National Aeronautics and Space Administration

Space Technology Mission Directorate - Lunar Surface Innovation Initiative (LSII)

Lightweight Surface Manipulation System (LSMS) Overview for Blue Origin | Tom C. Jones | 08/21/20

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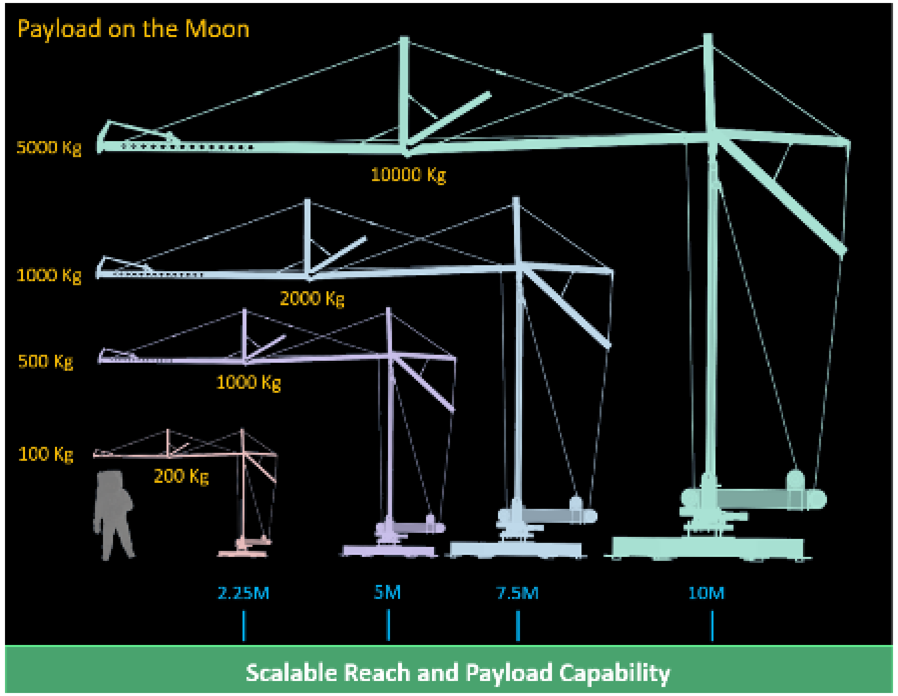
Need: Payload Handling and Offloading for Surface Missions

- **The Problem:** NASA and commercial lunar landers require a large variety of different size and mass payloads to be maneuvered, deployed and/or offloaded.

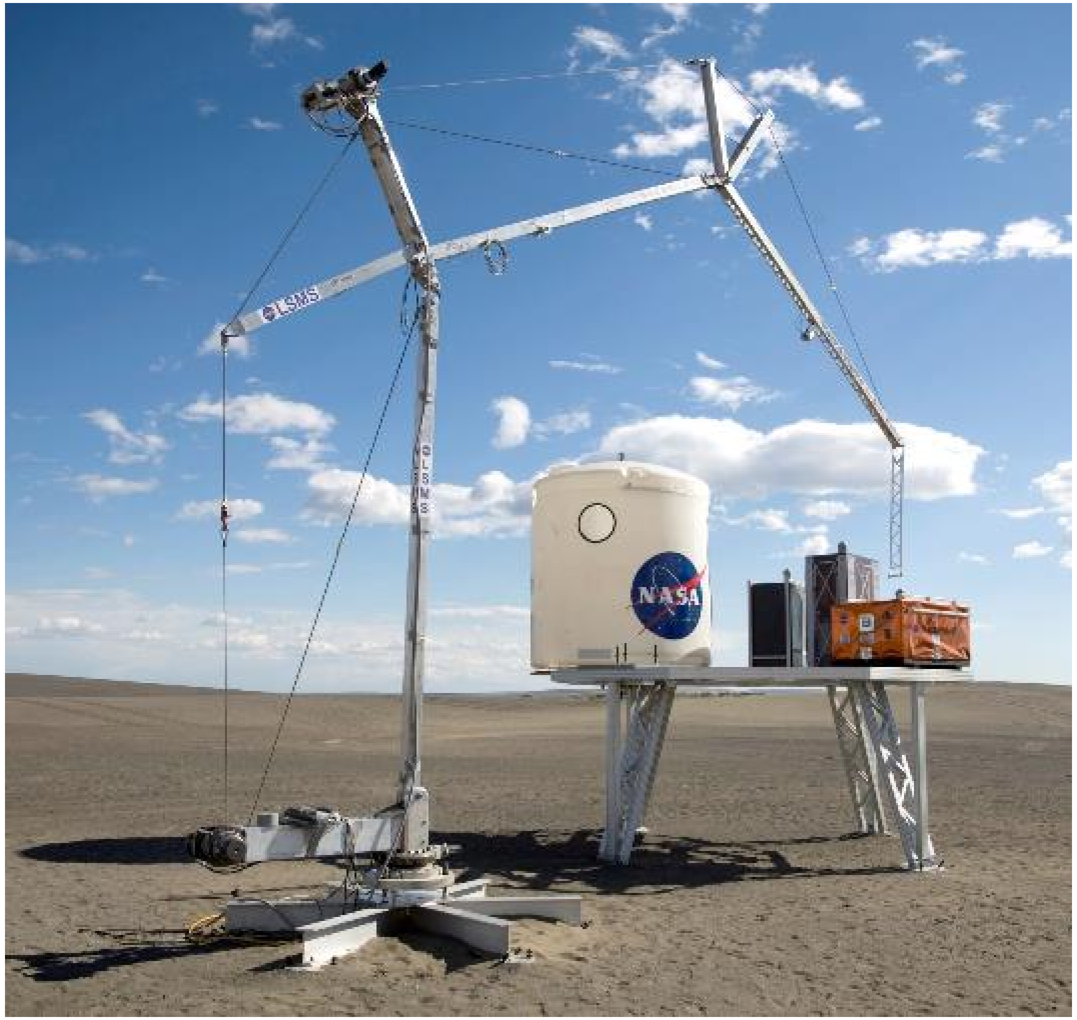
- **The Need:** A versatile manipulation system that can perform payload handling and other tasks.
  - Lightweight, power-efficient, and small footprint on lander.
  - Design scalable to different reach and payload mass requirements.
  - Perform multiple functions that reduces the need for many specialized systems.

