Persistent Platforms in Space – Next Generation Infrastructure

- Deep Space Gateway
- In Space Manufacturing
- In Space Robotic Manufacturing and Assembly

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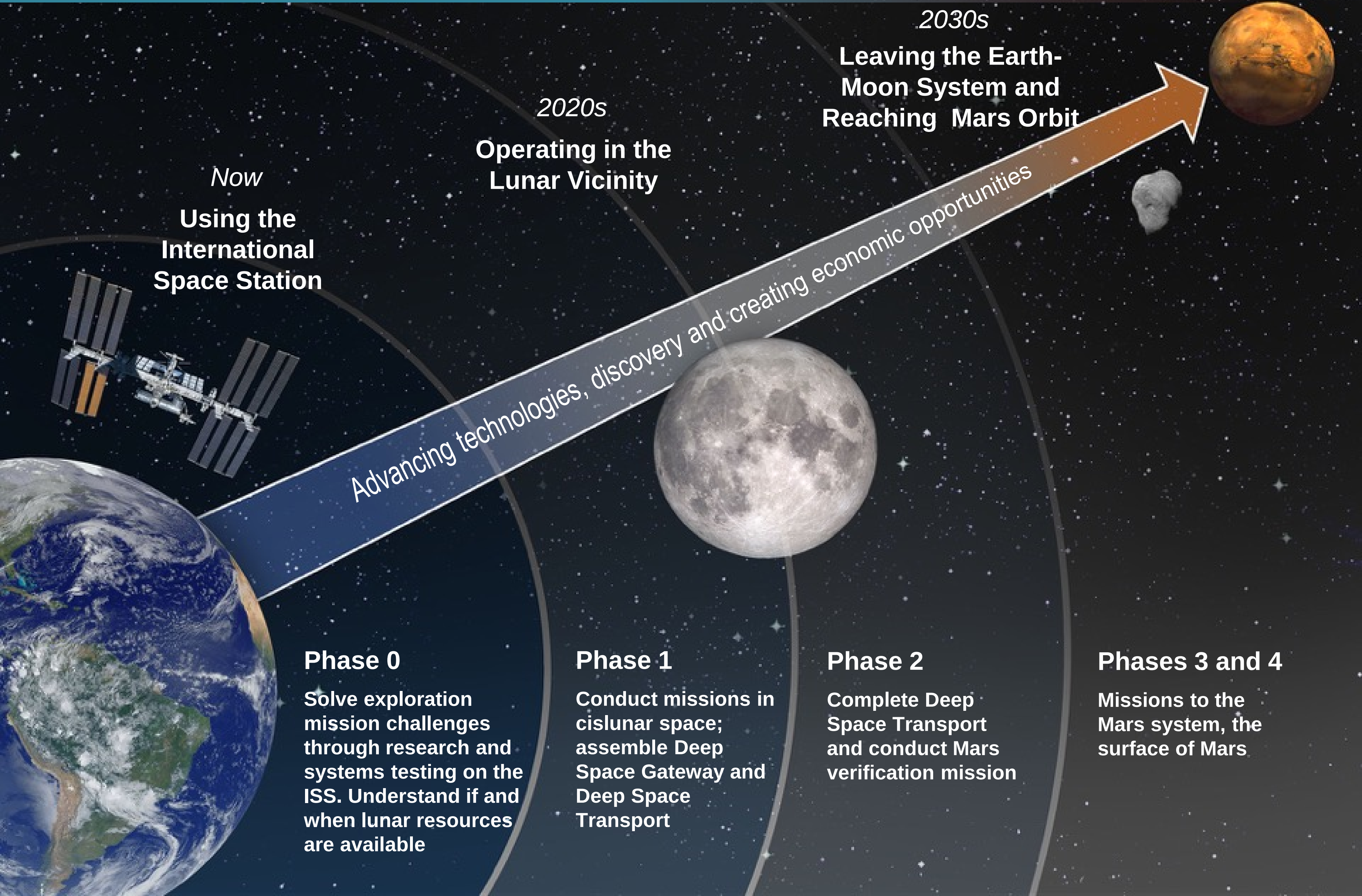
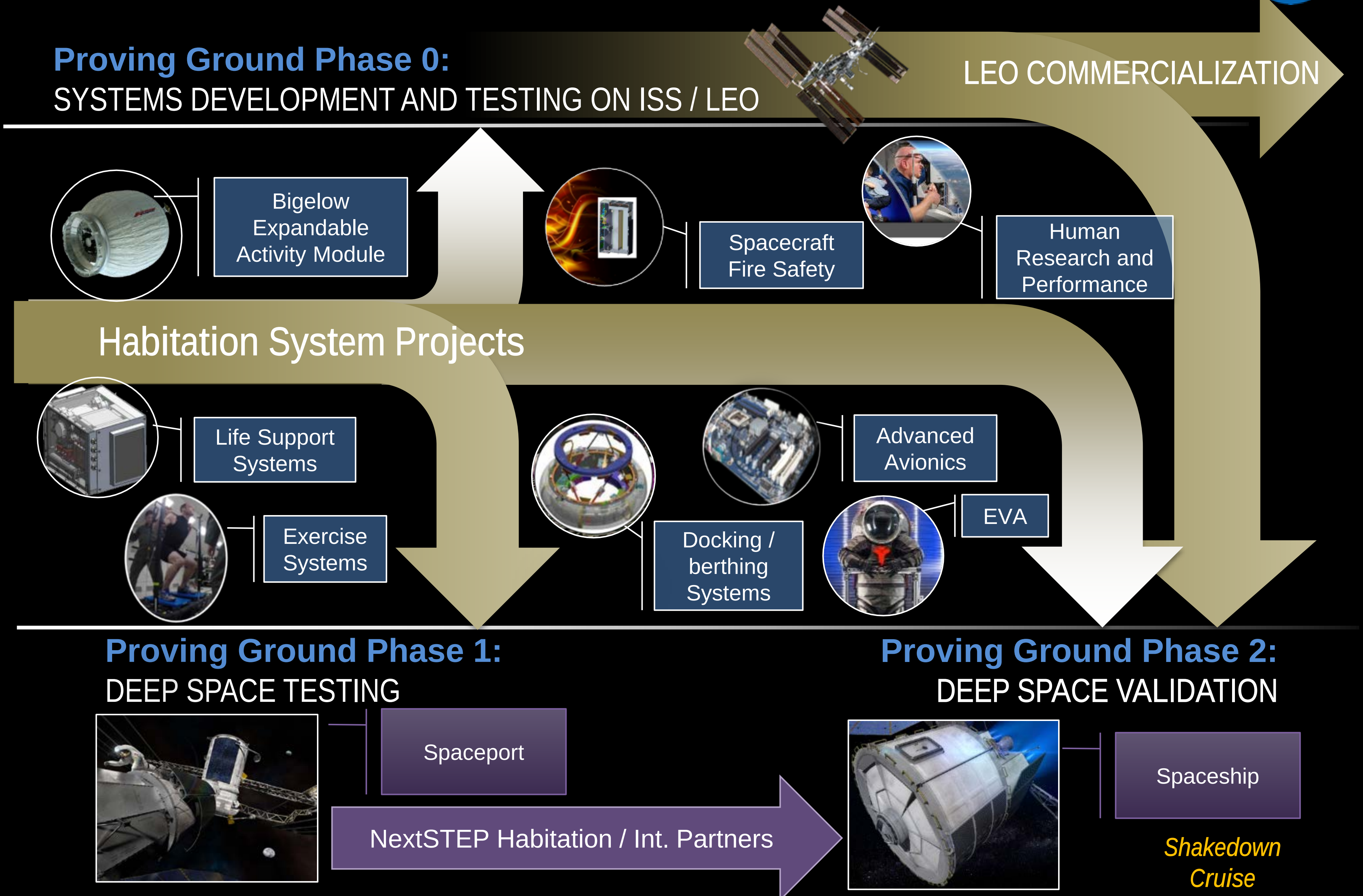
Exploring Space In Partnership



