NASA's Habitation Development Status:

Current Concepts and ISRU Opportunities

National Aeronautics and Space Administration

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NASA's Habitation Systems Development Office

ARTEMIS

NASA's Habitation Systems Development Team

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NASA’s Moon to Mars Strategy and Objectives

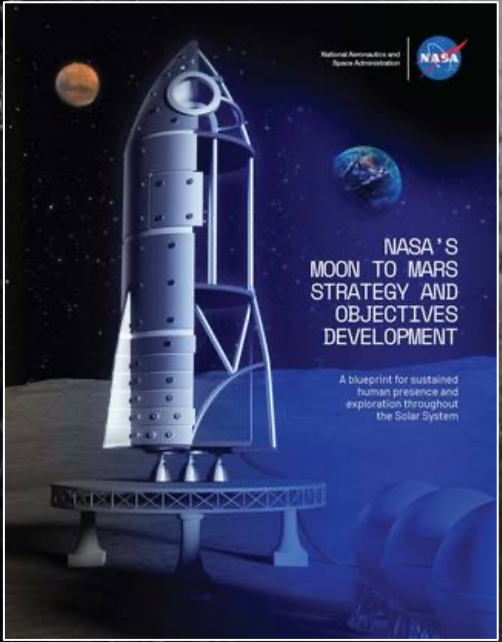
A blueprint for future human exploration (Architecting from the Right)

ARCHITECTURE

Iterate and evolve through annual Architecture Concept Reviews

Goals and Objectives

- **SCIENCE**
- **TRANSPORTATION AND HABITATION**
- **LUNAR AND MARS INFRASTRUCTURE**
- **OPERATIONS**



go.nasa.gov/3zzSNhp

Requested feedback on these objectives in summer 2022 from the following key stakeholders:

- NASA workforce: our greatest asset
- International partners: our key current and future, anticipated collaborators
- U.S. industry, academia, DOE, NIH, NSF, etc.: our national leaders in space research and capabilities

Executing from the Left: Segments and Sub-architectures

Segment: A portion of the architecture, identified by one or more notional missions or integrated use cases, illustrating the interaction, relationships, and connections of the sub-architectures through progressively increasing operational complexity and objective satisfaction.

Human Lunar Return	Foundational Exploration	Sustained Lunar Evolution	Humans to Mars
Initial capabilities, systems, and operations necessary to re-establish human presence and initial utilization (science, etc.) on and around the Moon.	Expansion of lunar capabilities, systems, and operations supporting complex orbital and surface missions to conduct utilization (science, etc.) and Mars forward precursor missions.	Enabling capabilities, systems, and operations to support regional and global utilization (science, etc.), economic opportunity, and a steady cadence of human presence on and around the Moon.	Initial capabilities, systems, and operations necessary to establish human presence and initial utilization (science, etc.) on Mars and continued exploration.
Focus for ACR 22			**Focus for ACR 23**

Sub-architecture: A group of tightly-coupled systems, functions, and capabilities that perform together to accomplish architecture objectives.

Communication, Positioning, Navigation, and Timing • Habitation • Human Systems • Logistics • Mobility Systems • Power • Transportation • Utilization Systems

ACR = Architecture Concept Review

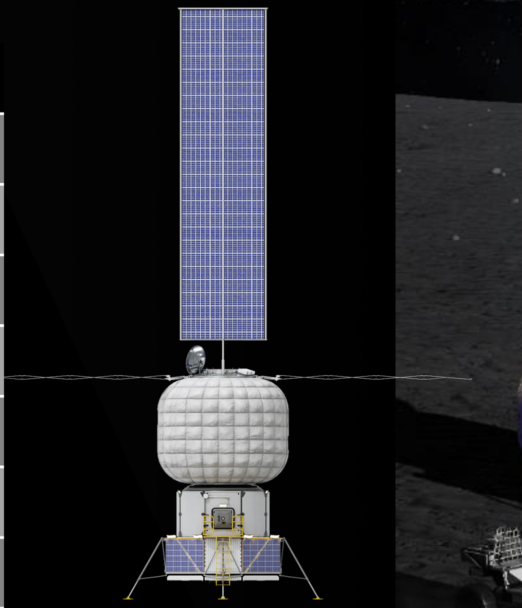
Surface Habitat Reference Concept

NASA's surface habitat concept serves as a central hub for building & initial sustainment of Artemis' **<u>Foundational Exploration</u>** activities

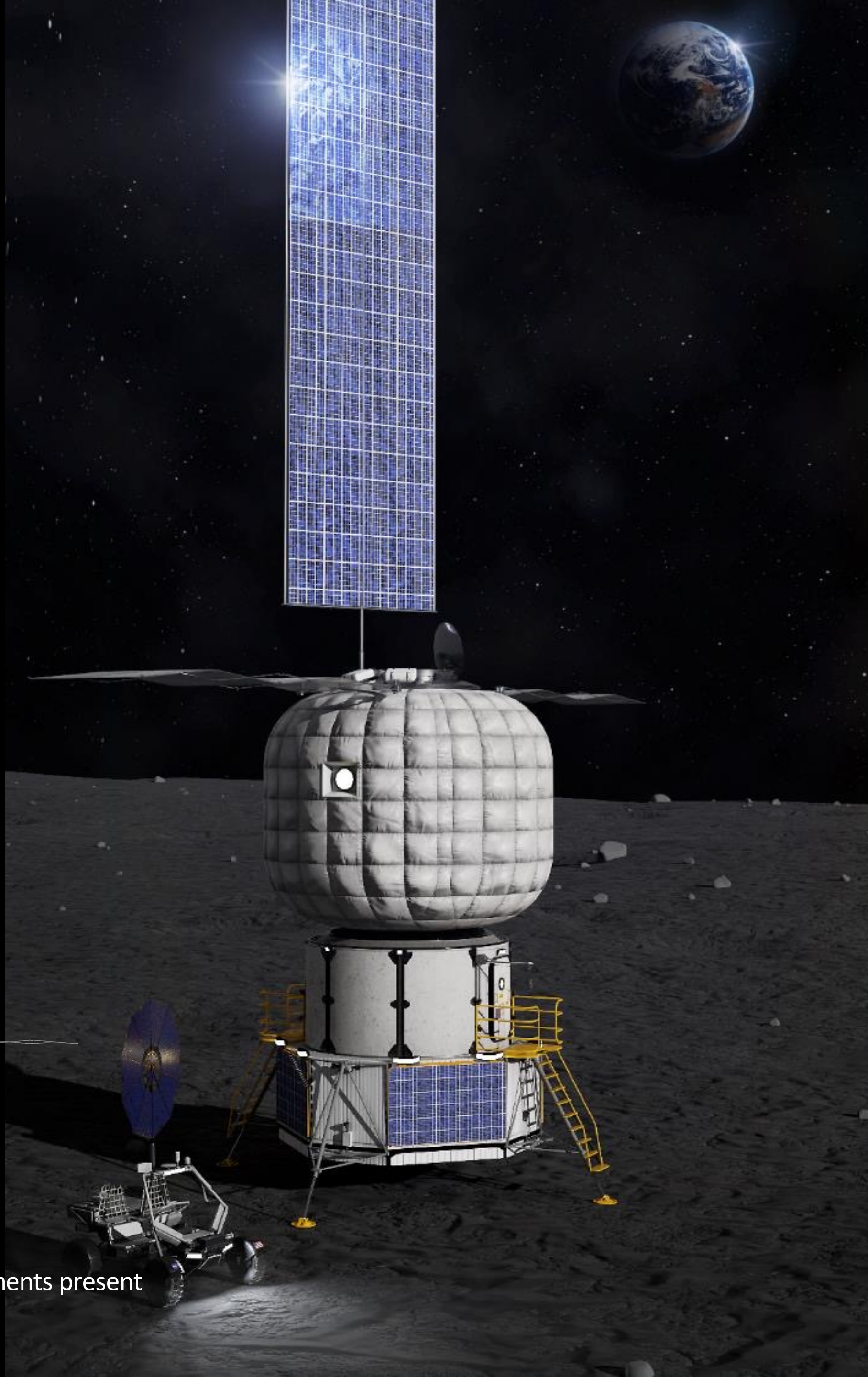
Key Surface Habitat functions:

