National Aeronautics and Space Administration

Overview of NASA's Moon-to-Mars Planetary Autonomous Construction Technology

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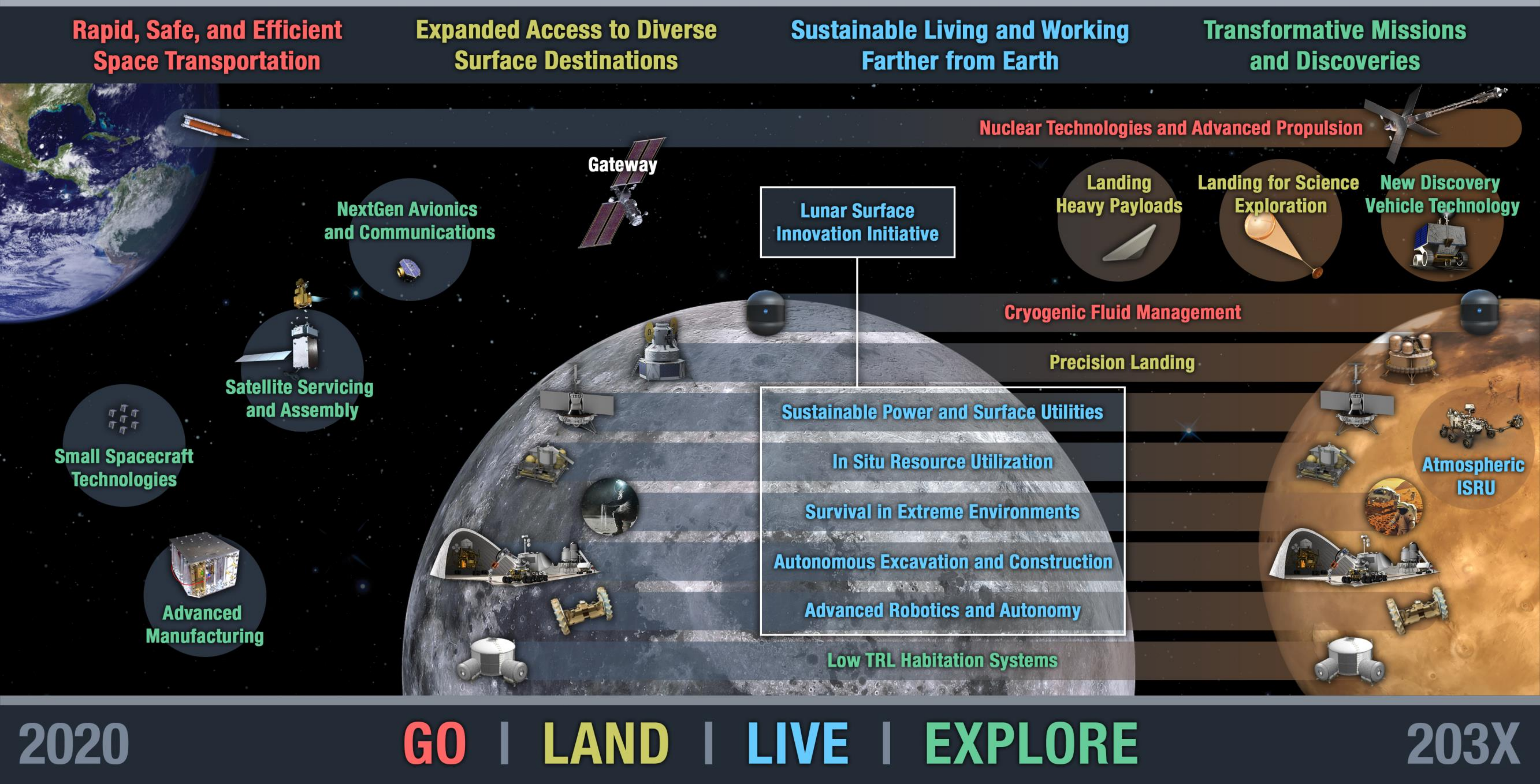
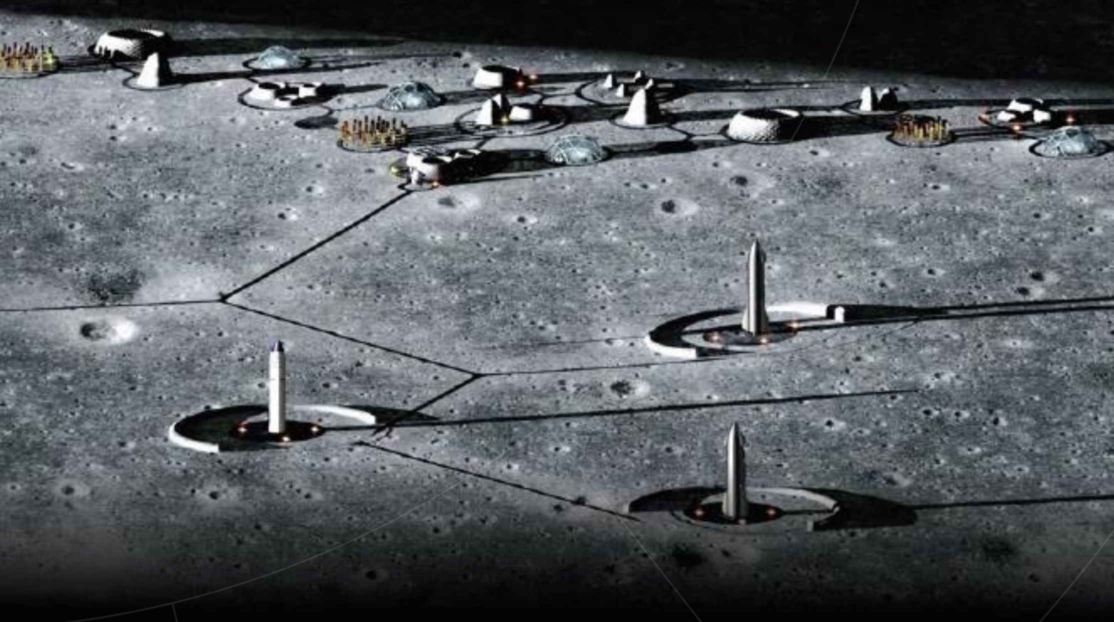
TECHNOLOGY DRIVES EXPLORATION



