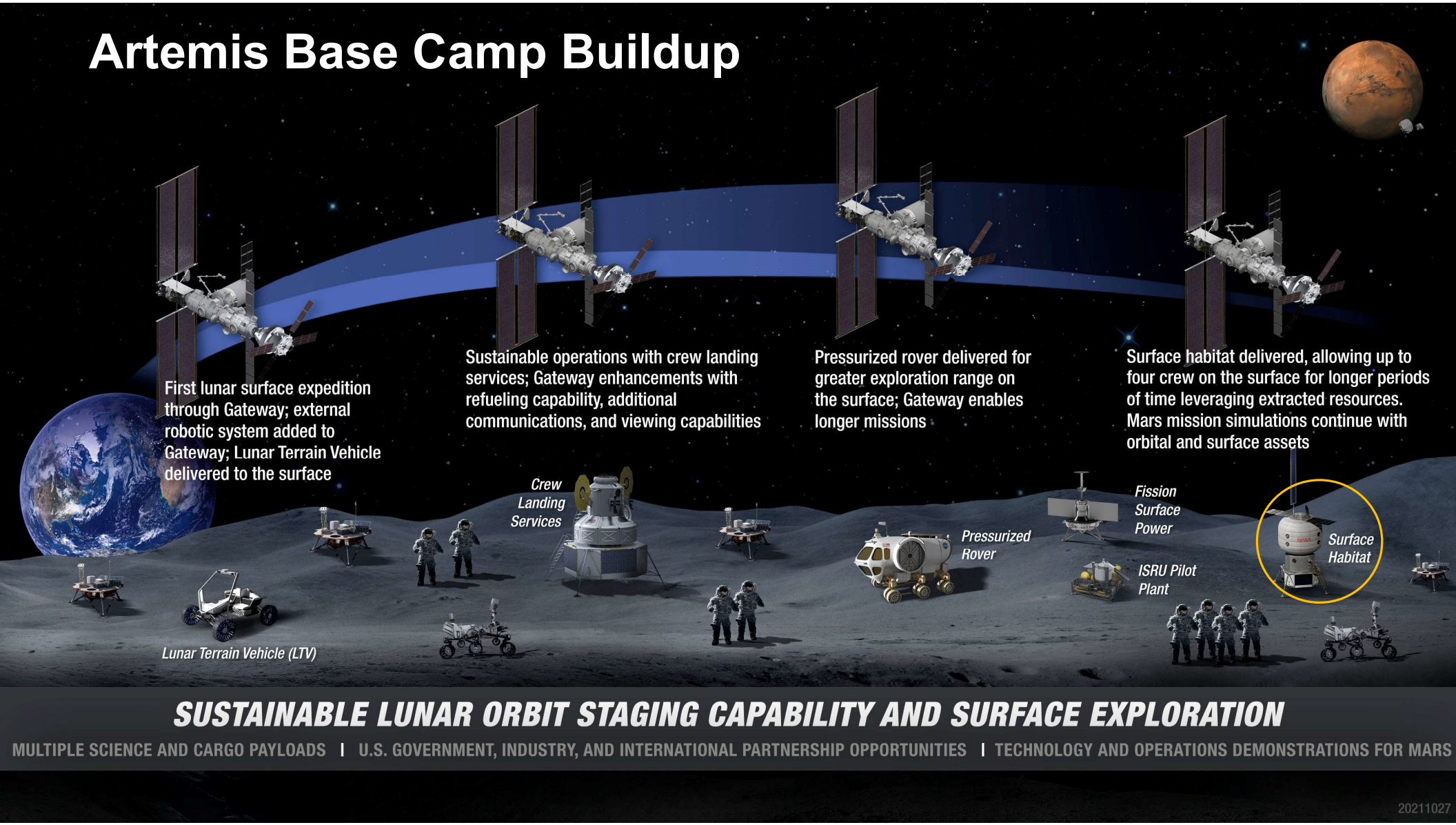
Habitation Systems Development Overview

Briefing for National Academies of Science, Engineering, and Medicine

NASA Marshall Space Flight Center


Artemis Base Camp Buildup
First lunar surface expedition through Gateway; external robotic system added to Gateway; Lunar Terrain Vehicle delivered to the surface
Sustainable operations with crew landing services; Gateway enhancements with refueling capability, additional communications, and viewing capabilities
Pressurized rover delivered for greater exploration range on the surface; Gateway enables longer missions