- Power generation & energy storage (100 hrs)
- Open/Regenerative Environmental Control & Life Support (ECLS)
- Extravehicular Activity (EVA) support & suit maintenance
- Communications & data relay
- Medical support

Surface Habitat Concept Design Characteristics[1]	
Crew Size	2 crew (nominal) – 4 crew (surge*)
Mission Duration	~30 days (initial) – 60 days (extended)
Lifetime	15 years
Mass Target	12 mt (goal)
Max Power	15 KWe
Pressurized Volume	~190 m^3
Operating Pressure	8.2 – 10.2 psia (70.3 – 56.5 kPa)
Oxygen Composition	34-26.5% (limits for 8.2-10.2 psia)



*Surge capacity when other elements present



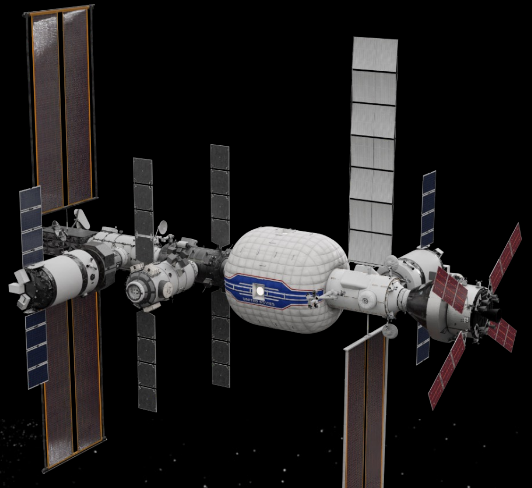
[1] Harris, Danny W., et al. *Moon to Mars (M2M) Habitation Considerations: A Snap Shot As of January 2022*. No. M-1538. 2022.

Transit Habitat Reference Concept

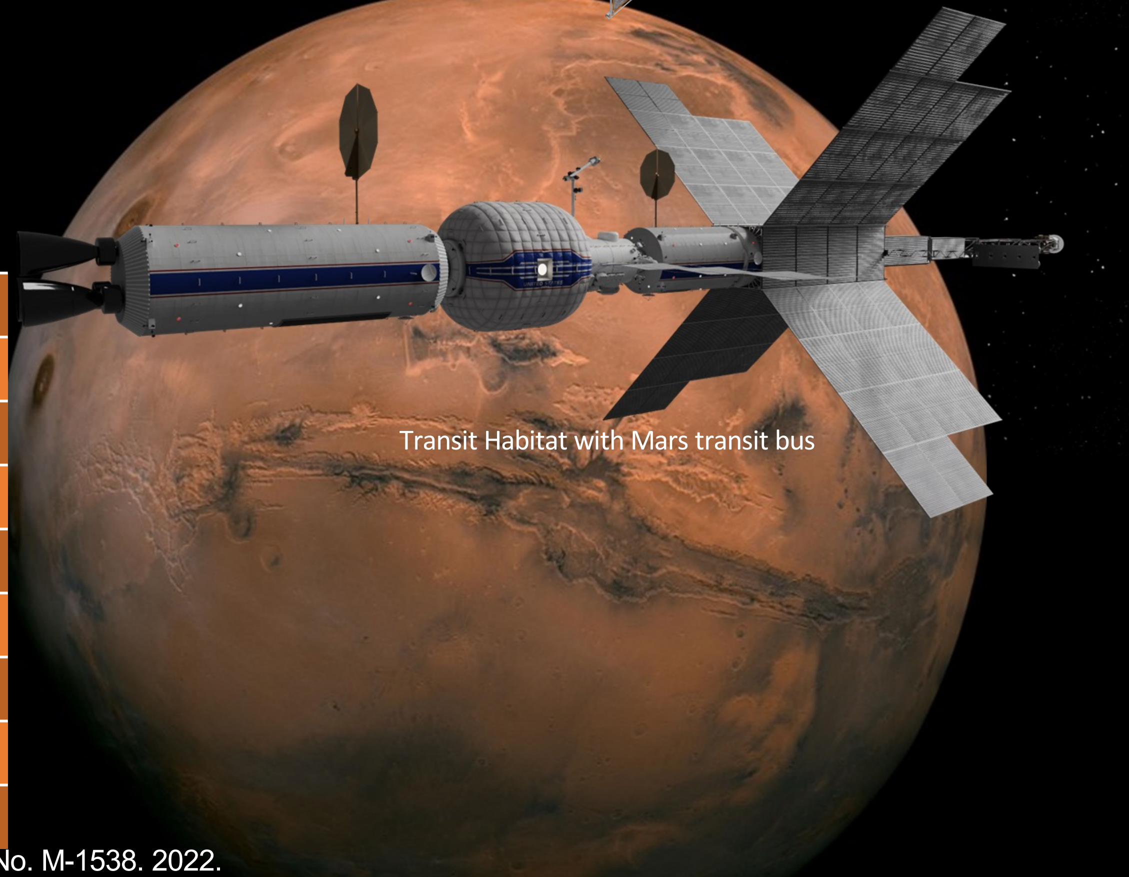
NASA's transit habitat serves as crew living quarters during Mars analog and exploration missions during Artemis' **Foundational Exploration** through **Humans to Mars** activities

Key Transit Habitat functions:

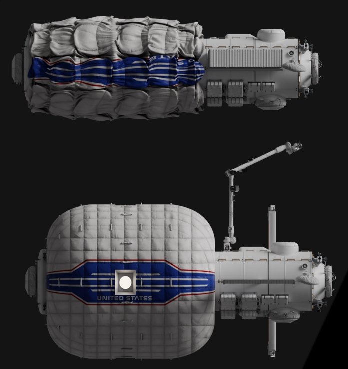
- Resource sharing and interfacing across multiple lunar and Mars architectures
- Radiation and Solar Proton Event (SPE) protection
- Docking capabilities
- Regenerative ECLS
- Logistics storage



Transit Habitat at Gateway



Transit Habitat with Mars transit bus



Transit Habitat Concept Design Characteristics[1]

Crew Size	4 crew
Mission Duration	Up to 1,200 days
Solar Orbital Range	0.6 – 1.6 AU
Lifetime	15 years
Mass Target	26.4 mt dry, ~50 mt Mars departure mass
Max Power	20 KWe
Pressurized Volume	~400 m^3
Operating Pressure	10.2 – 14.7 psia (56.5-101.4 kPa)
Oxygen Composition	26.5-24.1% (limits for 10.2-14.7 psia)

[1] Harris, Danny W., et al. *Moon to Mars (M2M) Habitation Considerations: A Snap Shot As of January 2022*. No. M-1538. 2022.