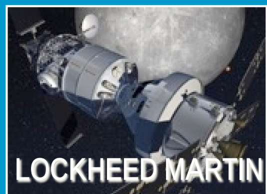
Deep-Space Habitation Development Strategy



NextSTEP Habitation Overview

NextSTEP Phase 1: 2015-2016

Cislunar habitation concepts that leverage commercialization plans for LEO



FOUR SIGNIFICANTLY DIFFERENT CONCEPTS RECEIVED

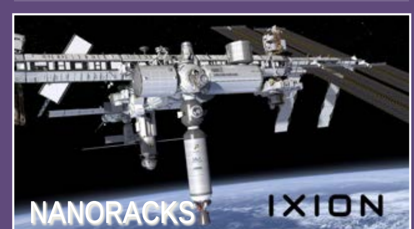
Partners develop required deliverables, including concept descriptions with concept of operations, NextSTEP Phase 2 proposals, and statements of work.

NextSTEP Phase 2: 2016-2018

FIVE GROUND PROTOTYPES BY 2018

- Partners refine concepts and develop ground prototypes.
- NASA leads standards and common interfaces development.

ONE CONCEPT STUDY

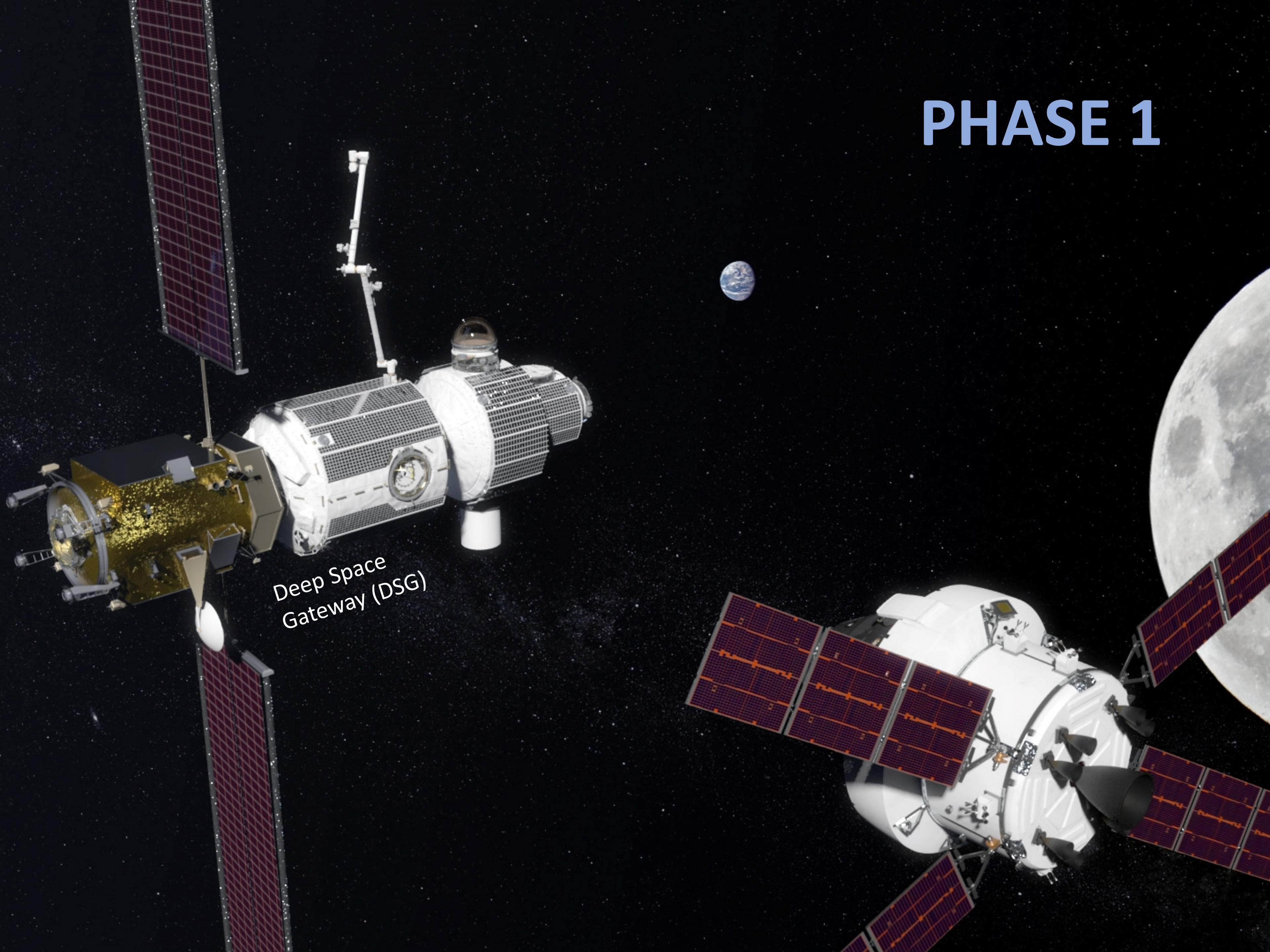


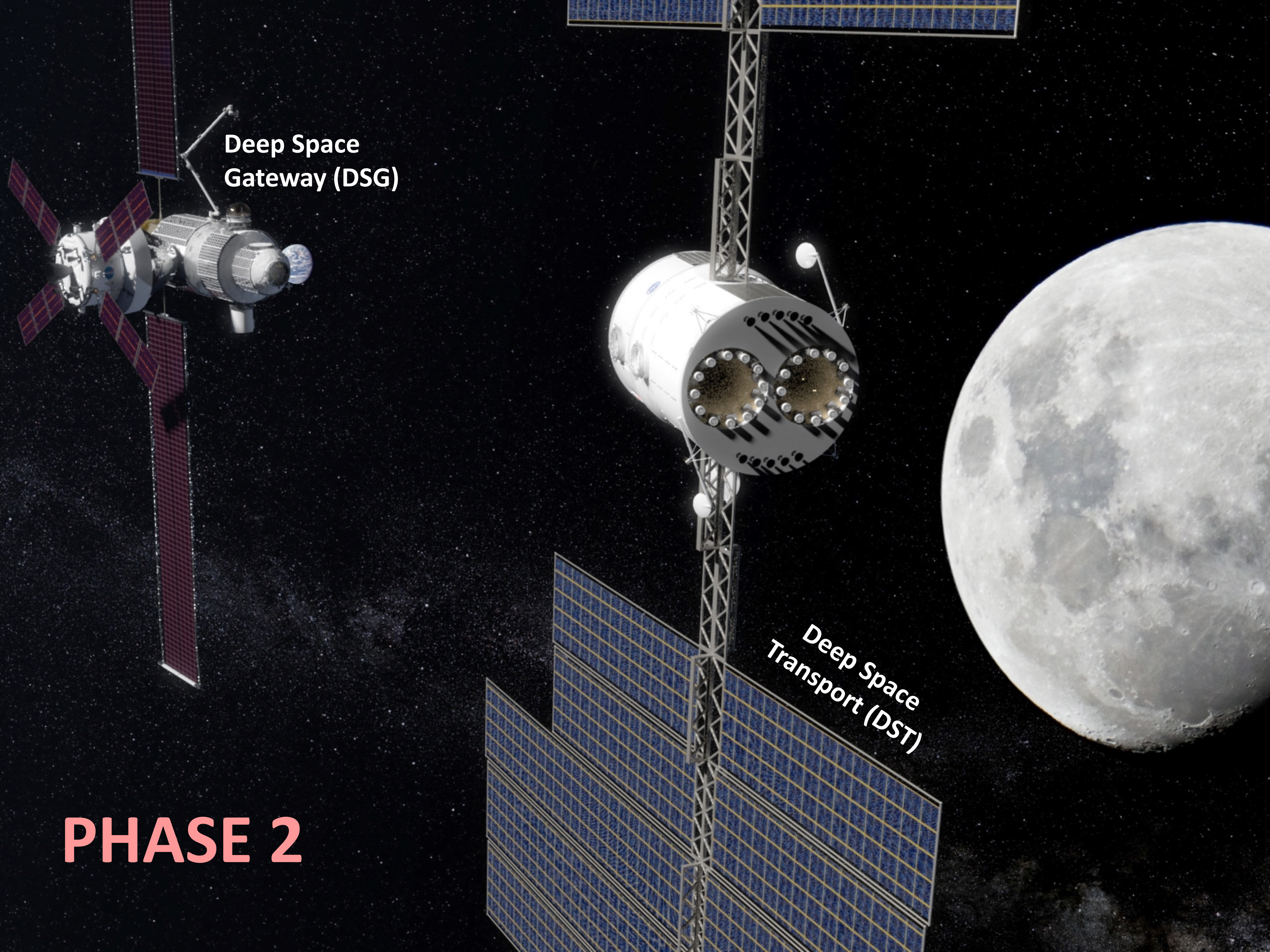
Initial discussions with international partners

Define reference habitat architecture in preparation for Phase 3.

