The Gateway's First Habitable Element – HALO (Habitation and Logistics Outpost)

Future In-Space Operations (FISO)

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Introduction to Northrop Grumman

Aeronautics Systems

- Autonomous Systems
- Aerospace Structures
- Advanced Technologies and Concepts
- Aircraft Design, Integration and Manufacturing
- Long-range Strike
- Multi-Domain Integration and Operations
- Intelligence, Surveillance and Reconnaissance
- Battle Management

Defense Systems

- Integrated Air & Missile Defense
- Defensive Cyber and Information Operations
- Platform Modernization and Fleet Operations Support
- Advanced Weapons
- Precision Munitions
- Software Systems Modernization and Sustainment
- Training and Simulation
- Propulsion Systems

Mission Systems

- Airborne Sensors and Networks
- Artificial Intelligence/Machine Learning
- Cyber and Intelligence Mission Solutions
- Navigation, Targeting and Survivability
- Maritime/Land Systems and Sensors
- Engineering & Sciences
- Emerging Concepts Development
- Multi-domain C2
- Agile/DevSecOps Systems

Space Systems

Launch Vehicles

- Propulsion Systems
- Commercial Satellites
- Military and Civil Space Systems
- Science and National Security Satellites

Human Exploration and Operations

- Space Components
- Missile Defense
- Space Exploration
- Space ISR Systems

Space Systems Overview

Sector Operating Businesses

Strategic Space Systems

Workforce ~**8,000** people

- AMP Program
- Intelligence, Surveillance and Reconnaissance
- Protected Comms
- Resilience and Rapid Prototyping
- Missile Warning and Defense
- James Webb Space Telescope Program
- Directed Energy
- System Operation and Maintenance

Major operations in Redondo Beach, El Segundo and Azusa, California

Tactical Space Systems

Workforce ~**4,000** people

- Earth and Space Science Satellites
- Commercial Communication Satellites
- **Human Exploration Systems**
- Space Logistics Systems
- National Security Space Systems
- Space Components
- Space Technical Services

Major operations in Virginia, California, Maryland and Arizona

Payload and Ground Systems

Workforce ~**3,000** people

- Integrated National Security Systems
- Strategic Forces Programs
- Remote Sensing Programs

Major operations in Colorado, California and Maryland

Launch and Missile Defense Systems

Workforce ~**6,000** people

- Missile Defense Solutions
- Interceptor Launch Vehicles
- Target Launch Vehicles
- Hypersonic Vehicles
- Space Launch Vehicles
- Solid Rocket Motor Propulsion

Major operations in Utah, Arizona, Alabama and Colorado

Strategic Deterrent Systems

Workforce ~**1,500** people

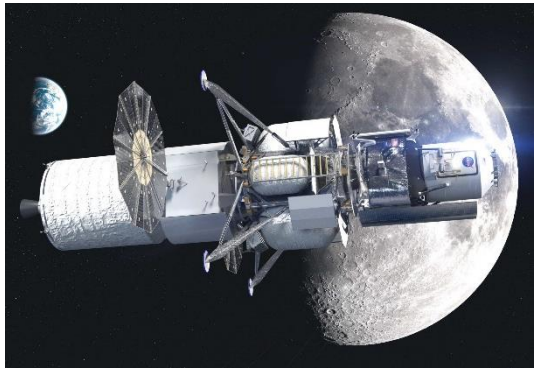
- Ground-based Leg of Nuclear Triad
- GBSD EMD Execution
- Minuteman III Sustainment

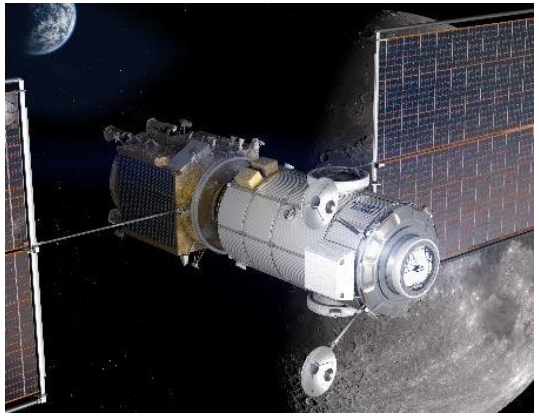
Major operations in Utah, Alabama and California