NextSTEP Appendix A - Habitation

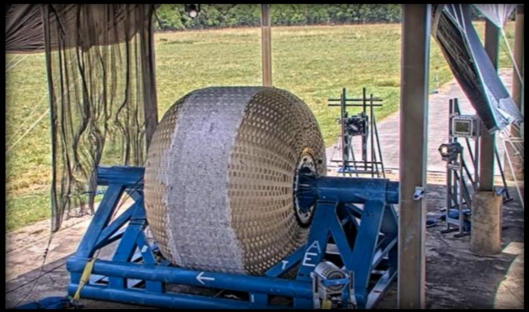
Advancing near-term habitation reference concepts through collaborative public-private partnerships

- Current contracted partners
  - Boeing
  - Lockheed Martin
  - Sierra Space
- Softgoods (inflatable) advancement
  - Burst testing:
    - Determine ultimate burst pressure of article
  - Creep testing*:
    - Determine material deformation under load
    - Estimate operation life of structure
- Additional efforts:
  - Habitat concept design & maturation
  - Structural material trades & exploration

*2 Sierra Space creep tests completed outside of NextSTEP funding via reimbursable space act agreements.

Sierra Space Burst Test Video - YouTube

Lockheed Martin Burst Test Video - YouTube



NASA before/after images from test conducted at Johnson Space Center in collaboration with Sierra Space and ILC Dover

Habitation System Challenges

Surface Habitat

- ❖ Limited spares/logistical resupply chain
- Logistics storage capacity
- ❖ Limited maintenance & repair capability
- ❖ Radiation protection
- Dormancy periods (up to 3 years)
- ❖ Survive the night thermal/power
  - Power conservation
  - Energy storage solutions
- Delivery mass constraints
- Dust contamination

Common challenge (Limited spares/logistical resupply chain ↔ No spares/logistical resupply chain)

Common challenge (Limited maintenance & repair capability ↔ No maintenance & repair capability)

Transit Habitat

- ❖ No spares/logistical resupply chain
- Logistics (frozen & dry) storage capacity
- ❖ No maintenance & repair capability
- Radiation protection
- Dormancy periods (up to 3 years)
- Impact on propulsion element size
- ❖ Communications delays/blackouts
- Human health and performance for long duration microgravity missions
- ❖ Waste and trash management in transit/loiter

❖ Possible ISRU opportunity or in-situ service

Challenges faced by NASA's current habitation concepts may be opportunities for ISRU demonstration

ISRU Opportunities for Habitation

Logistics Reduction

- In-situ produced **oxygen & water** for ECLS supply/replenishment
- In-situ produced **oxygen & hydrogen** for fuel cell reactant replenishment

Maintenance Support

- In-situ produced **feedstocks** for additive manufacture of spare/replacement parts
- Landing pads, roads, berms to mitigate plume effects & debris transport

Radiation Protection

- Regolith-produced **shielding materials** for safe havens or fission power systems

Survival Power

- **Power generation and/or energy storage as a service**
- Regolith-produced **thermal barriers** for sensitive materials

Communications Support

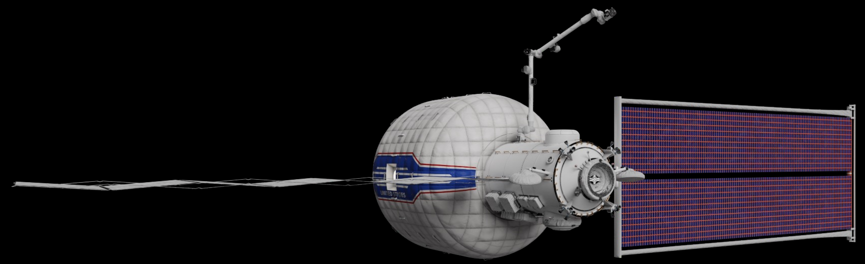
- Disruption-tolerant **relay systems as a service**

Consumable[1,2]	Surface Habitat (4 crew, 28 days)	Transit Habitat (4-crew, 1110 days)
Oxygen (open-loop)	92+ kg	N/A
Oxygen (regenerative)	30 kg	123 kg
Water (open-loop)	1,139+ kg	N/A
Water (regenerative)	288 kg	182 kg

[1] Harris, Danny W., et al. *Moon to Mars (M2M) Habitation Considerations: A Snap Shot As of January 2022*. No. M-1538. 2022.
[2] Anderson, Molly S., Michael K. Ewert, and John F. Keener. *Life support baseline values and assumptions document*. No. NASA/TP-2015-218570/REV1. 2018.

Habitat outputs (packaging & human waste materials, unprocessed CO_2, etc.) may also be available to support repurposing

ISRU pilot demonstrations may mitigate habitation challenges while building towards sustainable & profitable capabilities