Phase 3: 2018+

- Partnership and Acquisition approach, leveraging domestic and international capabilities
- Development of deep space habitation capabilities
- Deliverables: flight unit(s)


PHASE 1
Deep Space
Gateway (DSG)


Deep Space
Gateway (DSG)
Deep Space
Transport (DST)
PHASE 2

In-Space Manufacturing (ISM) Path to Exploration

GROUND-BASED	EARTH RELIANT ISS	PROVING GROUND Cis-lunar	EARTH INDEPENDENT Mars

Earth-Based Platform
- **Certification & Inspection Process**
- **Design Properties Database**
- **Additive Manufacturing Automation**
- **Ground-based Technology Maturation & Demonstration**
- ***AM for Exploration Support Systems (e.g. ECLSS) Design, Development & Test***
- ***Additive Construction***
- ***Regolith (Feedstock)***

Space Launch System

ISS Test-bed Platform
- **3D Print Demo**
- **Additive Manufacturing Facility**
- **In-space Recycling**
- **In-space Metals**
- **Printable Electronics**
- **Multi-material Fab Lab**
- **In-line NDE**
- **External Manufacturing**
- **On-demand Parts Catalogue**
- **Exploration Systems Demonstration and Operational Validation**

Asteroids

Planetary Surfaces Platform
- **Multi-materials Fab Lab (metals, polymers, automation, printable electronics)**
- **Food/Medical Grade Polymer Printing & Recycling**
- **Additive Construction Technologies**
- **Regolith Materials – Feedstock**
- **AM Exploration Systems**