Space Systems Integrated End-to-End Portfolio Meets Our Customers' Mission Needs

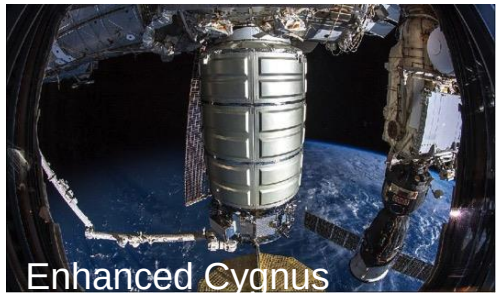
Northrop Grumman Space Systems

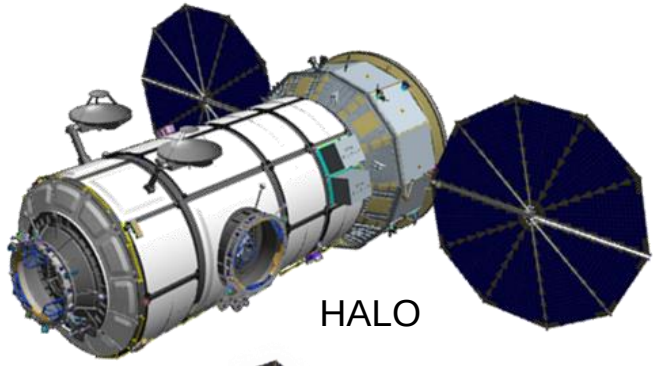
- Northrop Grumman Space Systems (NGSpace) is an industry leading provider of end-to-end space mission solutions focused on agility, affordability, innovation and reliability
- NGSpace Launch Systems is providing the five segment boosters for NASA's Space Launch System (SLS) and the main launch-abort motor and the attitude control motor for the Orion Crew Vehicle's Launch Abort System (LAS)
  - In addition NG propulsion systems are employed in the company's Pegasus, Minotaur, and Antares rockets as well as in Delta IV.
- NGSS Tactical Space covers Civil & Commercial Satellites (CCS) and National Security Space, including CCS's NASA Human Exploration and Operations (HEO) and Science, and Commercial Satellites
- Currently HEO is resupplying the International Space Station (ISS) with the Cygnus spacecraft via Cargo Resupply Services (CRS) and developing elements to support NASA Gateway and Artemis programs
  - HALO to be the first habitable element of the Gateway and part of the Co-Manifested Vehicle (CMV)
  - Human Landing System (HLS) Transfer Element to support the Artemis program to land humans back on the lunar surface

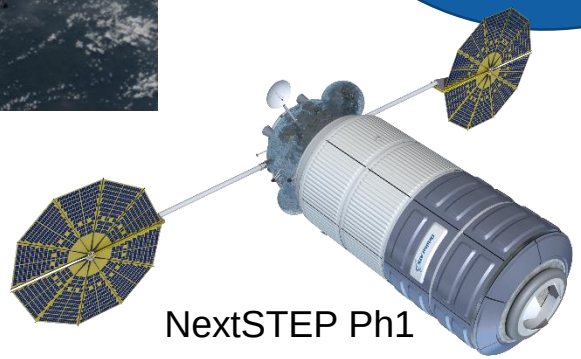


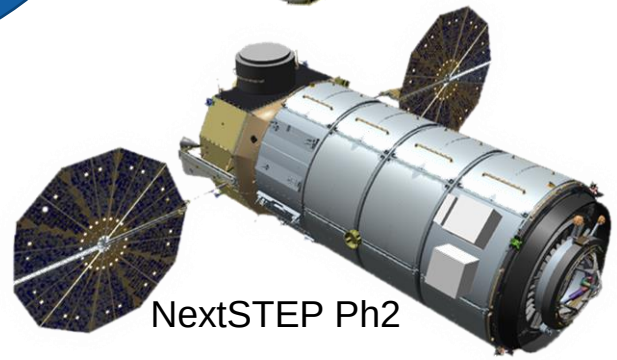


Roadmap from Cygnus to CMV (Co-Manifested Vehicle)