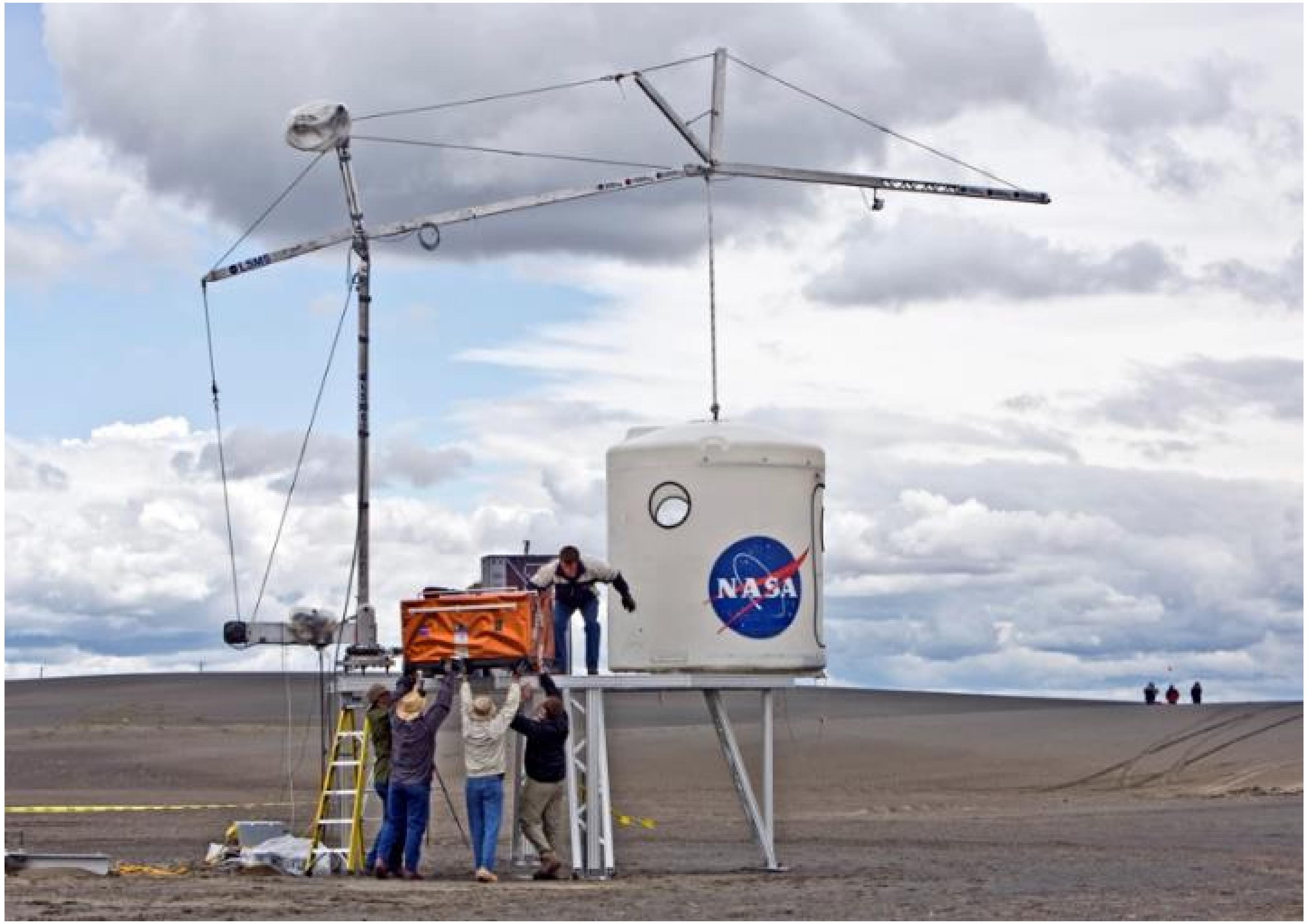
Image Credit: Adrian Pingstone, Public Domain https://commons.wikimedia.org/wiki/File:Tower.crane.bristol.arp.jpg



