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

Now
Using the International Space Station

2020s
Operating in the Lunar Vicinity

2030s
Leaving the Earth-Moon System and Reaching Mars Orbit

Advancing technologies, discovery and creating economic opportunities

Phase 0
Solve exploration mission challenges through research and systems testing on the ISS. Understand if and when lunar resources are available

Phase 1
Conduct missions in cislunar space; assemble Deep Space Gateway and Deep Space Transport

Phase 2
Complete Deep Space Transport and conduct Mars verification mission

Phases 3 and 4
Missions to the Mars system, the surface of Mars
Deep-Space Habitation Development Strategy

**Proving Ground Phase 0:** Systems Development and Testing on ISS / LEO

**Proving Ground Phase 1:** Deep Space Testing

**Proving Ground Phase 2:** Deep Space Validation

**Habitation System Projects:**
- Bigelow Expandable Activity Module
- Life Support Systems
- Exercise Systems
- Spacecraft Fire Safety
- Advanced Avionics
- Docking / berthing Systems
- EVA

**NextSTEP Habitation / Int. Partners**

**LEO Commercialization**

**Spaceport**

**Shakedown Cruise**
NextSTEP Habitation Overview

**NextSTEP Phase 1: 2015-2016**

Cislunar habitation concepts that leverage commercialization plans for LEO

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

**NextSTEP Phase 2: 2016-2018**

- Partners refine concepts and develop ground prototypes.
- NASA leads standards and common interfaces development.
- 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)
Phase 2:
Deep Space Transport
Deep Space Gateway (DSG)
Deep Space Gateway (DSG)
In-Space Manufacturing (ISM) Path to Exploration

**GROUND-BASED**
- 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)

**EARTH RELIANT ISS**
- 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

**PROVING GROUND Cis-lunar**
- 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

**EARTH INDEPENDENT Mars**
**In-space Robotic Manufacturing and Assembly Overview**

**Archinaut**
A Versatile In-Space Precision Manufacturing and Assembly System

**Dragonfly**
On-Orbit Robotic Installation and Reconfiguration of Large Solid Radio Frequency (RF) Reflectors

**CIRAS**
A Commercial Infrastructure for Robotic Assembly and Services

**Tipping Point Objective**
Archinaut:
A ground demonstration of additive manufacturing of extended structures and assembly of those structures in a relevant space environment.

Dragonfly:
A ground demonstration of robotic assembly interfaces and additive manufacture of antenna support structures meeting EHF performance requirements.

CIRAS:
A ground demonstration of reversible and repeatable robotic joining methods for mechanical and electrical connections feasible for multiple space assembly geometries.

**Team**
Archinaut:
Made In Space, Northrop Grumman Corp., Oceaneering Space Systems, Ames Research Center

Dragonfly:
Space Systems/Loral, Langley Research Center, Ames Research Center, Tethers Unlimited, MDA US & Brampton

CIRAS:
Orbital ATK, Glenn Research Center, Langley Research Center, Naval Research Laboratory
ISM enables the ‘Design for Maintainability’ approach Required for Sustainable Exploration missions.

In-Space Manufacturing (ISM) Program Timeline

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**Insight:**

ISM enables the ‘Design for Maintainability’ approach Required for Sustainable Exploration missions.
**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 ton of CO₂ 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

**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

**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

**Initial Cislunar Habitation**

- Protect and support crew in deep space for up to 60 days
- Uncrewed operations during deployment and between uses
- Earth-independent operations

**Challenges**

- Mars Ascent Vehicle
  - Return crew to Mars orbit
  - Open loop ECLSS under approx. 400 kg
  - 5 years dormant before use

- Logistics Module
  - Logistics module to cislunar space
  - Launch on either SLS and ELV launch vehicles
  - Carries up to 5-10 t of pressurized logistics
  - 10-15 t total mass
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 m³ habitable volume and dry mass < 22 t
- Autonomous vehicle health monitoring and repair
- Advanced Exploration ECLSS with >85% H₂O recovery and 50% O₂ recovery from reduced CO₂
- ECLSS System (w/o spares): <5 t mass, <9 m² 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/cm² 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 m³ 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 m³ volume for logistics and spares
- Logistics Mass: 10.7 t
- EVA system with Phobos mobility and dust mitigation
- 4-5 years dormant before use
- 3-4 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 m³ volume for logistics and spares
- Logistics Mass: 21 t
- 4 years dormant before use and between uses