Moon-to Mars Planetary Autonomous Construction Technologies (MMPACT) Overview



GOAL

Develop, deliver, and demonstrate on-demand capabilities to protect astronauts and create infrastructure on the lunar surface via construction of landing pads, habitats, shelters, roadways, and blast shields using lunar regolith-based materials.

MMPACT is structured into three interrelated elements:

1. Olympus Construction Hardware Development
2. Construction Feedstock Materials Development
3. Microwave Structure Construction Capability

OBJECTIVES

- Demonstrate 3D-printing construction of various structures as materials evolve from Earth-based to exclusively *In Situ* Resource Utilization (ISRU)-based.
- Develop an approach for integrated sensors and monitoring in support of *in situ* verification & validation of Olympus system and printed structures.
- Develop microwave sintering ConOps, protocols/processing procedures and horn designs for lunar regolith simulant materials.
- Demonstrate microwave sintering construction of subscale structures while quantifying and managing thermal loads reflected from sintering regolith into the horn and waste heat.
- Develop cementitious blends that can originate from *in situ* resources for Olympus.
- Test and evaluate Olympus and MSCC products for use in the lunar environment.

MMPACT ELEMENTS, STRUCTURE, AND TEAM MEMBERS

PI: Clinton | **CE: Burlingame**

PM: Edmunson | **LSE: Thompson**

Resource Analyst: Clark

Construction Feedstock Materials Development
Edmunson

- MSFC CANs
  - Mississippi State University (2)
  - Branch Technologies
- MSFC CIFs (pending)
  - Mississippi State University
  - South Dakota School of Mines and Technology
- Penn State University (PSU) - NSTGRO

Olympus – Autonomous Construction System
Fiske

- AFWERX SBIR (W/AFCEC/TANG/DIU)
  - ICON Technologies
    - SEArch+
    - Bjarke Ingels Group
    - Blue Origin
    - Colorado School of Mines
- Jacobs
- LaRC
- MSFC CANs
  - UAH
  - University Of Mississippi
  - Drake State (2)
  - Sinte Gleska University
  - Blue Origin (In Review)
  - UAH (In Review)
  - Clarkson/PSU (In Review)
  - University Of Mississippi (In Review)
  - Kappler (In Review)
  - CANVAS (In Review)

Microwave Structure Construction Capability
Effinger

- JPL
- KSC
  - SURA
- LaRC
- Jacobs
- Dr. Holly Shulman
  - Microwave Properties North
- Radiance Technologies
- RW Bruce Assoc. LLC
  - JP Gerling Microwave Applications
  - Crown College
  - Space Resources Extraction Technologies
  - Microwave Materials Technologies
- Southern Research
- Aerie Aerospace
- MTS
- Logical Innovations
- Universities (2 Pending - FY22 Starts)

Autonomous Construction for the Lunar Outpost

Regolith-based Materials and Processes:

- Cementitious
- Geopolymers
- Thermosetting materials, including melting
- Laser sintered
- Microwave sintered

High Level Capability Gaps and Challenges

- Regolith excavation, beneficiation, transfer, and conveyance
- Deposition processes and associated materials
- Increased autonomy of operations
- Long-duration operation of mechanisms and parts under lunar environmental conditions (Reliability and Maintainability)
- Scale of construction activities
- Structural Health Monitoring and Repair
- Inspection and Certification of as-built structure
- Interdependencies on other infrastructure capabilities
- Material and construction requirements and standards