Text Color Legend

Foundational AM Technologies

AM for Exploration Systems

In-space Robotic Manufacturing and Assembly Overview

Concept by Made In Space

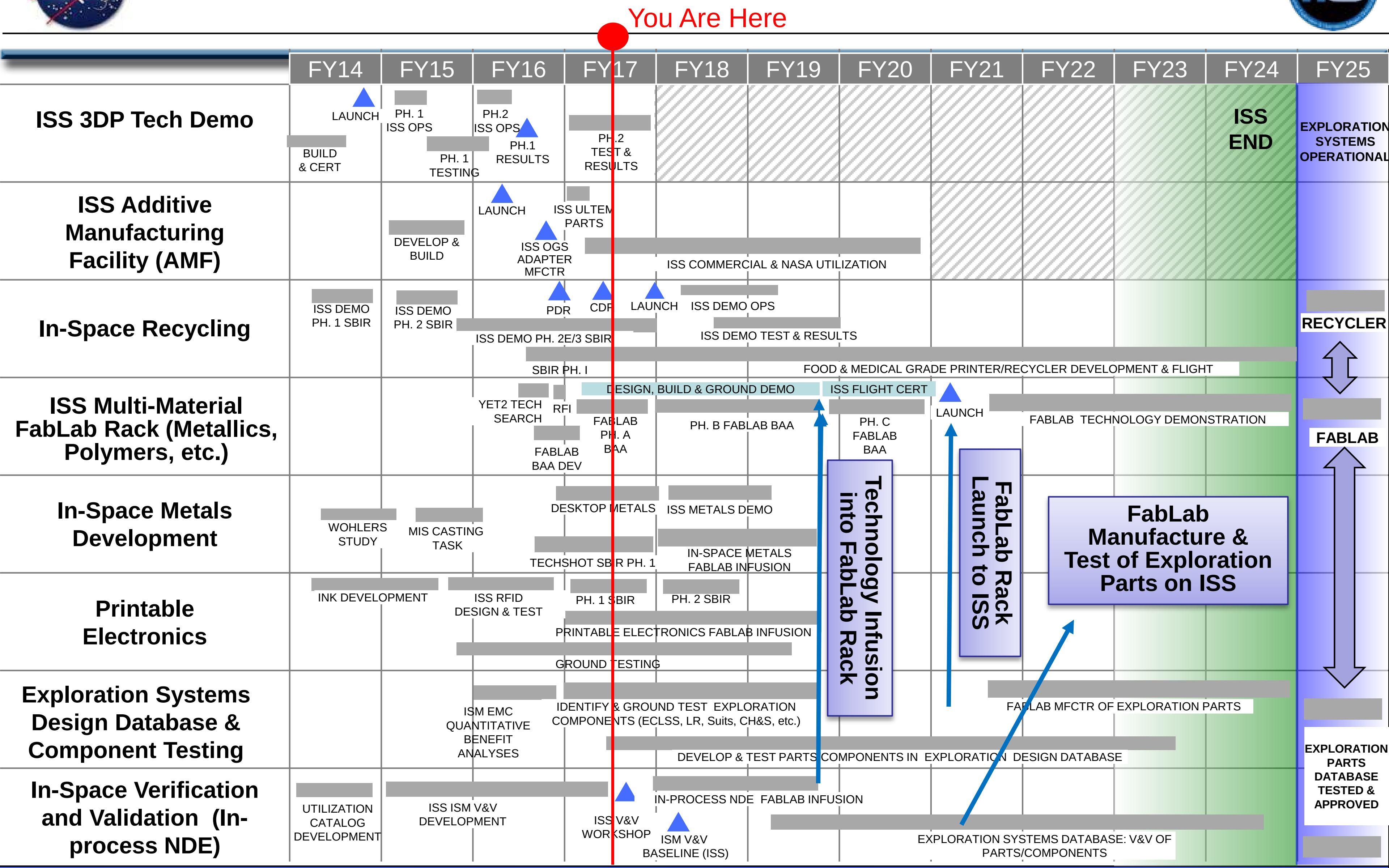
Concept by Space Systems/Loral

Concept by Orbital ATK

Archinaut	Dragonfly	CIRAS
A Versatile In-Space Precision Manufacturing and Assembly System	On-Orbit Robotic Installation and Reconfiguration of Large Solid Radio Frequency (RF) Reflectors	A Commercial Infrastructure for Robotic Assembly and Services
	Tipping Point Objective	
A ground demonstration of additive manufacturing of extended structures and assembly of those structures in a relevant space environment.	A ground demonstration of robotic assembly interfaces and additive manufacture of antenna support structures meeting EHF performance requirements.	A ground demonstration of reversible and repeatable robotic joining methods for mechanical and electrical connections feasible for multiple space assembly geometries.
	Team	
Made In Space, Northrop Grumman Corp., Oceaneering Space Systems, Ames Research Center	Space Systems/Loral, Langley Research Center, Ames Research Center, Tethers Unlimited, MDA US & Brampton	Orbital ATK, Glenn Research Center, Langley Research Center, Naval Research Laboratory

NASA

In-Space Manufacturing (ISM) Program Timeline



ISM enables the 'Design for Maintainability' approach Required for Sustainable Exploration missions.

Living in Space: Short Duration Habitation

Excursion Vehicle

Explore kilometers away from the destination habitat

- ✓ 2 crew for up to 2 weeks, contingency 4 crew for 1 week
- ✓ EVA pressure garment and PLSS <200 kg with dual-band radio avionics and radiation hardened bio-med sensors
- ✓ High frequency EVA (15 min. ingress-egress time)
- ✓ 4 years dormant before first use and between uses
- ✓ Design for reuse for 3 missions
- ✓ Lightweight exercise equipment under 25 kg

Challenges

Protect and support crew in deep space for up to 60 days

Uncrewed operations during deployment and between uses

Earth - independent operations

Initial Cislunar Habitation

Support crew each year for short duration stays in cislunar space

- ✓ 4 crew for up to 60 days
- ✓ EVA pressure garment and PLSS <200 kg with dual-band radio avionics and rad-hardened bio-med sensors
- ✓ High frequency EVA (15 min. ingress-egress time)
- ✓ Lightweight exercise equipment under 25 kg
- ✓ 1 year dormant before use
- ✓ Up to 300 days dormant between uses

Common Capabilities

4 crew for short durations (up to 60 days)

Support autonomous mission operations with time delay

Common, partially closed ECLSS under approx. 800 kg (3 years MTBF and 2 crew per torr of CO_2 removal)

