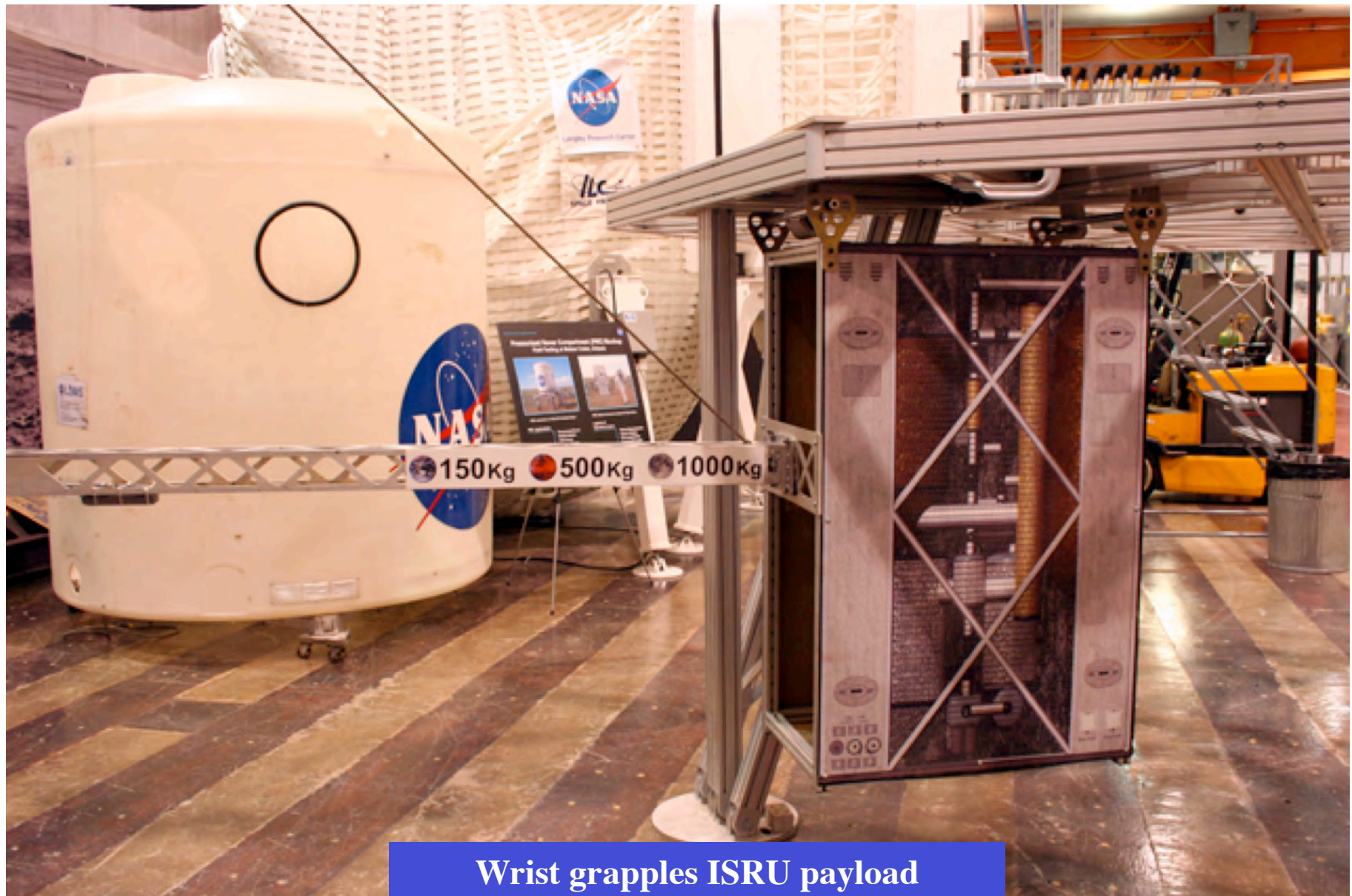


Increased Versatility: Payload Handling Using Fork Lift Mode Demonstrated (1)