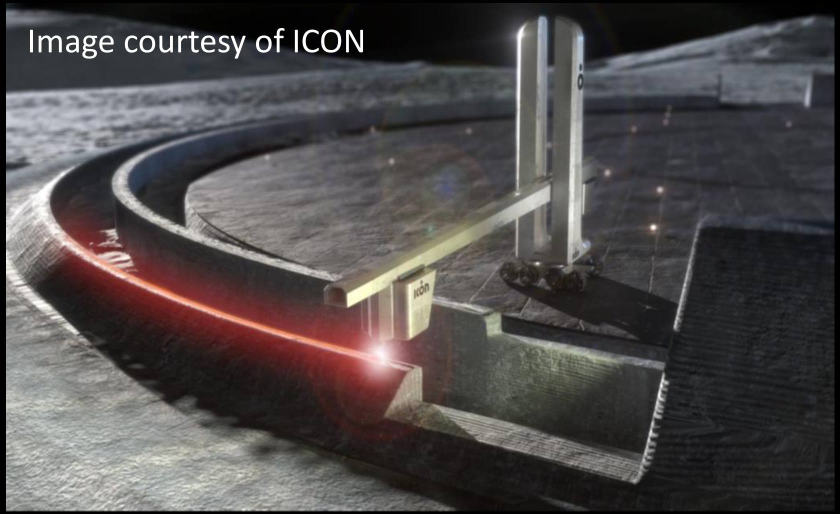


Image courtesy of ICON

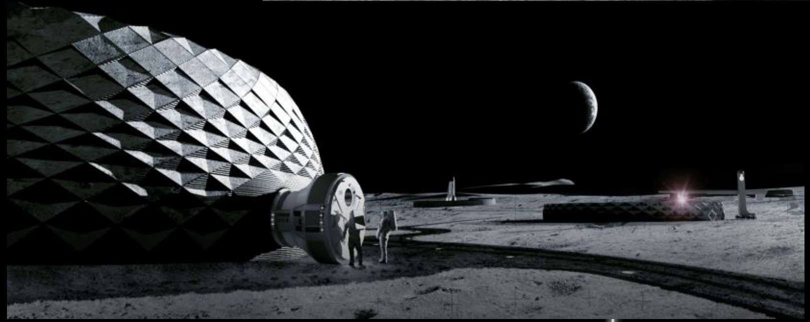