Autonomous rendezvous, prox ops, and docking

Ability to be teleoperated with <0.5 s latency

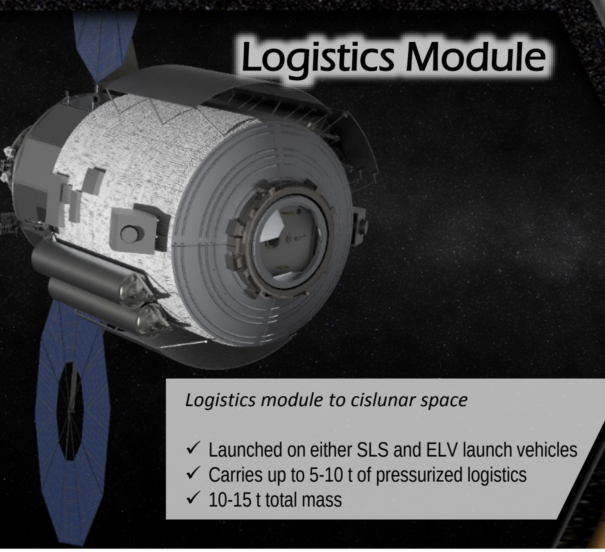
Communications to/from Earth and between elements

Common, lightweight pressure vessel and common hatch

15 year lifetime with long dormancy periods

Design for maintainability

Logistics Module



Logistics module to cislunar space

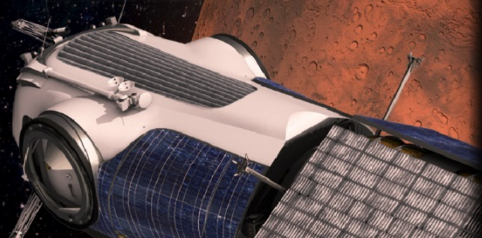
- ✓ Launched on either SLS and ELV launch vehicles
- ✓ Carries up to 5-10 t of pressurized logistics
- ✓ 10-15 t total mass

Mars Ascent Vehicle

Return crew to Mars orbit

- ✓ 4 crew for up to 3 days flight duration
- ✓ Open loop ECLSS under approx. 400 kg
- ✓ 5 years dormant before use

Mars Taxi



Transport crew between Mars orbit and Mars Moons

- ✓ 4 crew for up to 2.5 day crewed duration
- ✓ 560 days operational (uncrewed) at Mars
- ✓ 2 years dormant before use
- ✓ Up to 1.5 years dormant between uses

Living in Space: Long Duration Habitation

Challenges

Protect and support crew in deep space for up to 1100 days

Uncrewed operations during deployment and between uses

Reduced logistics and spares

Earth - independent operations

Common Capabilities

4 Crew for 500-1100 days

Common pressure vessel

15 year lifetime with long dormancy periods

Design for reusability across multiple missions

100 m^3 habitable volume and dry mass < 22 t

Autonomous vehicle health monitoring and repair

Advanced Exploration ECLSS with >85% H_2O recovery and 50% O_2 recovery from reduced CO_2

ECLSS System (w/o spares): <5 t mass, <9 m^2 volume, <4 kW power

Environmental monitoring with >80% detection rate without sample return

14-kW peak operational power and thermal management required

Autonomous mission operations with up to 24 minute one-way time delay

Autonomous medical care, behavioral health countermeasures, and other physiological countermeasures to counteract long duration missions without crew abort

Exercise equipment under 500 kg

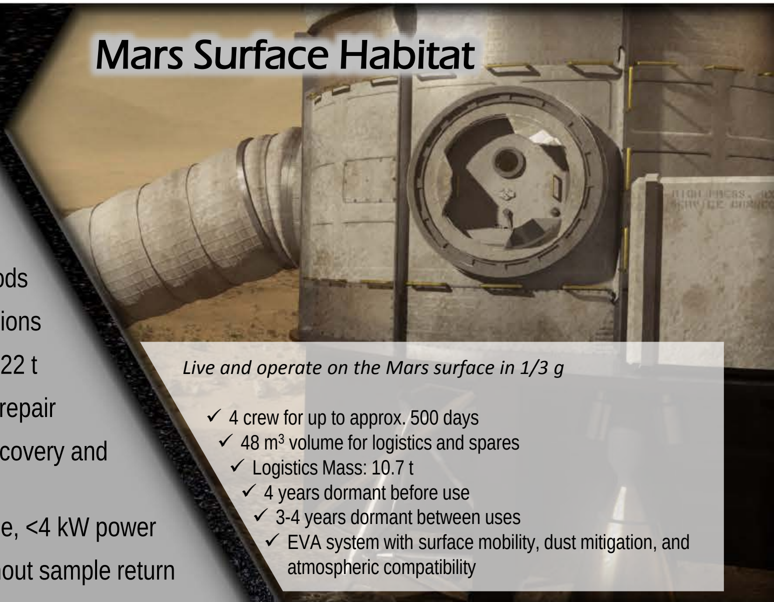
Provide 20-40 g/cm^2 of radiation protection