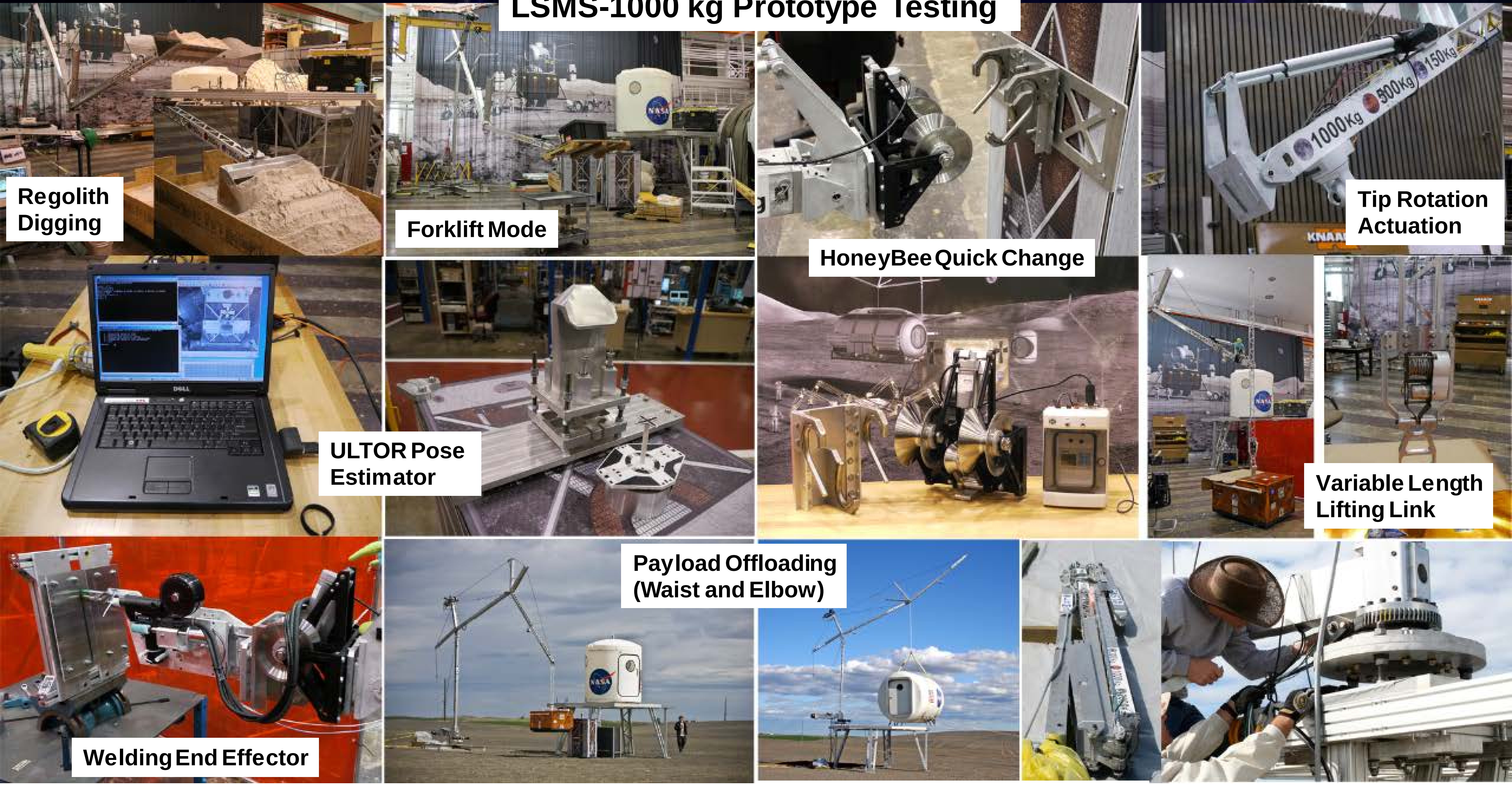
- **The Proposed Solution:** A lightweight, deployable manipulator, using design principles of structurally efficient commercial cranes, with the enhanced dexterity and multi-functionality of a robotic arm.