Image courtesy of Bjarke Ingels Group

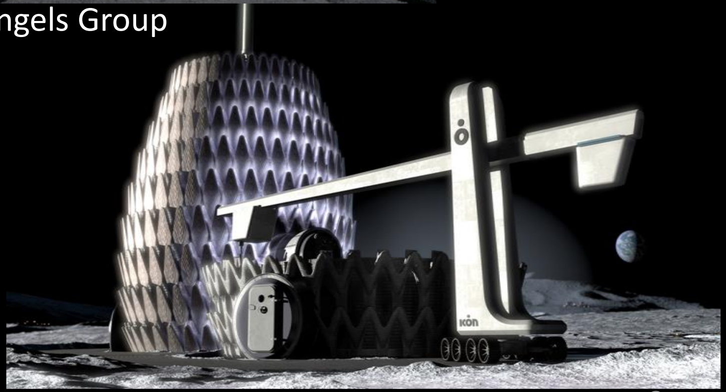
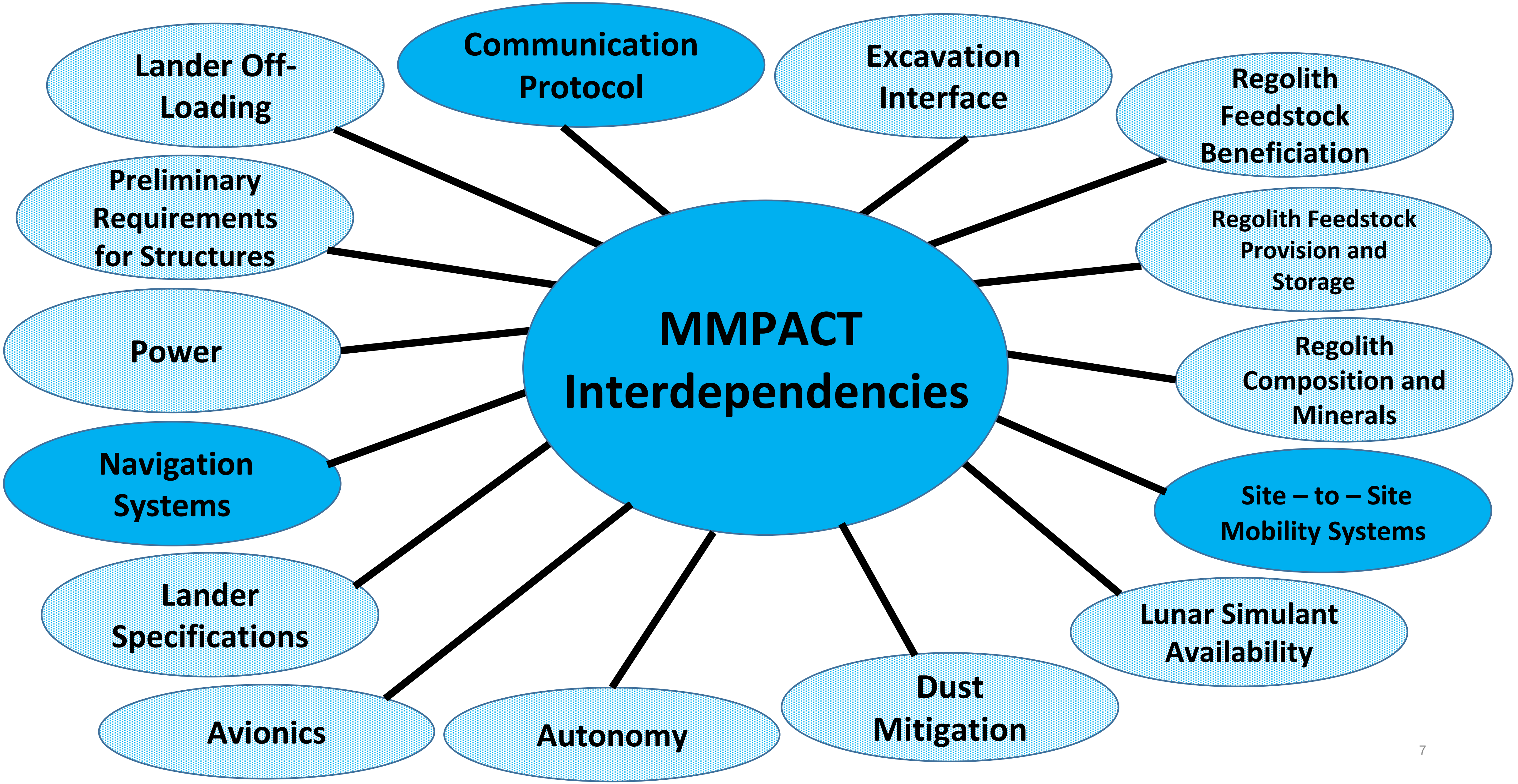