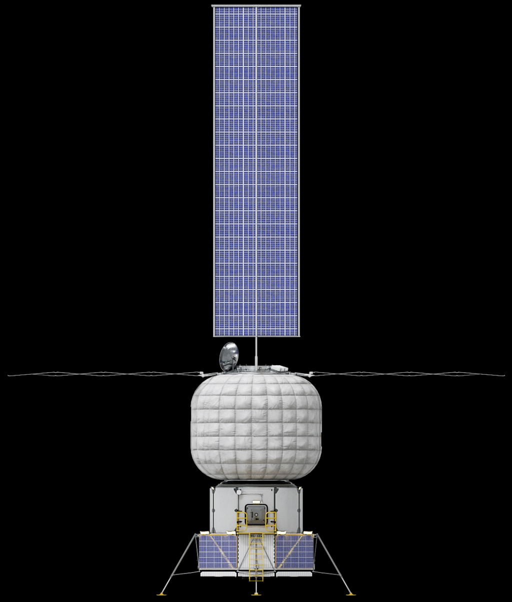


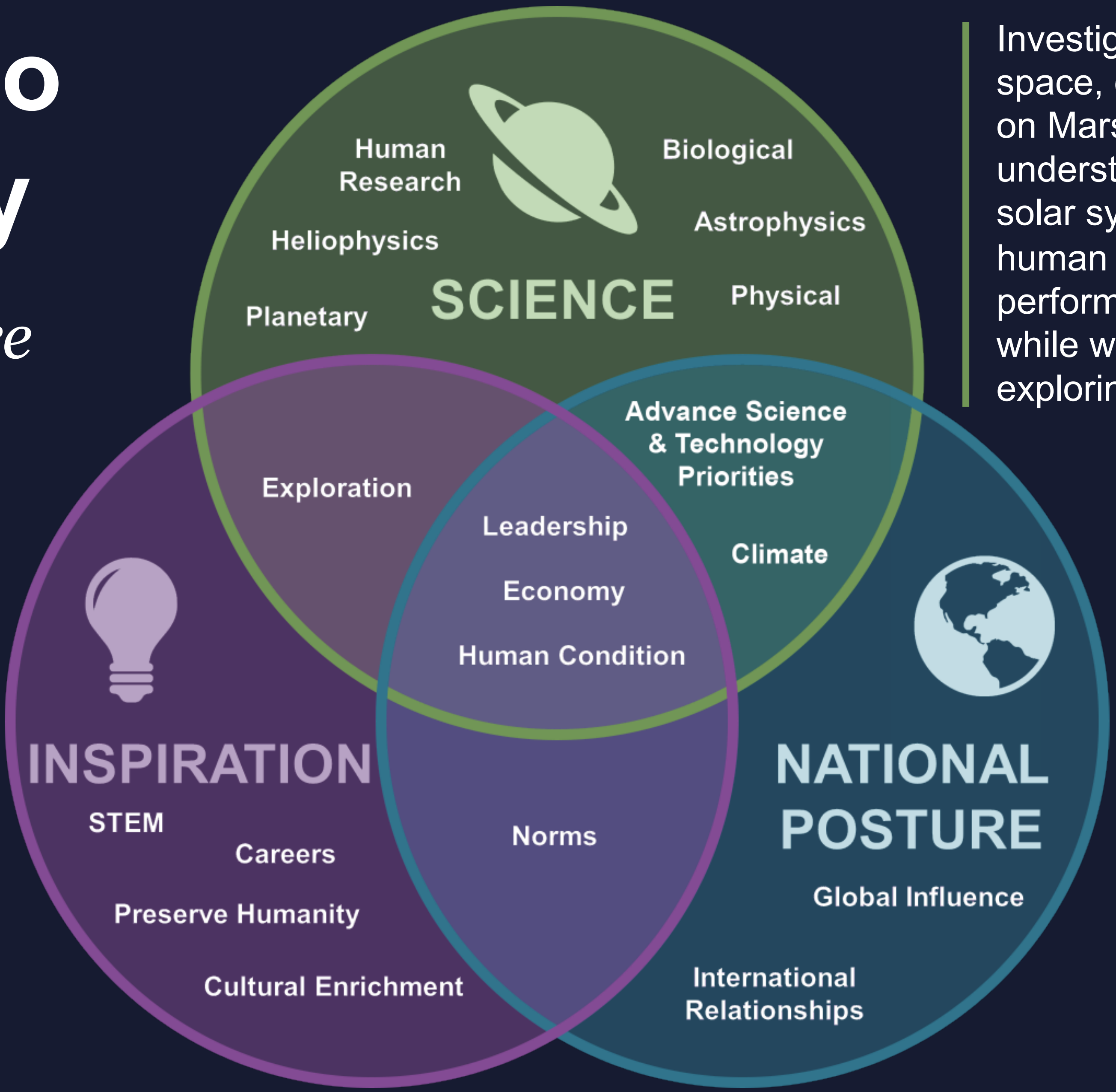
Image from ICON and SEArch+.

NASA.gov

BACKUP CHARTS

Benefits to Humanity

Why We Explore



Investigations in deep space, on the Moon, and on Mars will enhance our understanding of the solar system, Earth, the human body, and how to perform new operations while we are out there exploring.

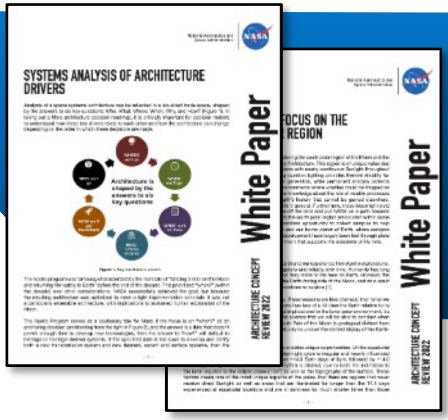
Accepting audacious challenges and succeeding through perseverance and tenacity in the face of adversity motivates current and future generations to dare mighty things.

What we choose to do, how we do those things, and who we do them with greatly impacts our place in the world today, our quality of life, and our possibilities for the future.

Architecture Concept Review Products

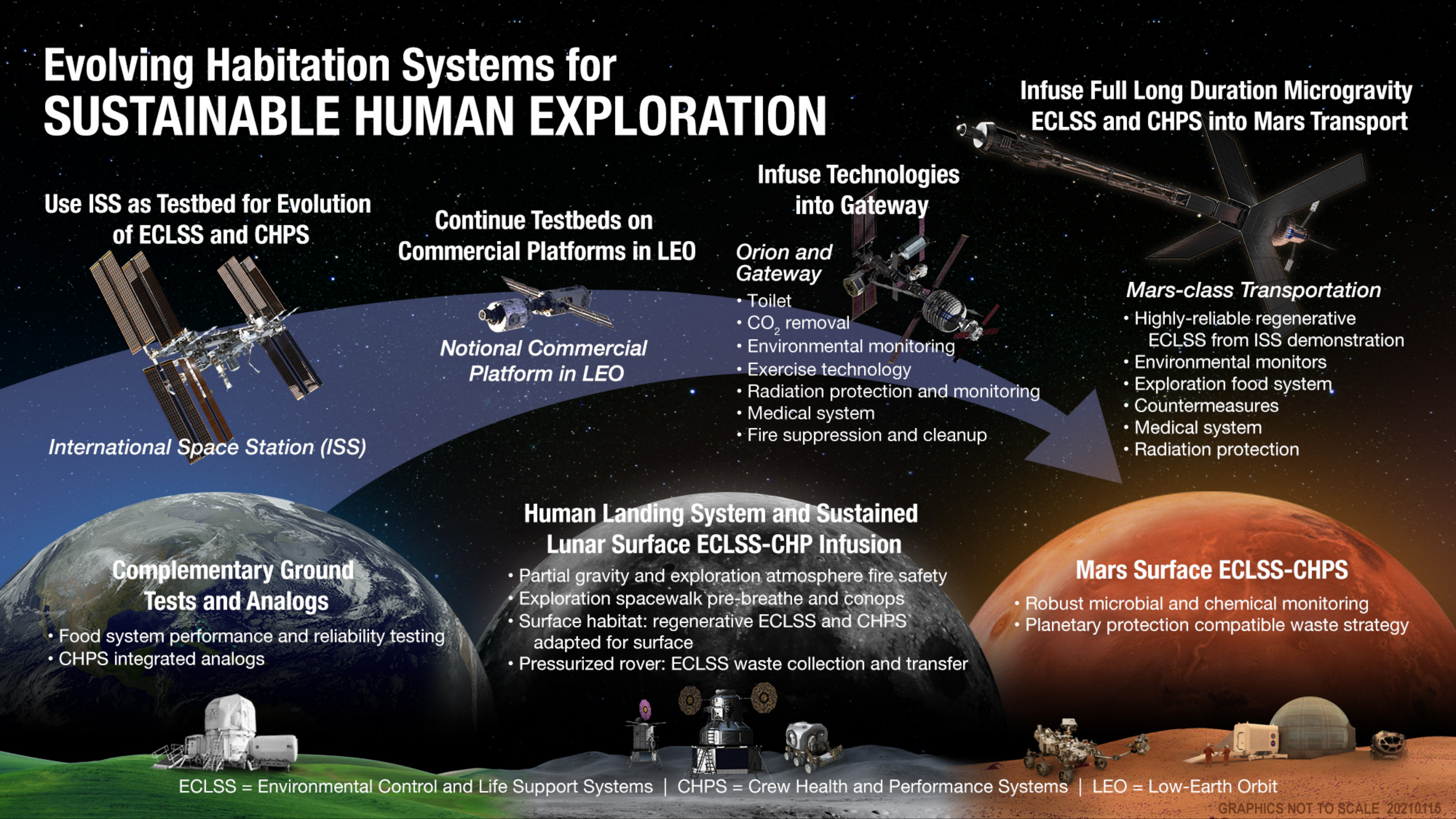
Architecture Definition Document
Detailed documentation snapshot of NASA's human spaceflight architecture and exploration strategy

Moon to Mars Architecture Summary
High-level overview of NASA's Moon to Mars architecture and exploration strategy