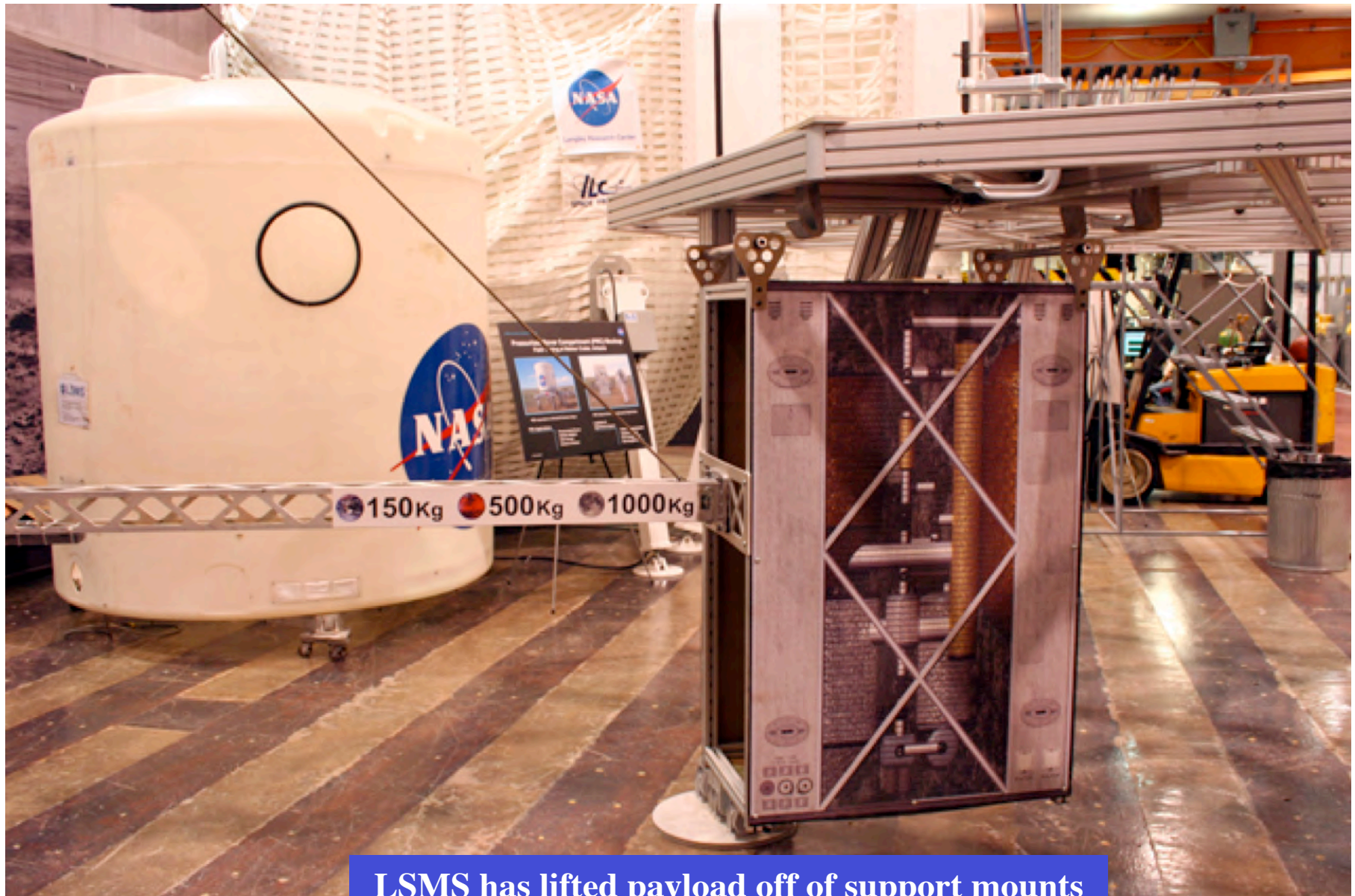
Increased Versatility: Payload Handling Using Fork Lift Mode Demonstrated (2)