Image courtesy of SEArch+

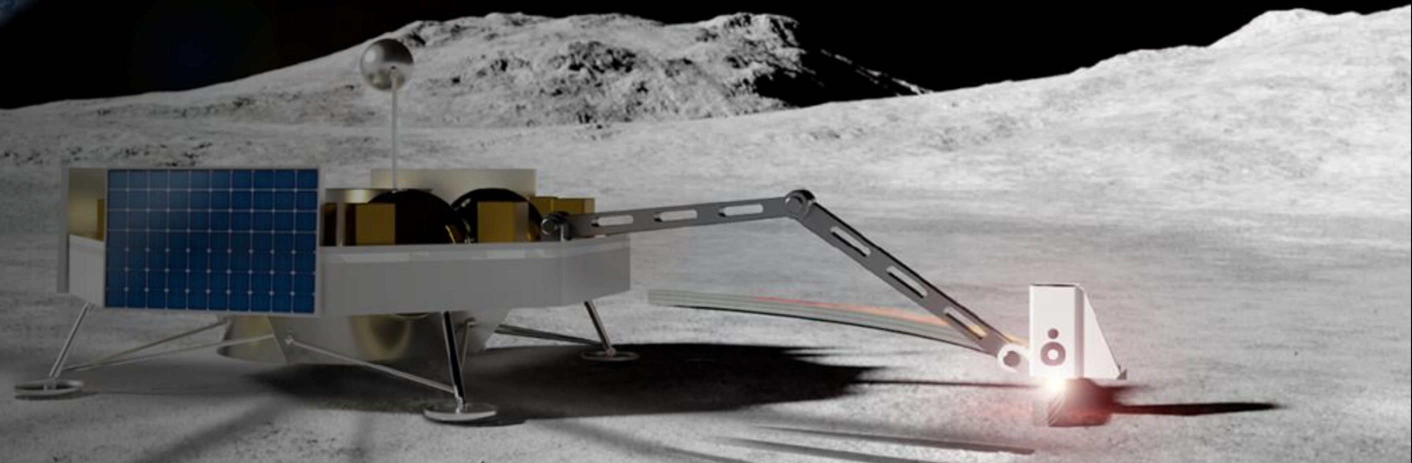
MMPACT Interdependencies (Primarily DM-2 and Beyond)