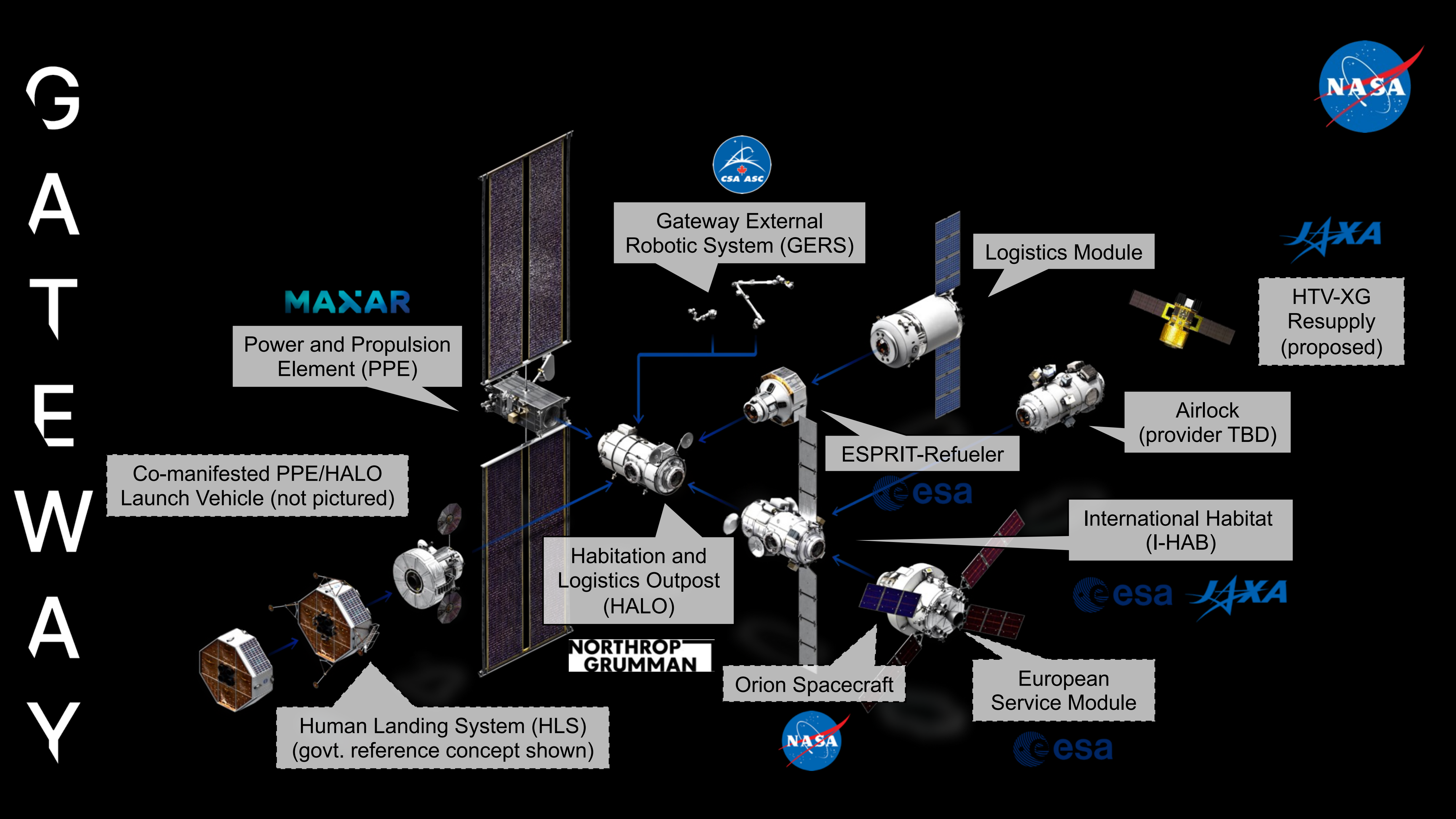


White Papers
Six papers on architecture study details for frequently discussed topics