Heritage: Field Testing of 1000 kg Lunar LSMS Prototype



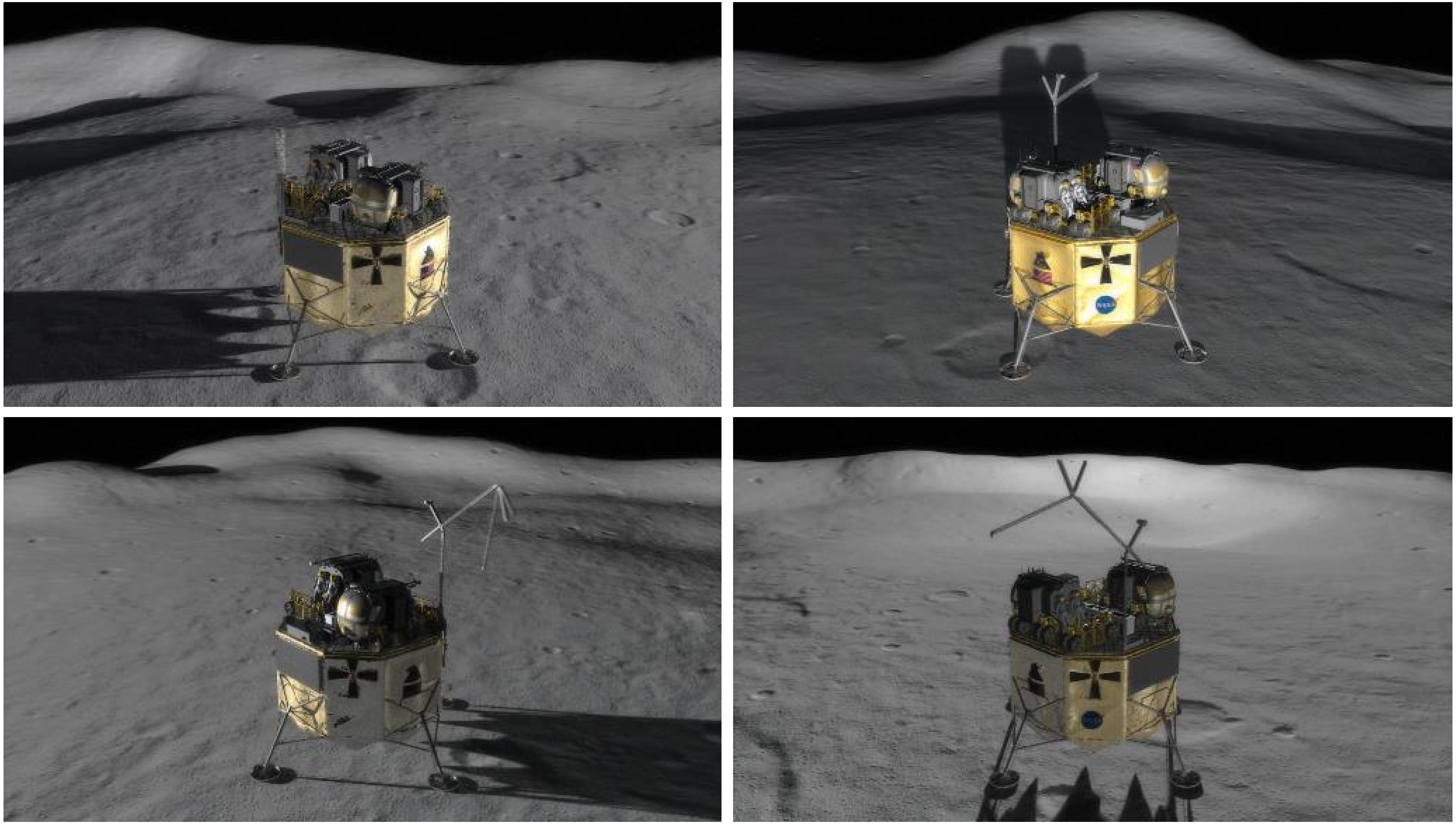


LSMS-1000 kg Prototype Testing

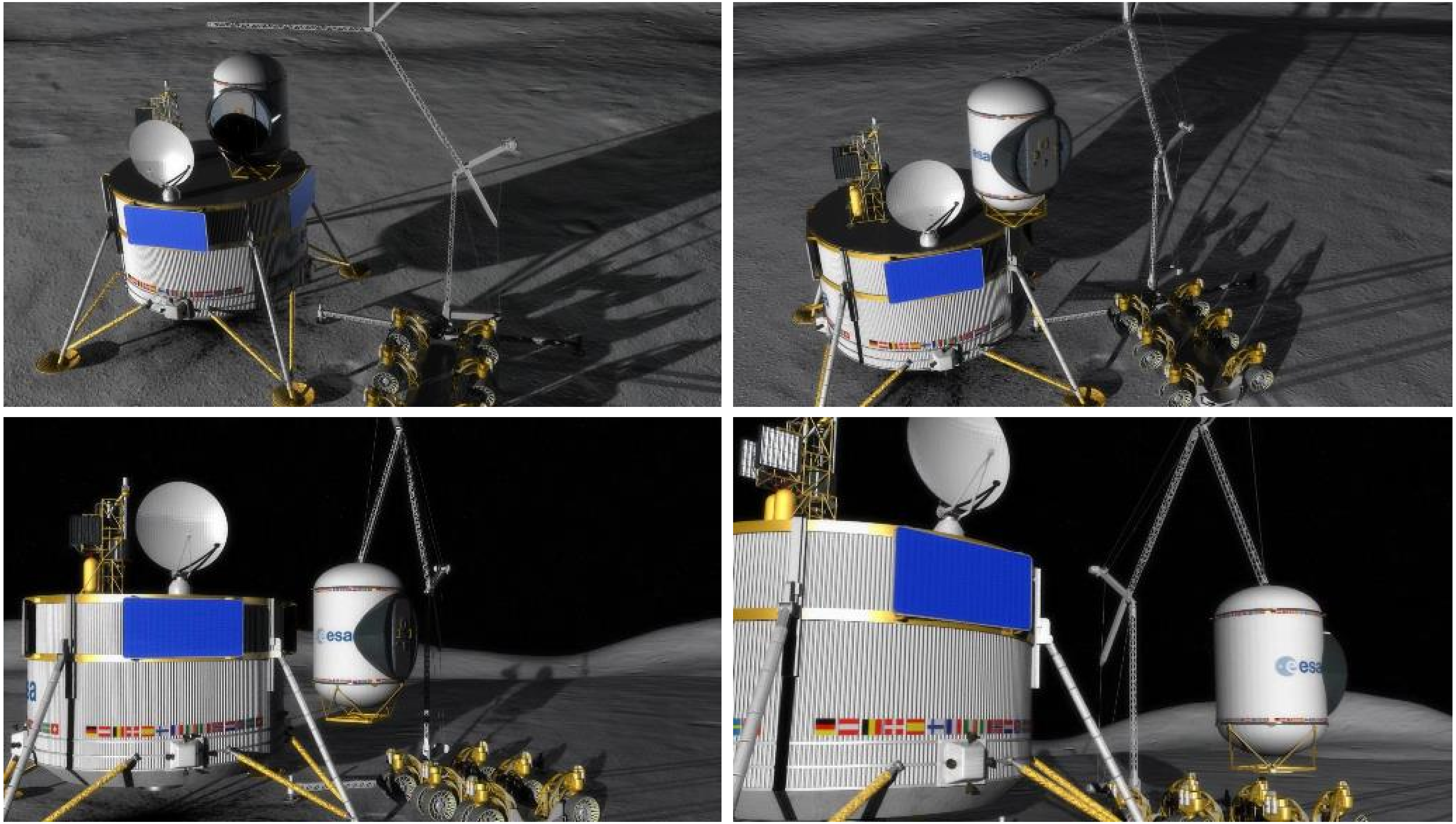


Field Trials 2008 – Moses Lake, WA