Initial Construction Technology Demonstration Mission, DM-1 (2026) MMPACT

Construction Roadmap

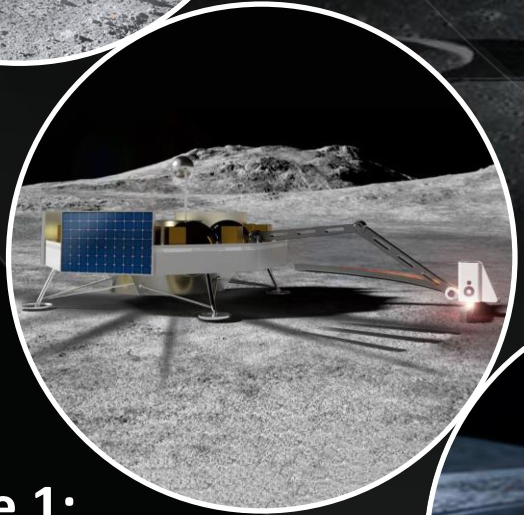
- Demonstrate downselected construction technique utilizing ISRU materials at small scale from lander base (horizontal and vertical subscale “proof of concept” elements)
- Results are critical to inform future construction demonstrations & characterize ISRU-based materials and construction processes for future autonomous construction of functional infrastructure elements
- Demonstration of remote/autonomous operations
- Initial demonstration of instrumentation and material
- Validation that Earth-based development and testing are sufficient analogs for lunar operations
- Anchors analytical models
- ***Rationale:*** *Must prove out initial construction concept in lunar environment*

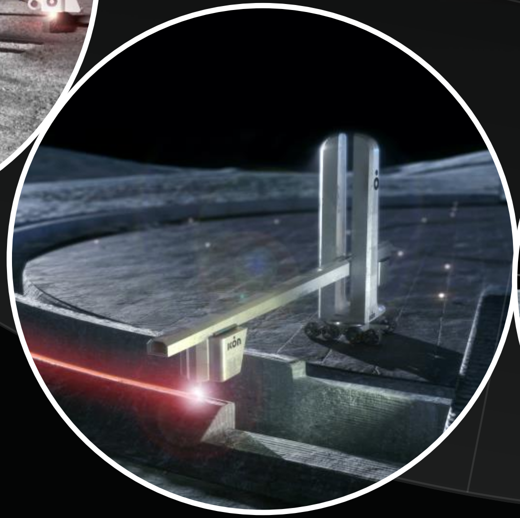


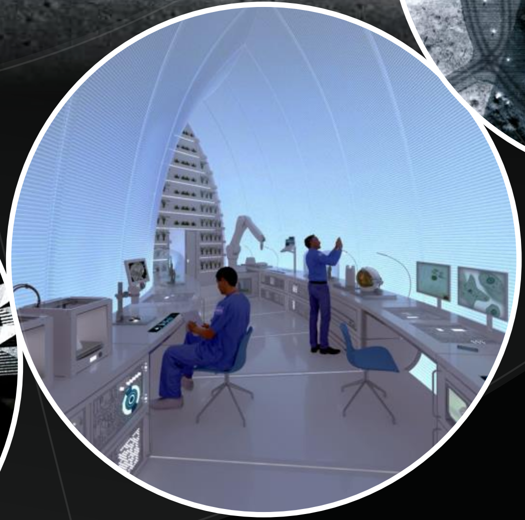
Outcome

- **TRL 6** achieved for autonomous ISRU consolidation into densified, subscale horizontal and vertical demonstration products
- **TRL 9** for limited hardware and instrumentation that will be used on later missions