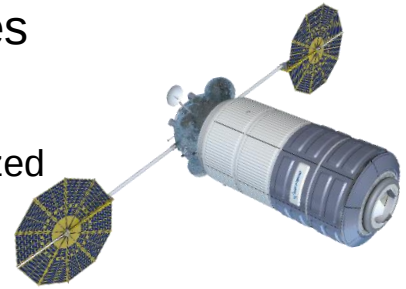


Cygnus Spacecraft

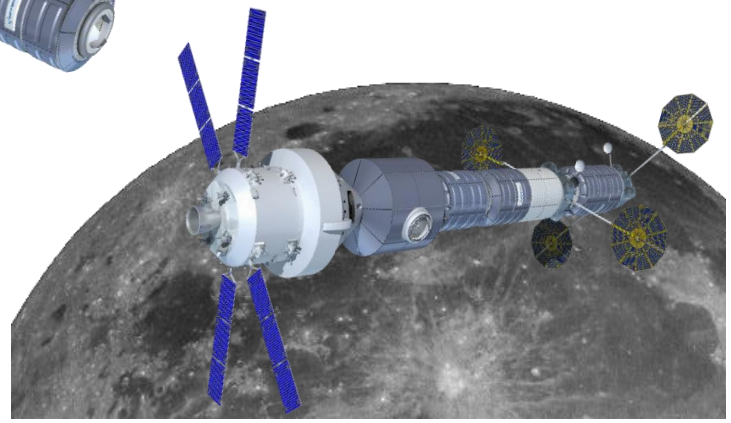
- NG is the prime contractor and developer of the Cygnus spacecraft, providing logistics support to the International Space Station (ISS) under NASA's Cargo Resupply Service (CRS) contract, including commercial and science payloads
- Cygnus is designed to be an advanced maneuvering spacecraft, incorporating elements drawn from Northrop Grumman and its partners' existing, flight-proven spacecraft technologies.
- The primary mission objectives of Cygnus flights to ISS are cargo delivery and trash removal with additional capabilities for NASA and Commercial payload operations
- It is a semi-autonomous delivery system for pressurized and unpressurized payloads and cargo, that meets NASA's human spaceflight rated vehicle requirements
- The Cygnus system is a flight-proven low-risk design with 14 highly-successful missions to-date and provides a basis for future evolved and derived vehicles to support NASA exploration and science

NextSTEP Studies

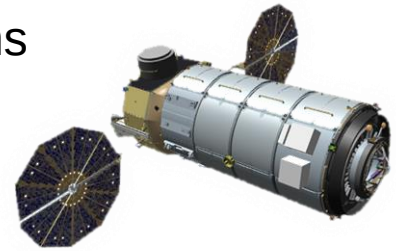
- The NextSTEP studies awarded by NASA focused on industries approach to a cislunar habitat concept
  - Derived from heritage, flight-proven Cygnus systems with a larger pressurized volume and increased capabilities to support a wide variety of missions

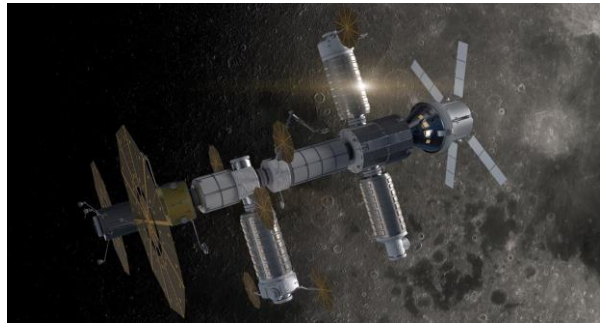


- Phase 1 looked at a complete cislunar Gateway, made up of multi modules
  - Primary element was the Initial Cislunar Habitat (ICH)



- Phase 2 evolved the concepts and lessons learned so the teams could build a full scale mock-up of their proposed systems
  - NASA identified the Power Propulsion Element (PPE) for the Gateway
  - Primary element was the Augmentation Module (AM)
  - Provide habitable pressurized volume for the crew for early phases of the Gateway to support lunar exploration
  - Provides a modular and distributed approach and dissimilar back up for power, ECLSS, GN&C and Propulsion to PPE