Surface Ops: LSMS Deployment from Vertical Stowage



Surface Ops: LSMS Offloading Lander from Mobility Asset



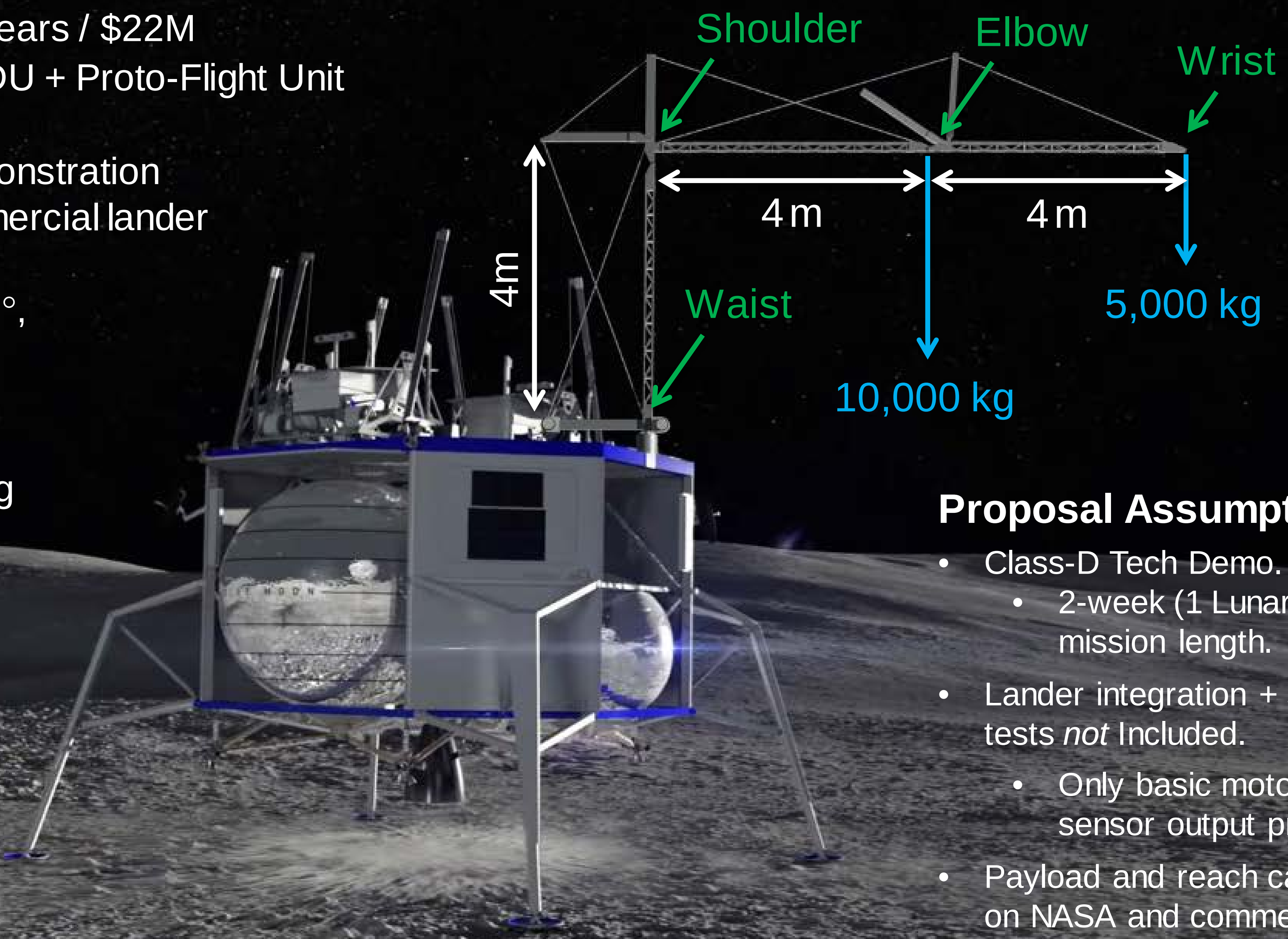
Concept: Versatile Lightweight Manipulator for Surface Missions