Lunar Construction Capability Development Roadmap





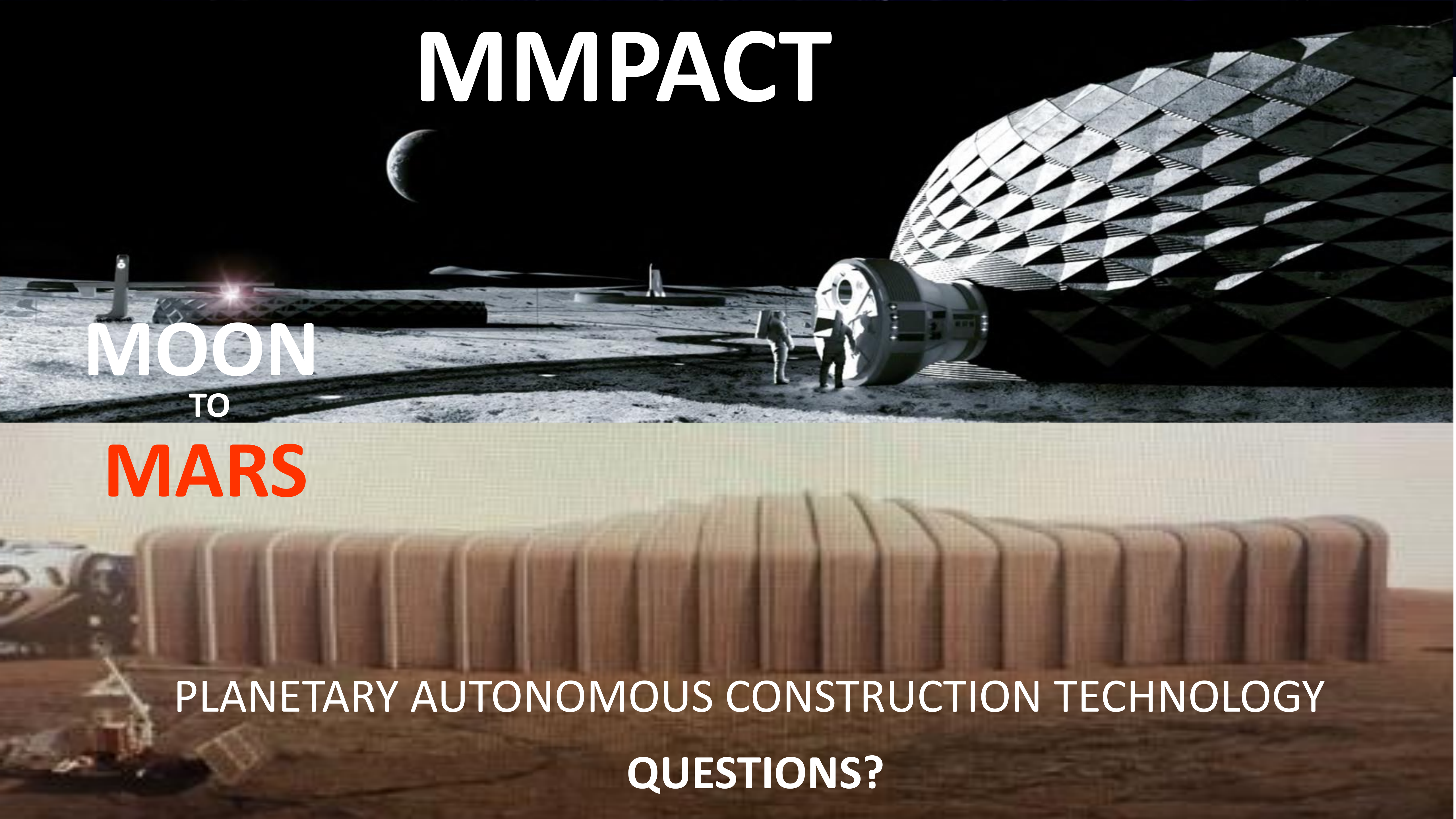


Phase 4: Complete build-out of the lunar base per the master plan and add additional structures as strategic expansion needs change over time.

Phase 1: Develop & demonstrate excavation & construction capabilities for on-demand fabrication of critical lunar infrastructure such as landing pads, structures, habitats, roadways, blast walls, etc.

Phase 2: Establish lunar infrastructure construction capability with the initial base habitat design structures.

Phase 3: Build the lunar base according to master plan to support the planned population size of the first permanent settlement (lunar outpost).


MMPACT
MOON
TO
MARS
PLANETARY AUTONOMOUS CONSTRUCTION TECHNOLOGY
QUESTIONS?