EVA pressure garment and PLSS <200 kg

Contingency EVA operations with 1 x 2-person EVA per month

Communications to/from Earth and between elements

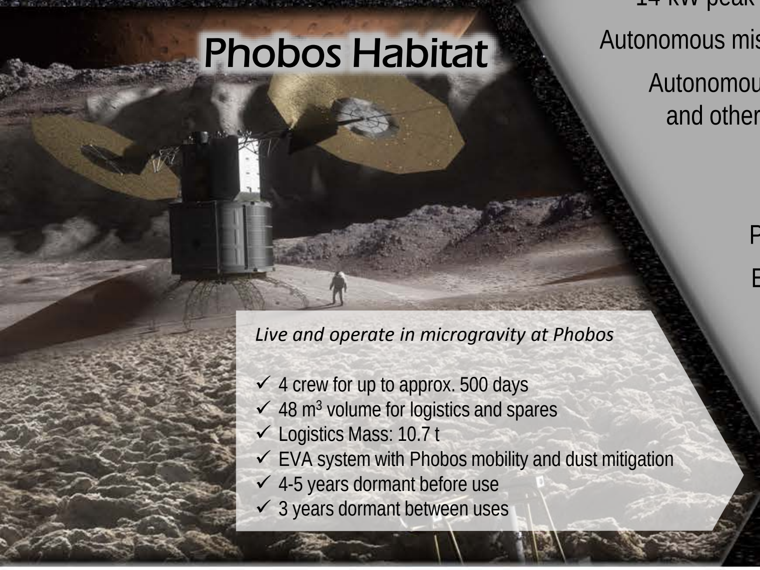
Mars Surface Habitat



Live and operate on the Mars surface in 1/3 g

- ✓ 4 crew for up to approx. 500 days
- ✓ 48 m^3 volume for logistics and spares
- ✓ Logistics Mass: 10.7 t
- ✓ 4 years dormant before use
- ✓ 3-4 years dormant between uses
- ✓ EVA system with surface mobility, dust mitigation, and atmospheric compatibility

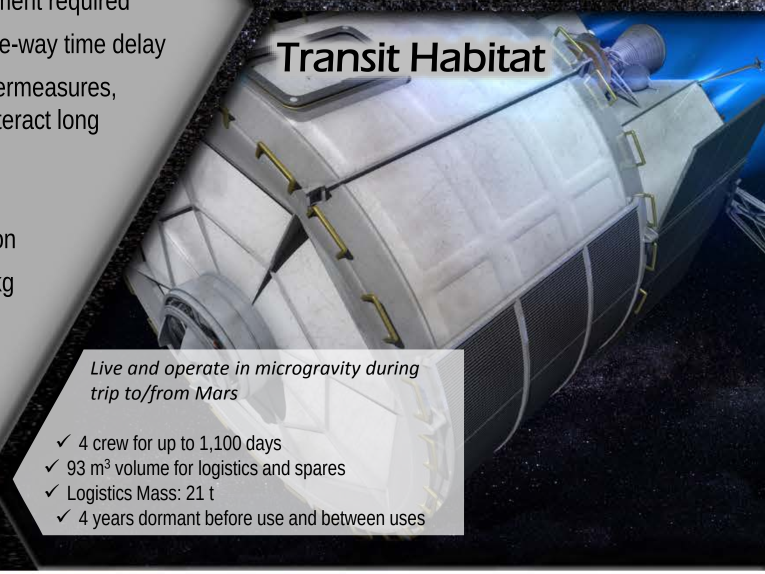
Phobos Habitat



Live and operate in microgravity at Phobos

- ✓ 4 crew for up to approx. 500 days
- ✓ 48 m^3 volume for logistics and spares
- ✓ Logistics Mass: 10.7 t
- ✓ EVA system with Phobos mobility and dust mitigation
- ✓ 4-5 years dormant before use
- ✓ 3 years dormant between uses

Transit Habitat



Live and operate in microgravity during trip to/from Mars

- ✓ 4 crew for up to 1,100 days
- ✓ 93 m^3 volume for logistics and spares
- ✓ Logistics Mass: 21 t
- ✓ 4 years dormant before use and between uses