www.nasa.gov/MoonToMarsArchitecture

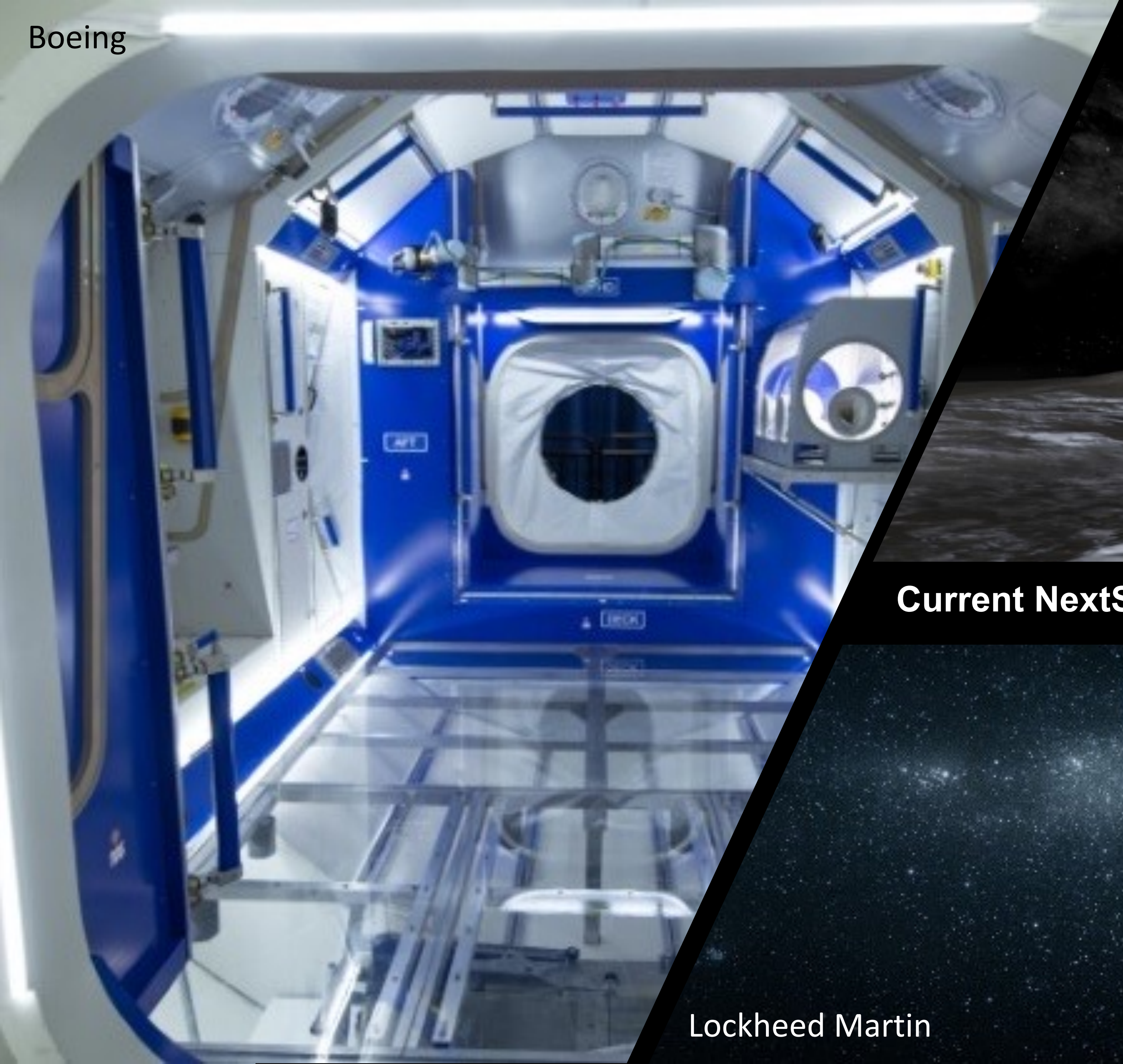


Evolving Habitation Systems for
SUSTAINABLE HUMAN EXPLORATION
Use ISS as Testbed for Evolution of ECLSS and CHPS
International Space Station (ISS)
Continue Testbeds on Commercial Platforms in LEO
Notional Commercial Platform in LEO
Infuse Technologies into Gateway
Orion and Gateway
• Toilet
• CO_2 removal
• Environmental monitoring
• Exercise technology
• Radiation protection and monitoring
• Medical system
• Fire suppression and cleanup
Infuse Full Long Duration Microgravity ECLSS and CHPS into Mars Transport
Mars-class Transportation
• Highly-reliable regenerative ECLSS from ISS demonstration
• Environmental monitors
• Exploration food system
• Countermeasures
• Medical system
• Radiation protection
Complementary Ground Tests and Analogs
• Food system performance and reliability testing
• CHPS integrated analogs
Human Landing System and Sustained Lunar Surface ECLSS-CHP Infusion
• Partial gravity and exploration atmosphere fire safety
• Exploration spacewalk pre-breathe and conops
• Surface habitat: regenerative ECLSS and CHPS adapted for surface
• Pressurized rover: ECLSS waste collection and transfer
Mars Surface ECLSS-CHPS
• Robust microbial and chemical monitoring
• Planetary protection compatible waste strategy
ECLSS = Environmental Control and Life Support Systems | CHPS = Crew Health and Performance Systems | LEO = Low-Earth Orbit
GRAPHICS NOT TO SCALE 20210115

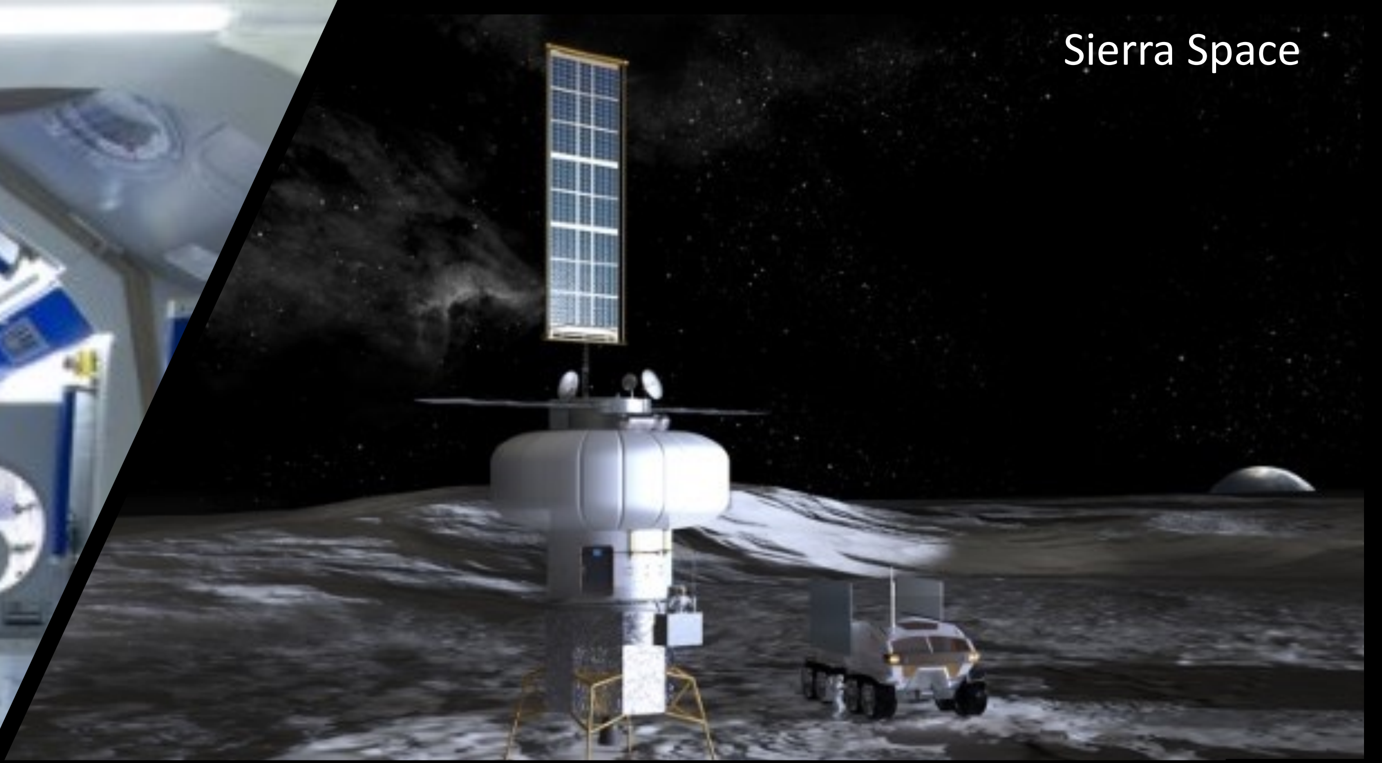

GATEWAY
Gateway External Robotic System (GERS)
Logistics Module
HTV-XG Resupply (proposed)
Power and Propulsion Element (PPE)
Airlock (provider TBD)
ESPRIT-Refueler
Co-manifested PPE/HALO Launch Vehicle (not pictured)
International Habitat (I-HAB)
Habitation and Logistics Outpost (HALO)
Orion Spacecraft
European Service Module
Human Landing System (HLS) (govt. reference concept shown)

NextSTEP Appendix A: Habitation Systems

Phase 1 – 2015-2016: Concept Designs and Operations
Phase 2 – 2016-2019: Prototype Development and Testing
Phase 3 – 2019-2023: Softgoods maturation & long-duration, in-space, and surface habitat concepts