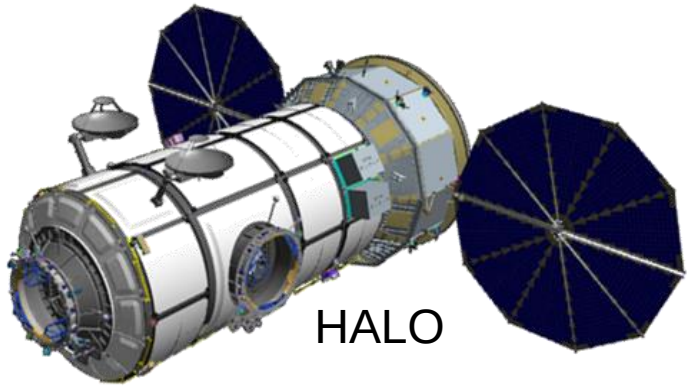


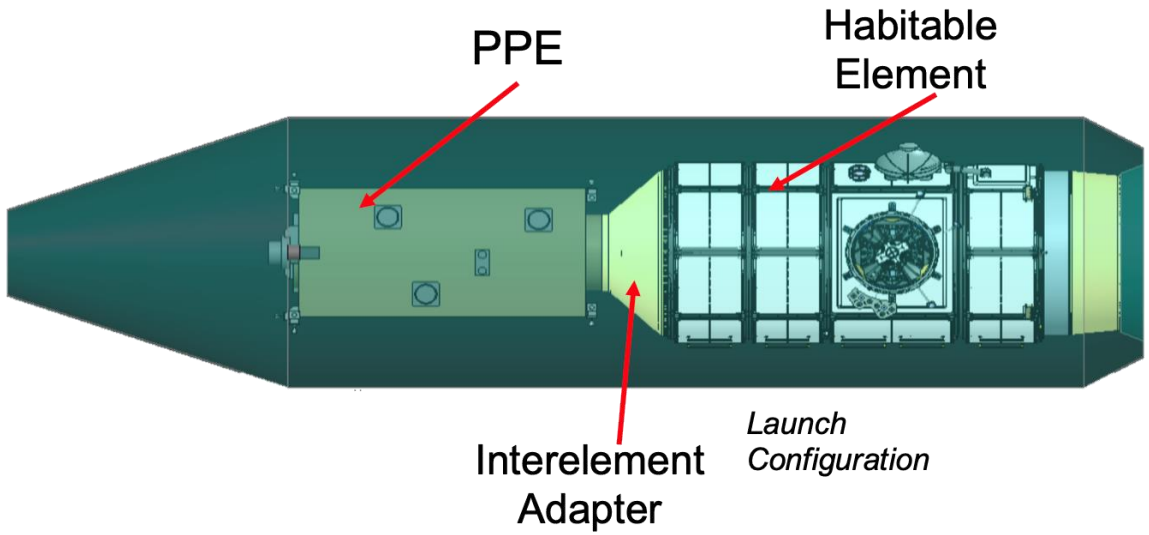
Habitation and Logistics Outpost (HALO)

- HALO will be the first pressurized module to support crew operations at Gateway, beginning with support for Artemis' return of humans to the lunar surface
  - Awarded to Northrop Grumman, completed PDR toward delivery ahead of Artemis 3 to support a 2024 landing
- NG's HALO, builds off of Cygnus, and the crew-tested design for day-in-the-life operations of the NextSTEP Augmentation Module, to provide a highly-capable system with lower-risk, and higher schedule-certainty
  - Increases habitable space
  - Provides two radial and one axial docking port for modules or visiting vehicles
  - Flexible for delivery with a Service Module or co-manifested

HALO to CMV

- System Changes
  - Service module replaced with PPE
  - No solar arrays, power from batteries and PPE
  - No propulsion systems required
  - No GNC systems required
  - No space to ground comm system required
  - No active NDS required for PPE/HALO connection
    - Added Inter-element Adaptor (IEA) between PPE/HALO for structure mate
- Mission Changes
  - Additional integrated systems checkouts on the ground post PPE/HALO mate vs in NRHO
  - NG no long performing spacecraft command and control
    - Reduction in MCC effort
  - Single launch since comanifested vehicle
  - Transit duration increased
    - 7-12 days to 300+ days
    - Using Electric Propulsion (EP)
  - Radiation exposure increase
  - No rendezvous/docking between PPE and HALO at NRHO
  - Reduced PPE/HALO post-docking checkout in NRHO