Timeline / Budget: 3 Years / $22M
Deliverables: LSMS EDU + Proto-Flight Unit

Target: Technology demonstration on a large commercial lander

Tasks: Self-Leveling ±15°, Self-Deployment, Payload Handling

LSMS Mass Goal: 500 Kg

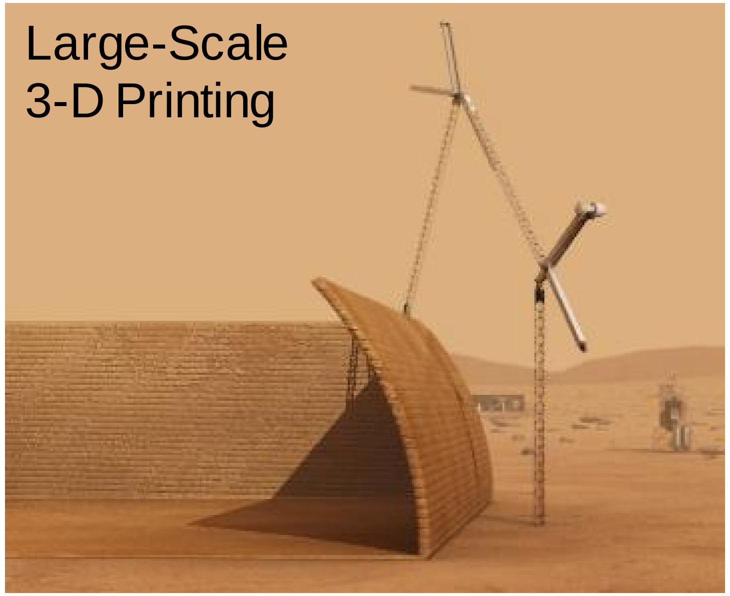


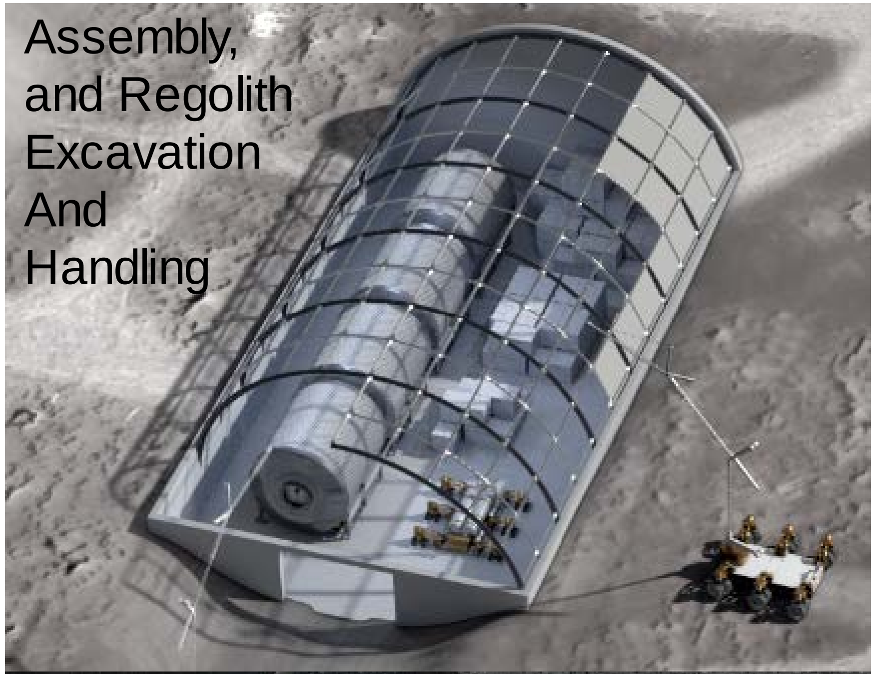
Lightweight
Surface
Manipulation
System
(**LSMS**)

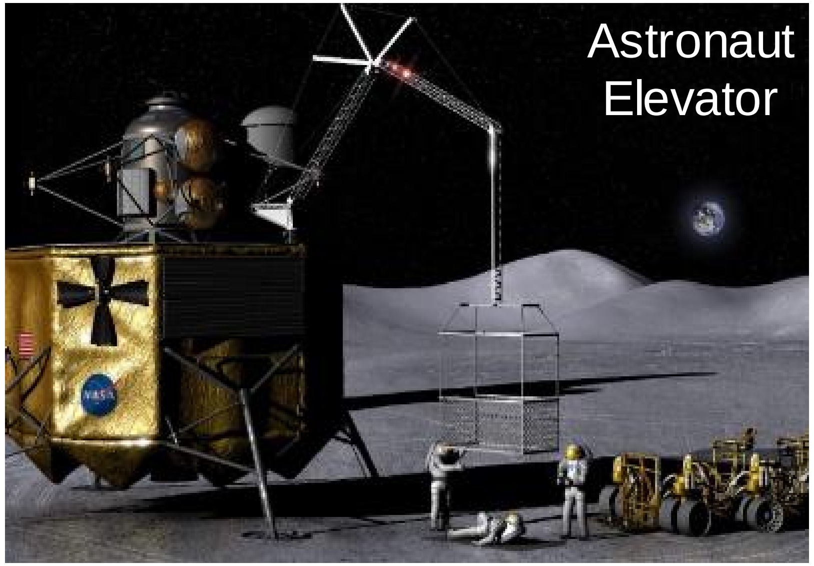
Proposal Assumptions:

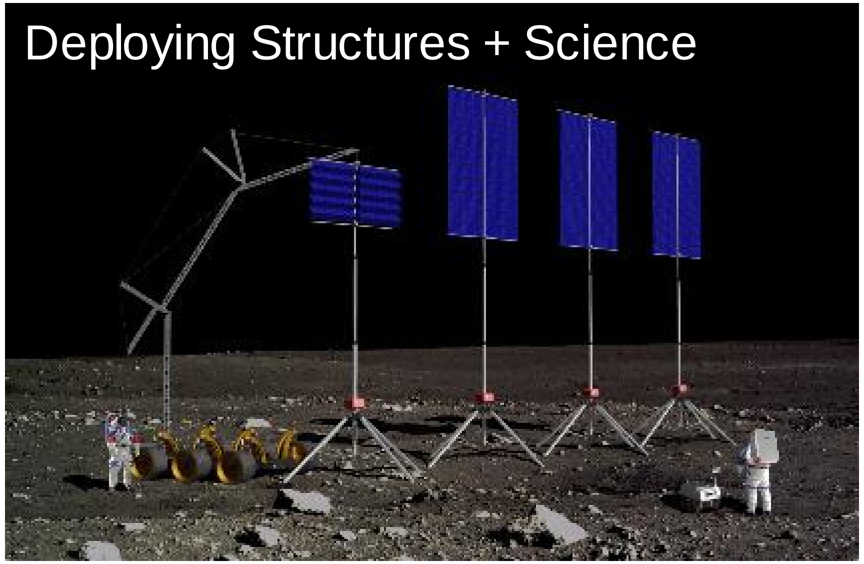
- Class-D Tech Demo.
  - 2-week (1 Lunar day) nominal mission length.
- Lander integration + system level tests *not* Included.
  - Only basic motor control, and sensor output provided.
- Payload and reach capability based on NASA and commercial needs.

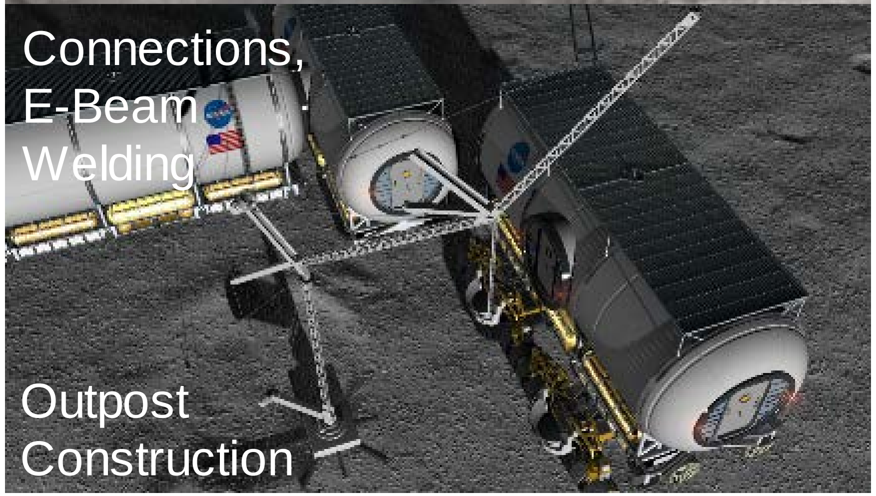
The Concept: LSMS Supports a Diverse Set of Capabilities and Functions