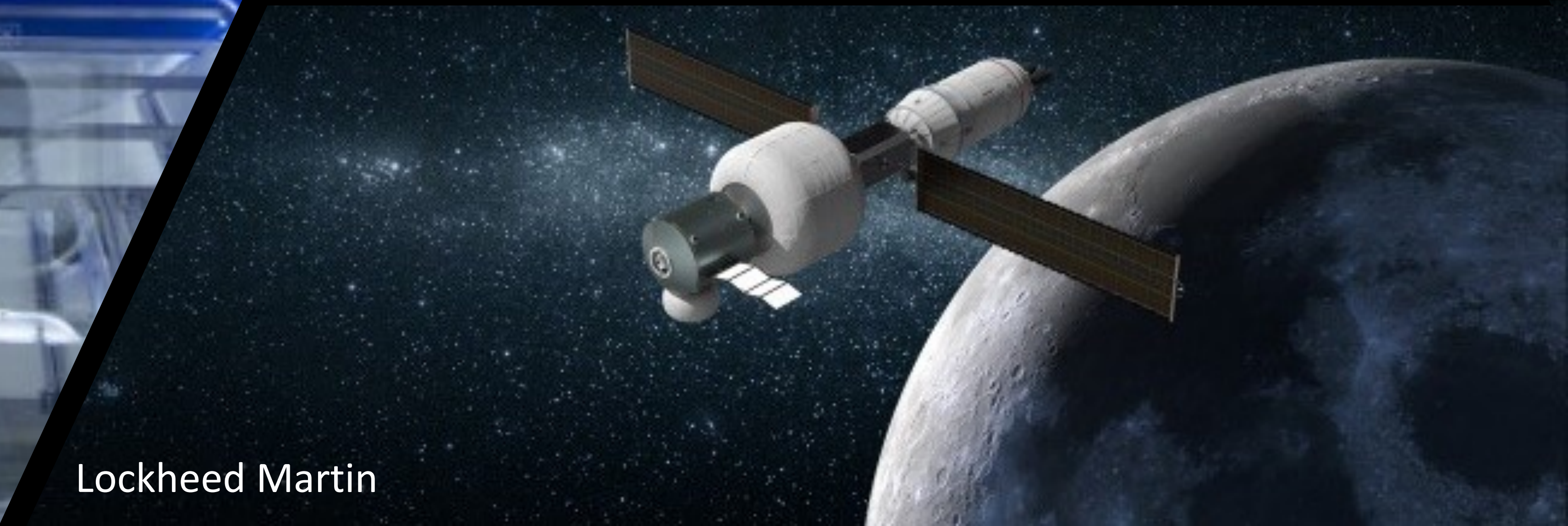


Boeing



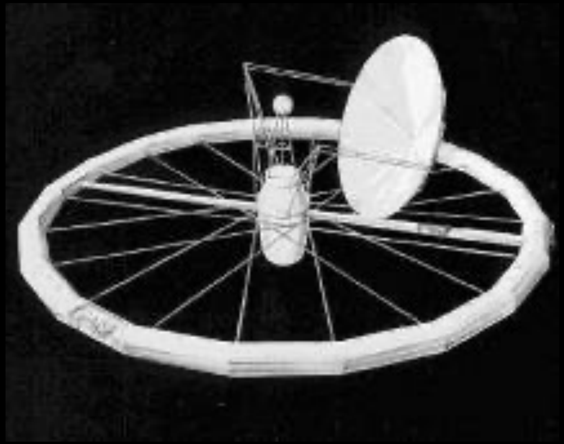
Sierra Space

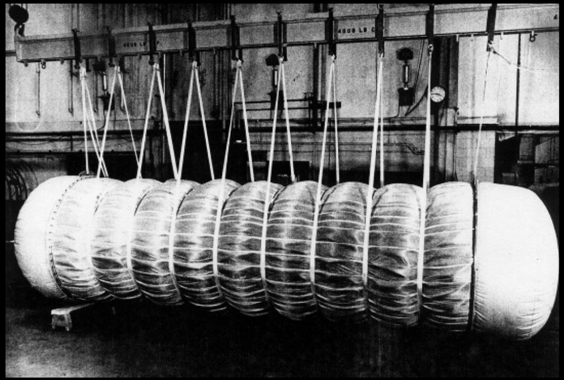
Current NextSTEP Appendix A commercial partners