Surface habitat delivered, allowing up to four crew on the surface for longer periods of time leveraging extracted resources. Mars mission simulations continue with orbital and surface assets
Crew Landing Services
Pressurized Rover
Fission Surface Power
ISRU Pilot Plant
Surface Habitat
Lunar Terrain Vehicle (LTV)
SUSTAINABLE LUNAR ORBIT STAGING CAPABILITY AND SURFACE EXPLORATION
MULTIPLE SCIENCE AND CARGO PAYLOADS | U.S. GOVERNMENT, INDUSTRY, AND INTERNATIONAL PARTNERSHIP OPPORTUNITIES | TECHNOLOGY AND OPERATIONS DEMONSTRATIONS FOR MARS
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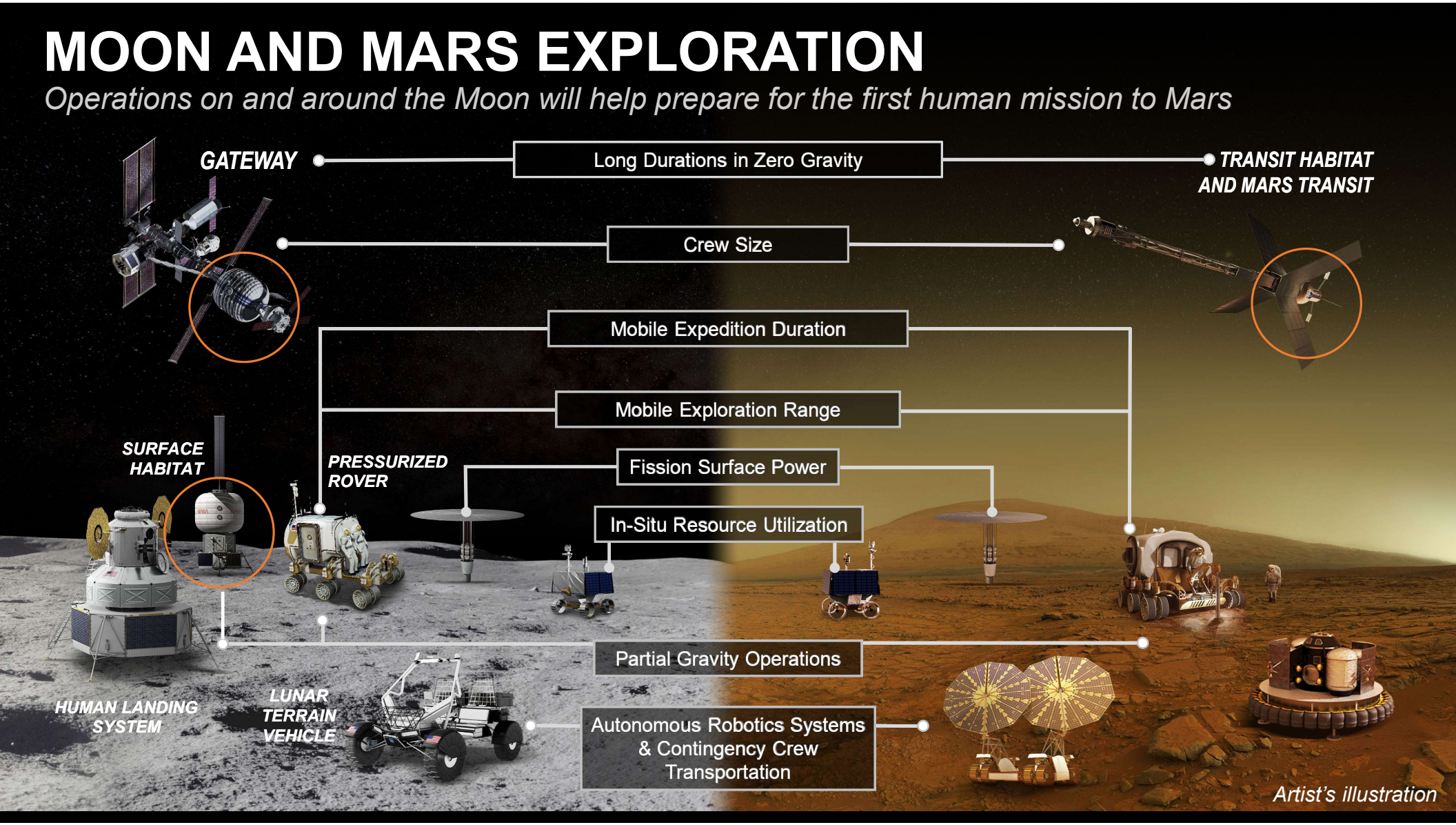
MOON AND MARS EXPLORATION