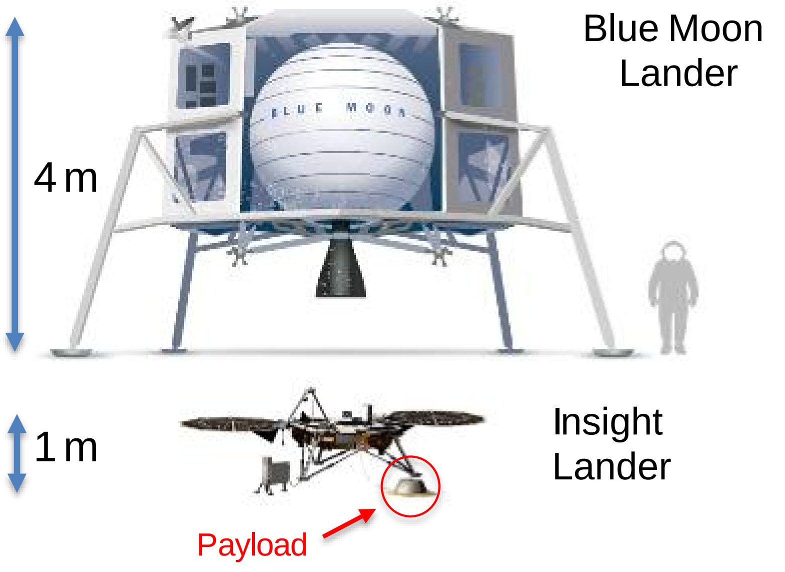






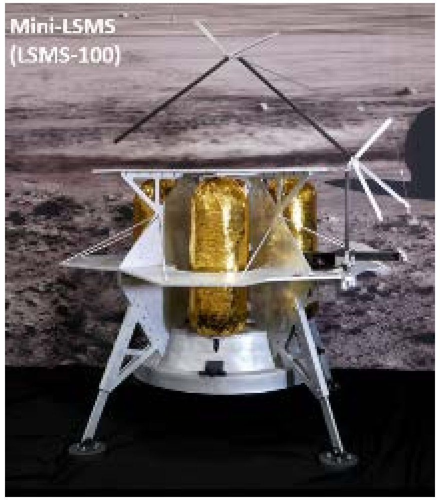
The State of the Art in Long Reach, High Mass Payload Handling for Moon and Mars Surfaces Does Not Exist

- **Current Status:** Mars Insight lander's 1.8-m arm, offloaded a 29-kg seismometer, 1 m to the Martian surface, one time.
  - Payload mass and size, reach required, and height and size of lander, are all significantly greater for large NASA and commercial landers.
  - Planetary-surface serial manipulators do not scale to heavy payloads.



- **LSMS Advantages vs. Other Approaches:**
  - Vs. Serial robotic arm:
    - Higher structural efficiency: tension-compression vs. bending.
    - Higher mechanical advantage: greater payload mass at a given reach.
    - Significantly lower system mass and power.
  - Vs. Davit:
    - Greater operational versatility in a lighter weight system.

- **Past Experience**
  - 1st generation prototype LSMS, over a decade of development and testing with successful field tests at Moses Lake, WA.
  - Recently, LSMS-mini prototype developed to demonstrate scalability to small landers.



Benefit: Provides Baseline Manipulator Capability while also Efficiently Enabling Multiple Additional Services

Value: Reduces the need for developing purpose-built hardware to perform additional critical functions on the surface; task-specific tools are quicker and less costly to develop and implement.

Benefits:

- LSMS addresses key technology areas in robotic systems (TX04), ISRU (TX06), Exploration (TX07), and materials and structures (TX12), along with collaborative opportunities for autonomy advancement.
- Commercial Lunar Payload Services (CLPS) integration provides rapid path to commercialization, cost-sharing, and reduced per-unit cost.
- Inexpensive to replicate the device once flight proven.

Goal: Develop Human Lander System (HLS)-class proto-flight LSMS to pre-integration with a lander.

Objectives:

- Build and test key components, and full-scale engineering demonstration unit (EDU). [TRL 3 → 5]
- Build proto-flight LSMS, ready for lander integration and system-level tests. [TRL 4 → 6]

Customer / Partners: Strong Pull from NASA and CLPS Partners for LSMS

- Customers/Infusion
  - Current
    - HEO: Artemis crewed and cargo missions to the lunar surface.
    - CLPS: Landers (e.g. Blue Origin), specific payload/demo
  - Potential
    - Additional CLPS and industry customers who need either the core manipulator or are developing tools that could utilize LSMS.
    - SMD: Mars surface missions.

- Partners
  - Existing Partners
    - LaRC: STMD LSII new start FY21.
    - GSFC: Full-scale vibration testing.
  - New Partners
    - Potential for commercial partnership on LSMS and end-effector tools.
    - Opportunities to leverage internal NASA work on bulk metallic glass (BMG) “cold” gearbox (JPL), autonomy (ARC and LaRC), ISRU support (KSC), and dust mitigation (LaRC and JSC).
    - Leverage universities involved in lunar technology development, and high school competition (VSGC).

Summary

Criteria	Narrative
Impact	Critical need for an efficient, versatile, and practical payload handling solution for Moon and Mars surface missions. *“The [LSMS] is key to the sustainability of our Artemis missions to the Moon and Mars” – Administrator Bridenstine.*
Relevance / Timeliness	Artemis landers currently require a viable payload offload device for large cargo and human missions. In addition, private lander providers, and their customers are very interested in the LSMS to provide offloading and added capabilities and services. There is a strong pull for this technology in FY23 and FY24 for CLPS.
Technical Approach	Leverage heritage LSMS prototype work, and design and build HLS-focused, 5,000-kg tip capable LSMS EDU and proto-flight unit. Critical technologies addressed via component and full-scale tests on self-leveling base, packaging and deployment, and environmental tests on primary mechanisms / cables.
Leveraging / Partnering	Strong opportunities for partnering with commercial CLPS/HLS vendors, space industry, and academia for cost sharing in tool and advanced autonomy development.
Cost / Schedule	3-Year, $22M development to proto-flight LSMS (Phase I). Follow-on phase II program would perform system integration w/ lunar lander (commercial or NASA)