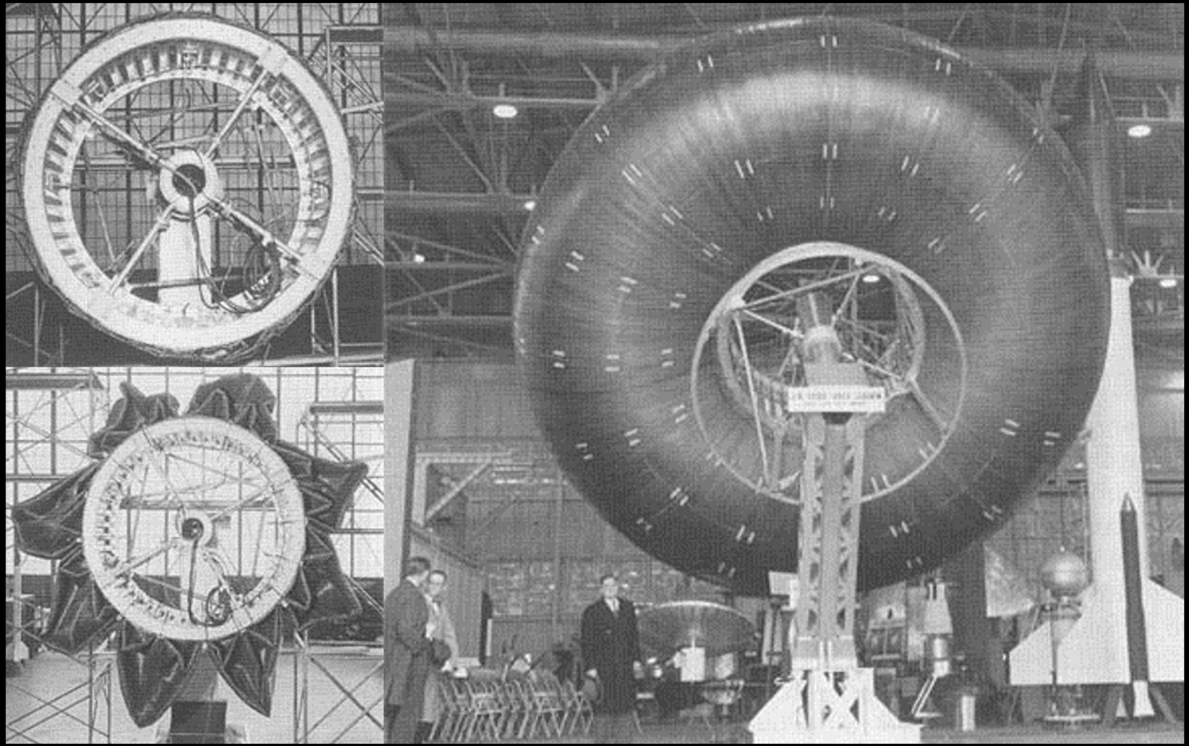


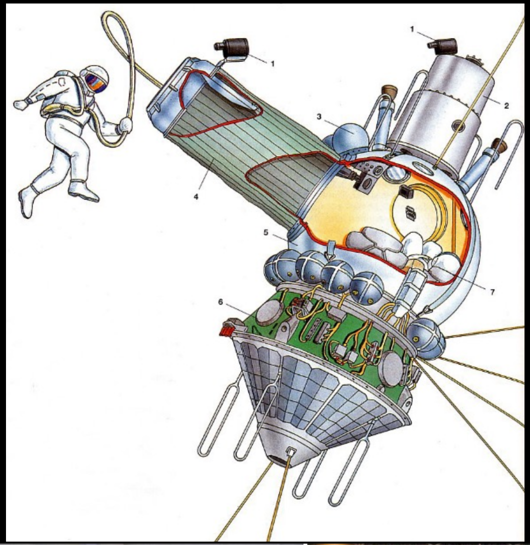
Lockheed Martin

History of Inflatables



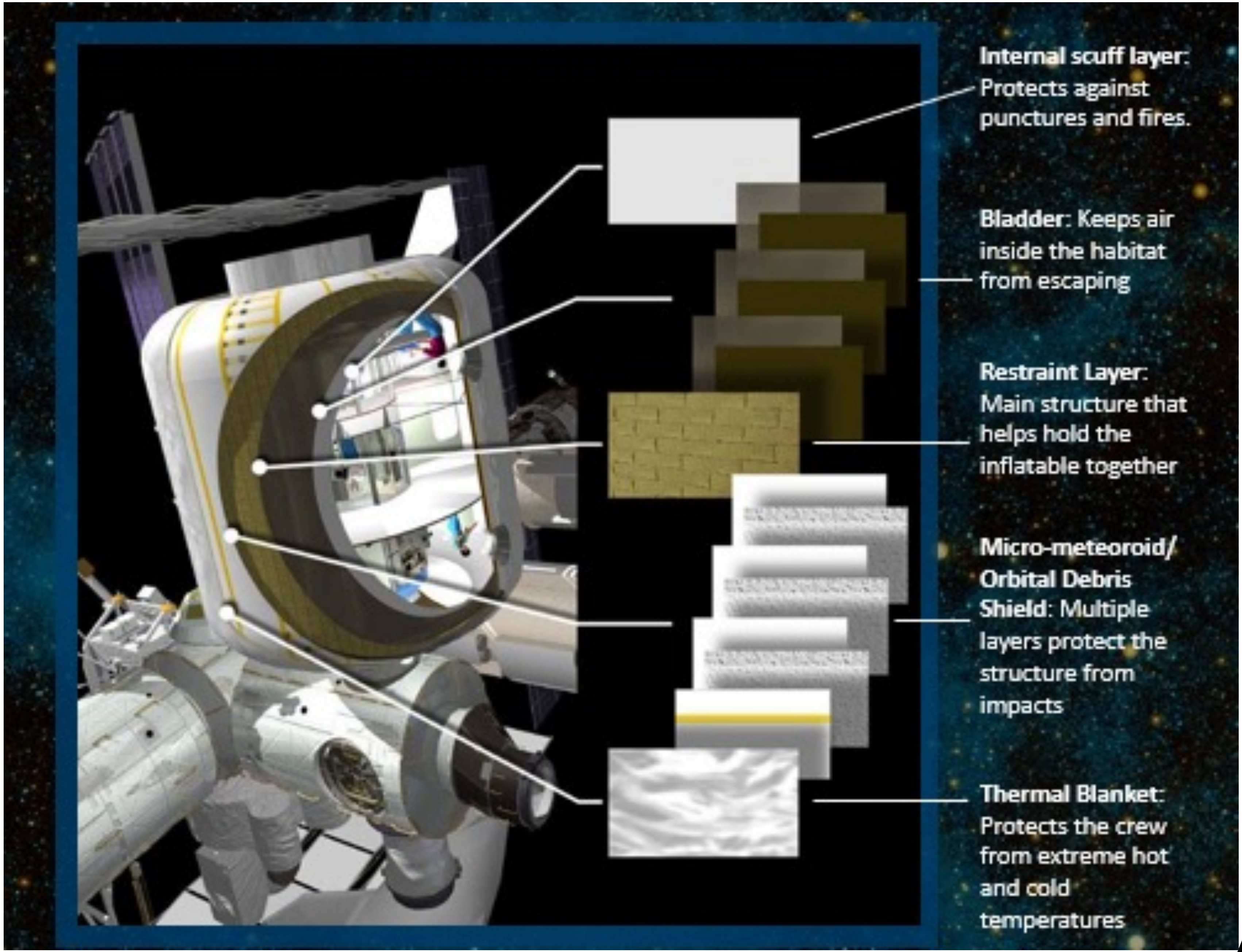






USSR Voshod 2 Volga Inflatable Airlock (1964)
(World's First EVA Was Out of An Inflatable Airlock)

Slide from Doug Litteken, JSC and Tom Jones, LaRC



Inflatable Material System

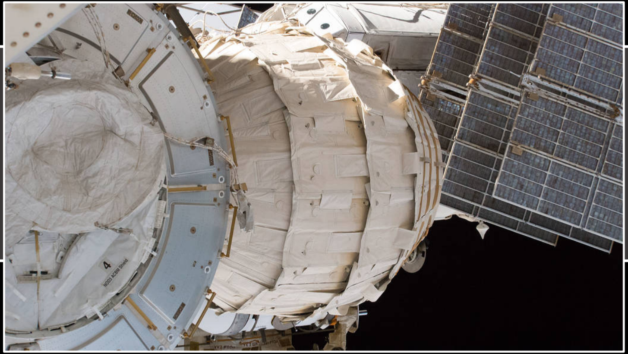
Types of Space Habitats

A class I habitat is a pre-integrated habitat, manufactured and integrated prior to launch

Example: ISS

A class II habitat is pre-fabricated prior to delivery, but deployed in space or on a planetary surface

Example: Inflatable ISS BEAM module



A class III habitat is built in situ using local resources

Example: 3D Printed Habitat on planetary surface

Image from ICON and SEArch+.

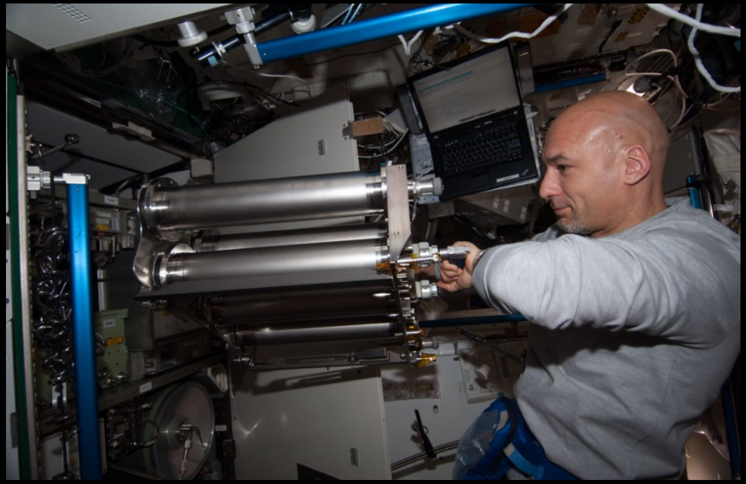
Marc Cohen and Kriss Kennedy, *"Habitats and Surface Construction Technology and Development Roadmap". Sept 4, 1997*

Life Support Systems Provide Clean Air and Water

Two types of Environmental Control and Life Support Systems (ECLSS):

- Open loop ECLSS = provide all water, oxygen, and food from either stowed materials or cargo resupply
  - No recycling of outputs to inputs
- Closed loop systems process waste products into other resources and recover usable constituents
  - Closed loop ECLSS reduces dependence on resupply and imparts significant mass savings for future missions
  - Earth itself is a closed loop ECLSS system


Urine Processor Assembly


Water Processing Assembly


Oxygen Generation System


Carbon Dioxide Removal Assembly

Human Needs on Space Missions

	Amount per crew member per day	4 crew on 30-day lunar surface mission
Food	2.4 kg (5.3 lbs)*	288 kg (635 lbs)
Drinking Water**	2.8 kg (6.2 lbs)	336 kg (744 lbs)
Water for food	0.5 kg (1.1 lbs)	60 kg (132 lbs)
Oxygen**	0.9 kg (2.0 lbs)	108 kg (240 lbs)
Clothing	0.2 kg (0.4 lbs)	24 kg (48 lbs)
Trash produced	1.7 kg (3.7 lbs)	204 kg (440 lbs)
CO2 produced**	1.1 kg (2.4 lbs)	132 kg (291 lbs)

*about 15 percent of this weight is food packaging material ** assumes 82 kg astronaut for consumables planning (~180 lbs)