Operations on and around the Moon will help prepare for the first human mission to Mars



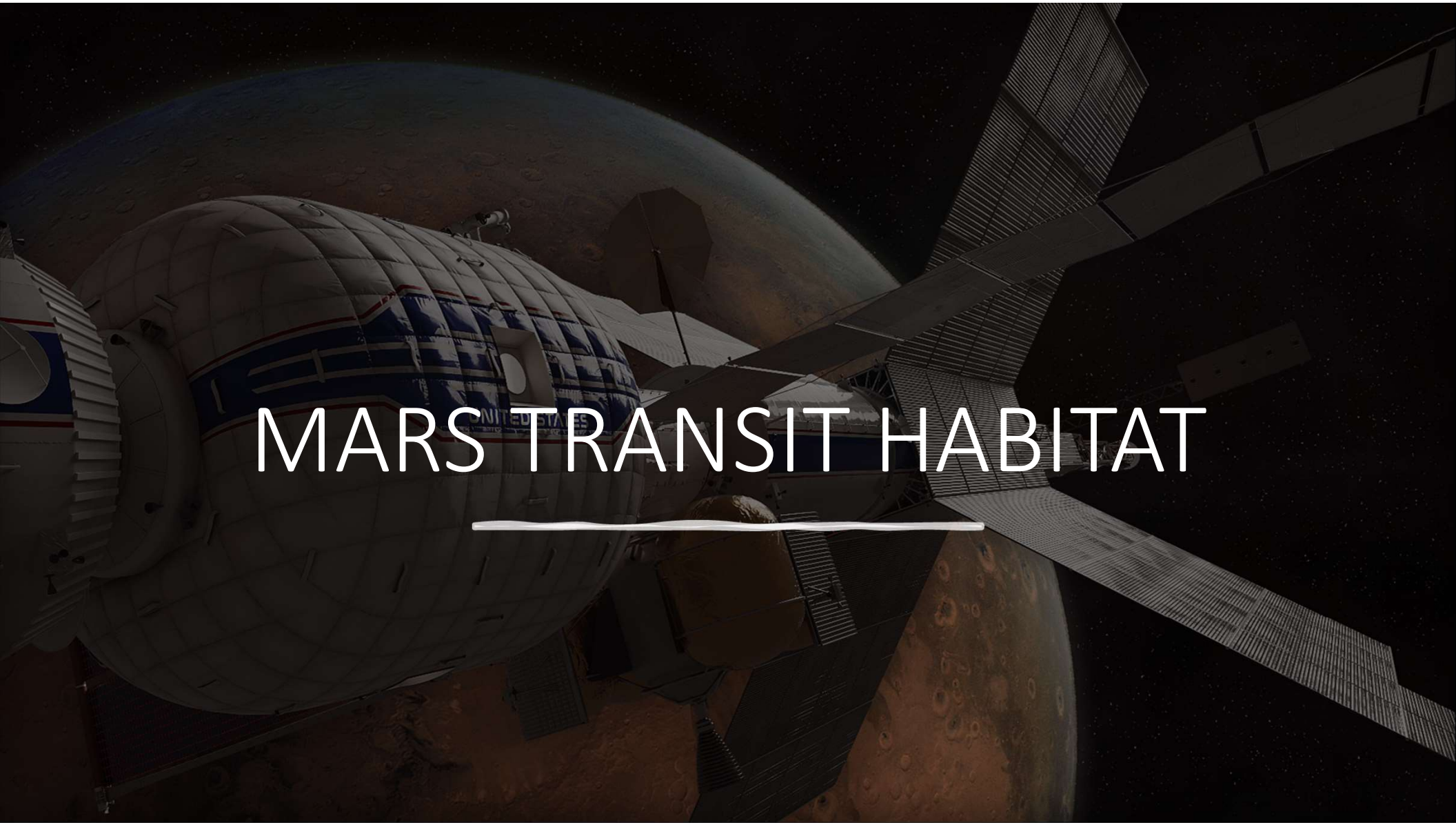
LUNAR SURFACE HABITATION

Surface Habitat Overview

- 2 crew for 30 days with short durations with 4 crew
- Pressurized Rover carries 2 crew with swap outs
- 15 year life with 10 year operational life
- 8.2 psia, 34% O_2 atmosphere
- Habitat remains on lander for operations
- Self-sufficient habitat once fully deployed on surface