Wrist grapples ISRU payload



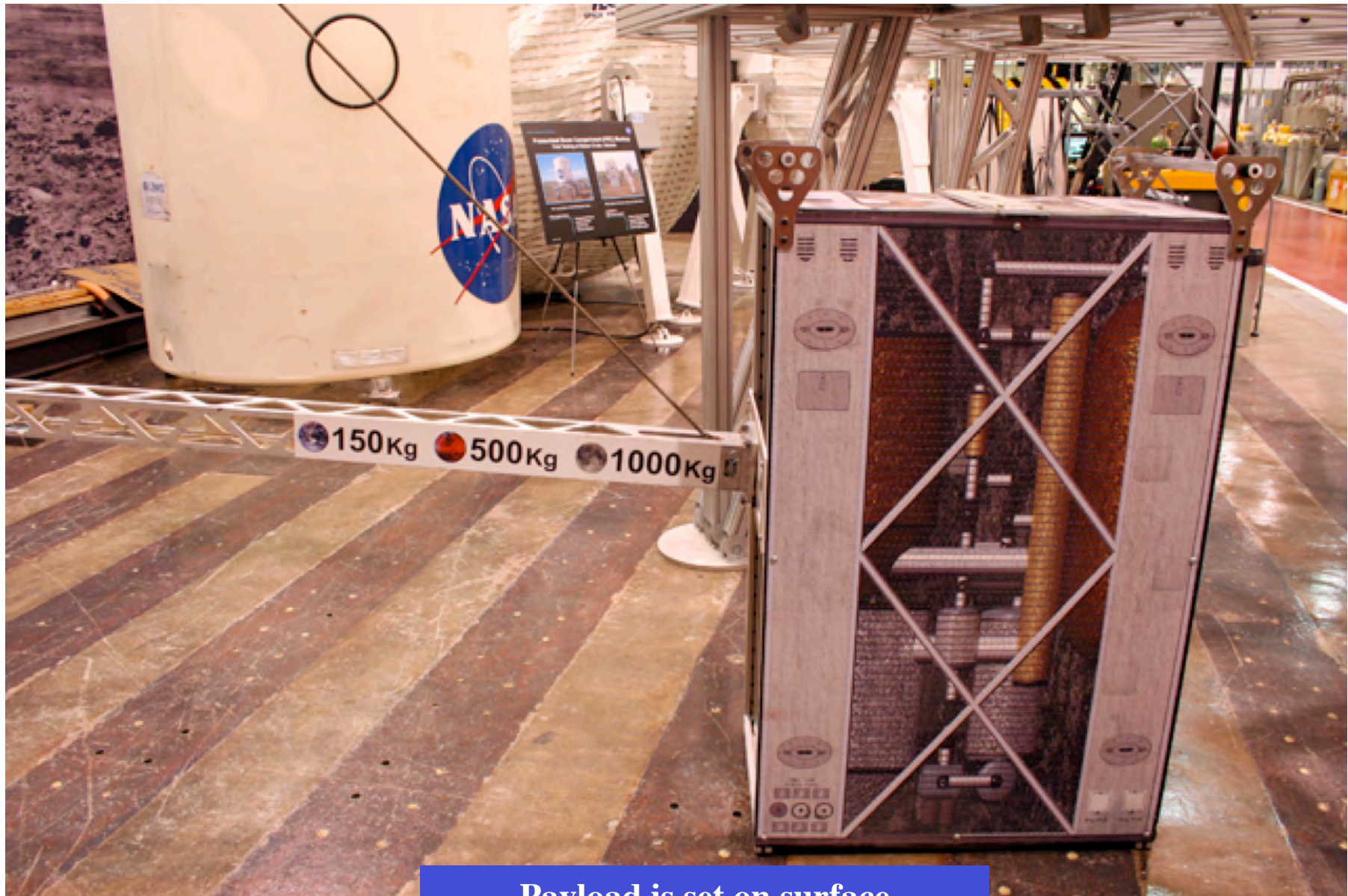
Increased Versatility: Payload Handling Using Fork Lift Mode Demonstrated (3)



LSMS has lifted payload off of support mounts



Increased Versatility: Payload Handling Using Fork Lift Mode Demonstrated (4)



Payload is set on surface



Increased Versatility: Regolith Scooping and Handling Operations Demonstrated (1)

- Constellation Architecture Scenario 5: Fission Power System (FSP)
- FSP remains on lander
- FSP near outpost (minimize cable mass)
- Regolith surrounding FSP used to attenuate radiation
- LSMS demonstrated necessary regolith handling operations



Scoop end-effector pushing forward through sand.



Increased Versatility: Regolith Scooping and Handling Operations Demonstrated (2)



Raising scooped sand above lander deck height.



Increased Versatility: Regolith Scooping and Handling Operations Demonstrated (3)



Dumping sand into container on top of lander deck.