  - Habitat provides its own energy storage, power generation, environmental control and life support systems, avionics, etc. and is not dependent on other surface assets
- 12 mt target delivery mass

Surface Habitation Challenges

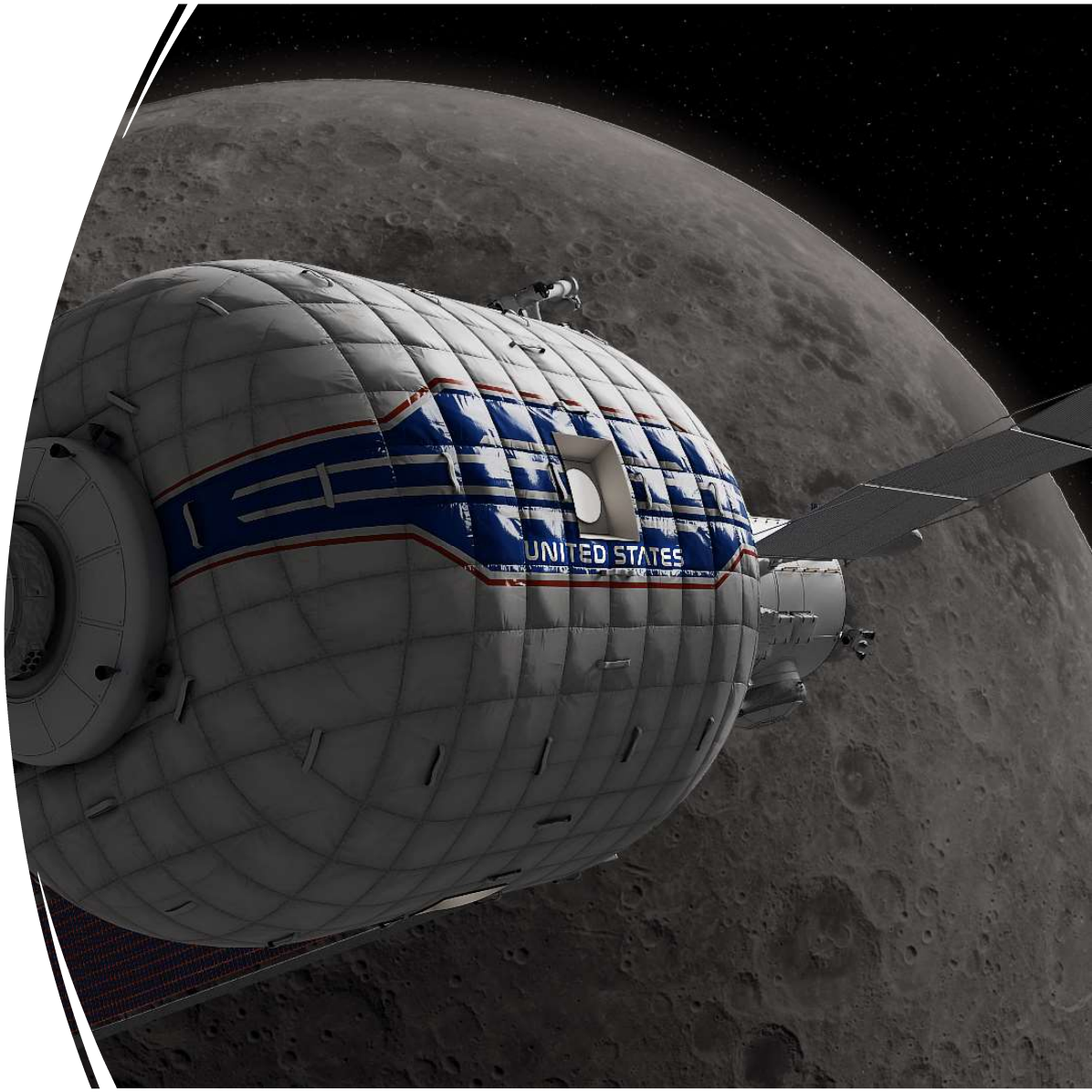
- Delivery Mass
- Functional Volumes
- Outfitting
- Dust mitigation
- Radiation
- Dormancy
- Survive the night thermal/power
  - Power conservation
  - Energy storage solutions with improved energy density
- Logistics delivery and loading
- Capability to maintain and repair systems

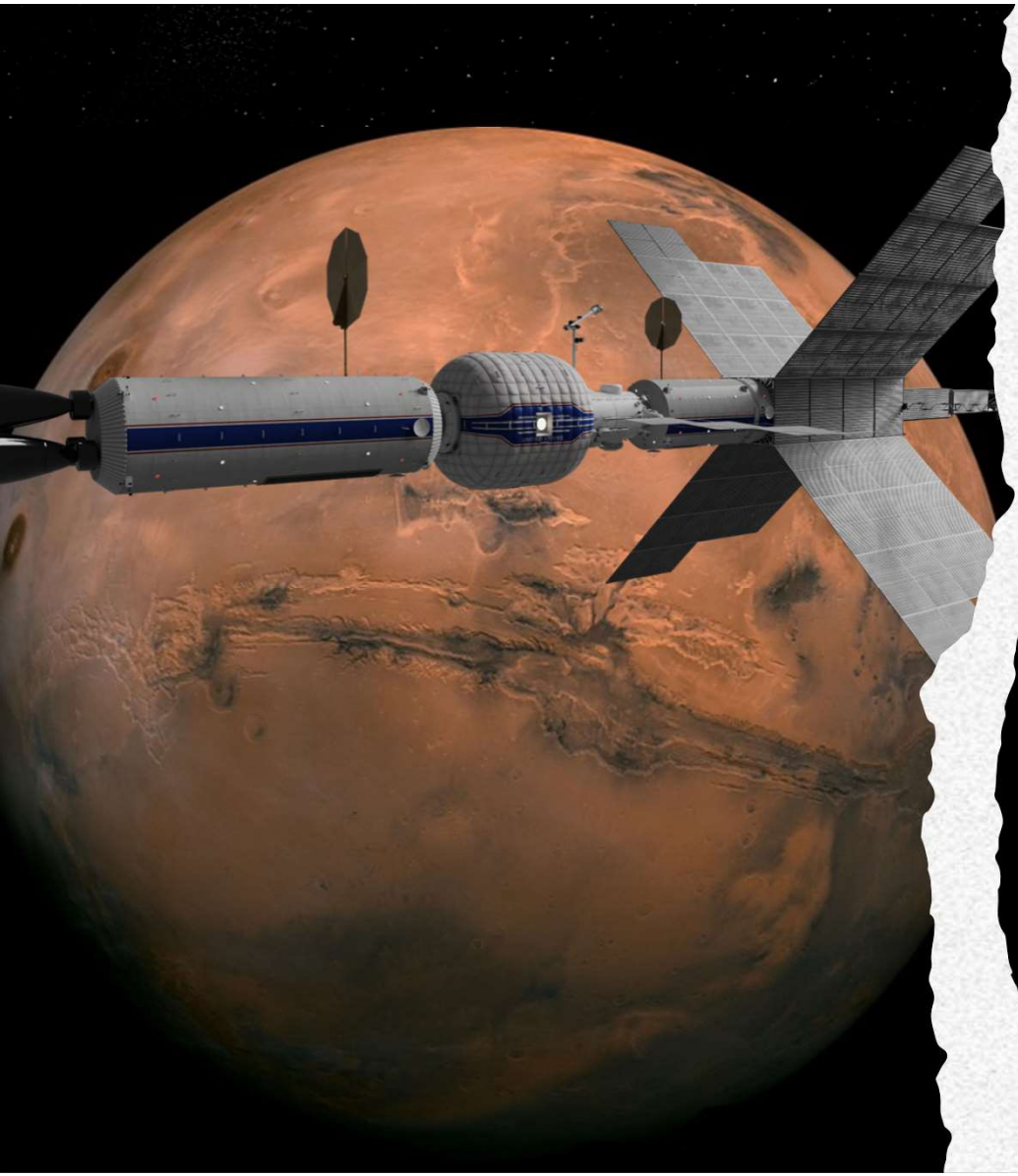


MARS TRANSIT HABITAT

Transit Habitat Overview

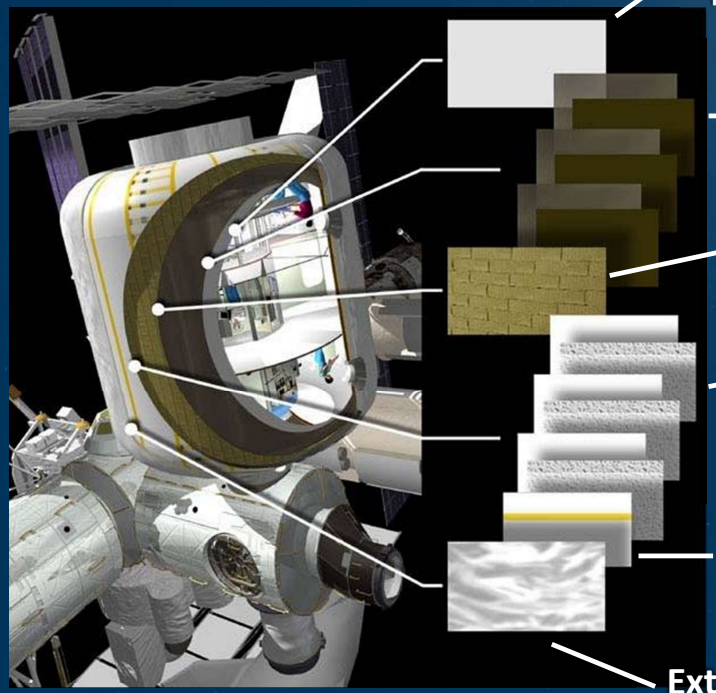
- Hybrid inflatable-metallic habitat with dry mass (26.4 metric tons) capable of being launched commercially and supplied with logistics in cis-lunar orbit (NRHO)
- Support 4-crew during Lunar-Mars Analog missions leading up to an up to 1,200 day Mars mission
- Dock w/ an interim propulsion bus or Gateway until Mars Propulsion System (MPS) elements available
- Extends Gateway operations beyond 60 days
- 10.2 psia (26.5% O2) atmosphere for Gateway ops
- 14.7 psia (21% O2) atmosphere for transit and analog missions
- Contingency Airlock and EVA capability
- Planned reuse for multiple missions over 15-year lifetime





Mars Transit Challenges

- No spares resupply chain
- Impact on propulsion element size
- Waste and trash management in transit/loiter orbits
- Logistics storage capacity for mission
- Human health and performance for long duration missions
- Long duration shakedown
- Radiation & Micrometeoroid Oribtal Debris (MMOD) protection
- Communication delays/blackouts
- Ability to recover from major habitation failures



Internal Scuff Layer: Protects against punctures and fires

Bladder: Keeps air inside the habitat from escaping

Restraint Layer: Main structure that helps hold the inflatable together

Micro-meteoroid/ Orbital Debris Shield: Multiple layers protect the structure from impacts

Thermal Blanket: Protects the crew from extreme temperatures

External Shield: Protects the habitat from erosion by molecules in space or moon dust

Inflatable Softgoods

Primary structural material for habitable volume in both lunar surface habitat and Mars transit habitat government reference designs

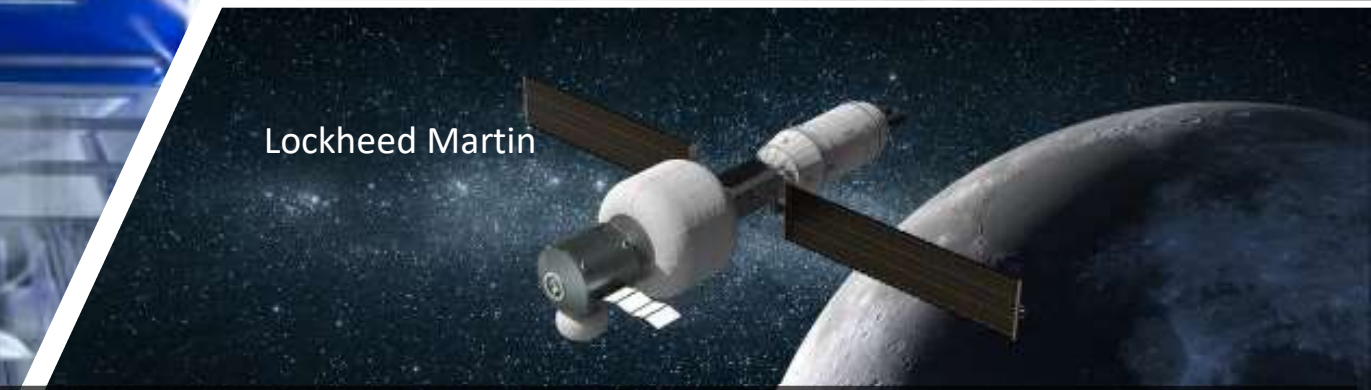
Commercial Partnerships

Public-Private Partnerships: NextSTEP Appendix A: Habitation Systems

Phase 3 Partners: Sierra Space, Lockheed Martin, and Boeing

Boeing

Sierra Space



Lockheed Martin

Phase 1 – 2015-2016: Concept Designs and Operations
Phase 2 – 2016-2019: Prototype Development and Testing
Phase 3 – 2019-present: Concept maturation and focus on long-duration, in-space and surface habitats

Inflatable softgoods testing

- NASA published certification guidelines for crewed inflatable softgoods structures in 2022
  - Recommends burst testing at subscale and full-scale module level, creep testing at component and subscale module level, among numerous other tests to determine failure modes and estimate operational life of structure
- Marshall has developed unique test capabilities to support softgoods certification
  - Subscale burst operational; full-scale burst test area will be first of its kind
  - Creep test position 1 operational; position 2 under construction
  - Currently supporting industry in testing and risk reduction efforts under both NextSTEP Appendix A and reimbursable space act agreements (RSAAs)
    - Testing supports both exploration habitation and commercial low earth orbit (LEO) development

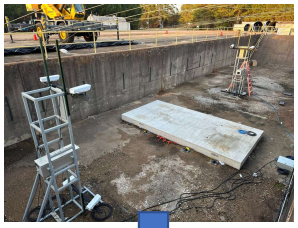

Baseline

CERTIFICATION GUIDELINES
FOR CREWED INFLATABLE
SOFTGOODS STRUCTURES

August 3, 2022

National Aeronautics and
Space Administration

Testing at MSFC



Subscale burst test for Sierra Space (NextSTEP)

Subscale creep test for Sierra Space (RSAA)