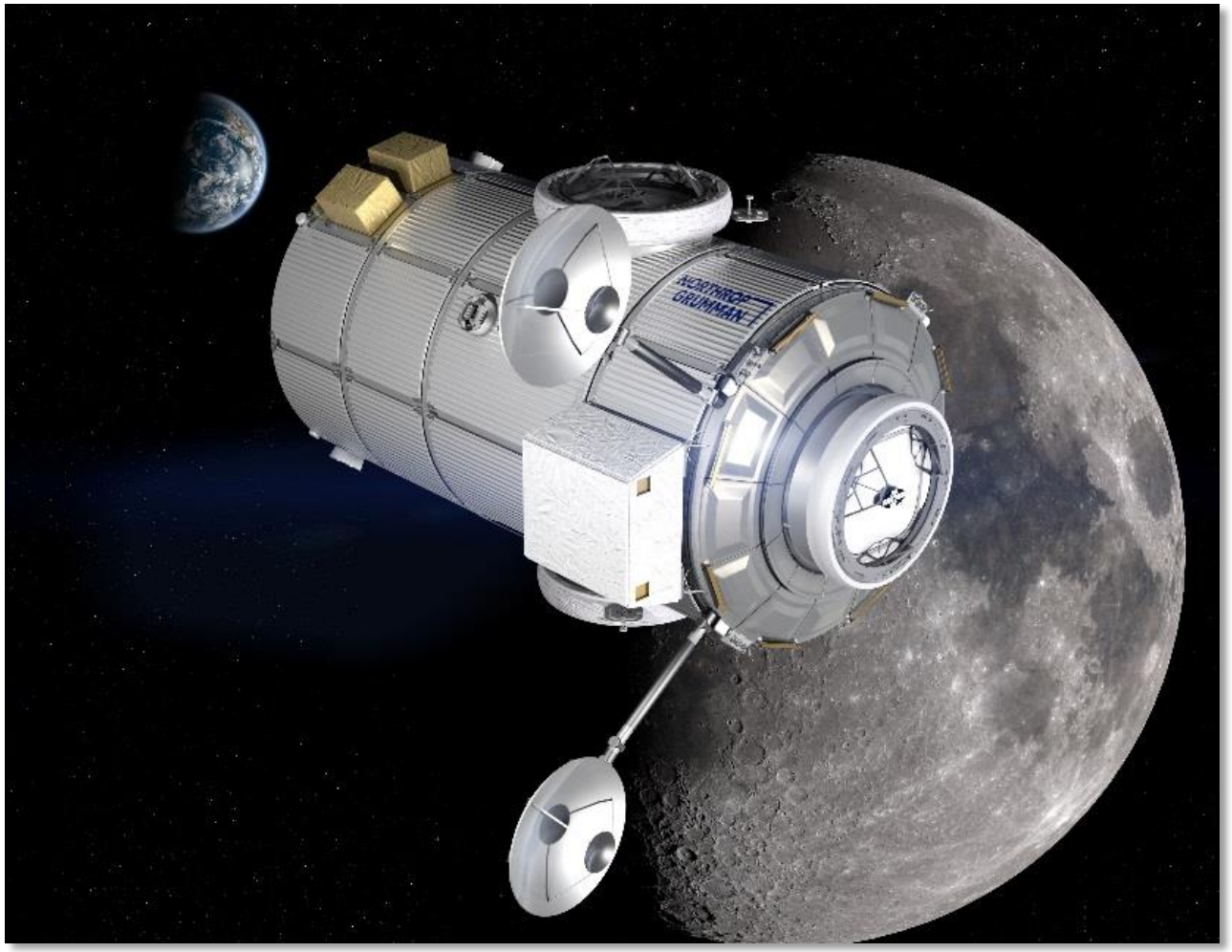


PPE/HALO = CMV: First Phase of Gateway

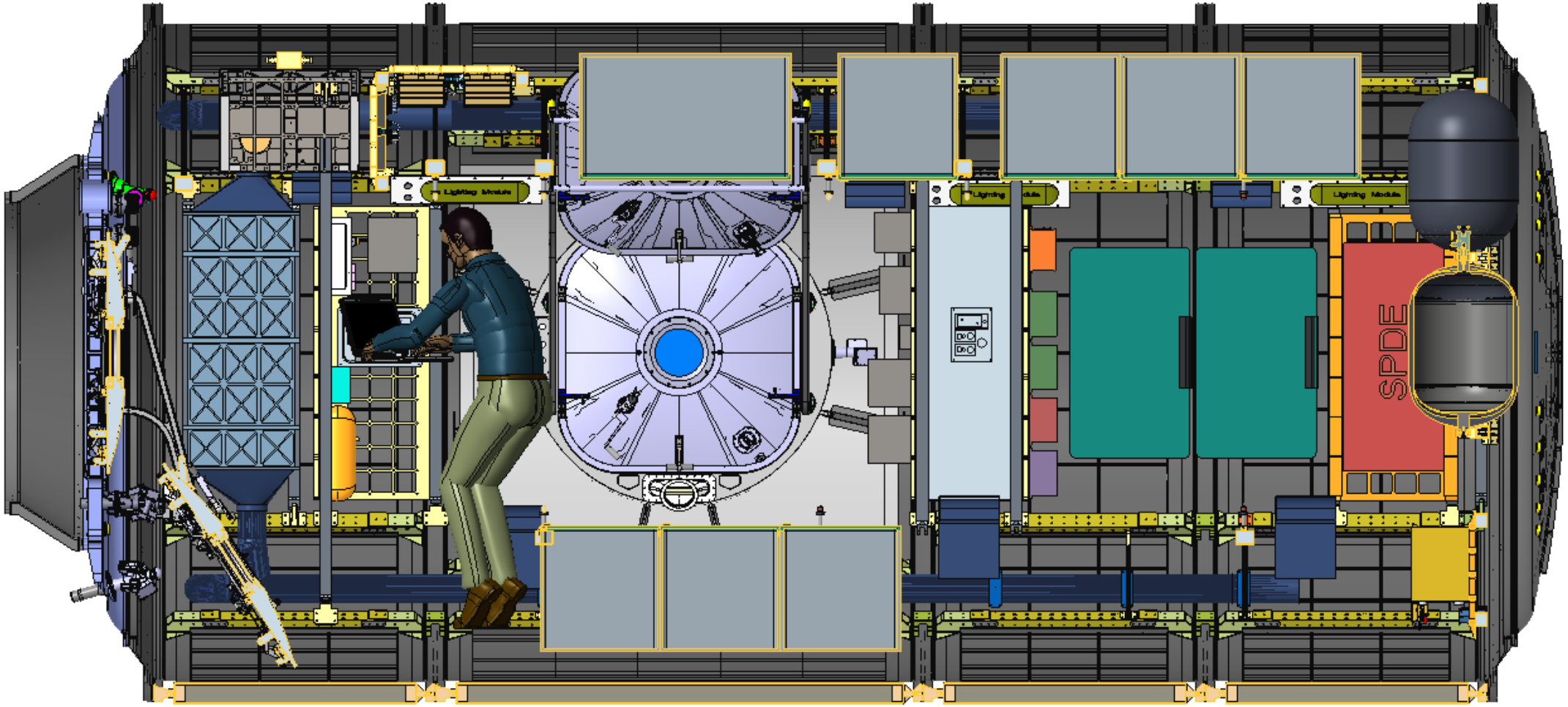
- The HALO module provides the capabilities for early habitable utilization of the Gateway, such as crew operational spaces, internal and external payload accommodations, external robotic interfaces, power and thermal control, oxygen/nitrogen supply and air circulation, and logistics storage for crew consumables
- HALO provides three visiting vehicle docking ports, hosts ESAs HALO Lunar Communication System (HLCS), and has interfaces to facilitate PPE refueling
- HALO is transported to a Near-Rectilinear Halo Orbit (NRHO) as a co-manifested configuration with the Power and Propulsion Element (PPE)
- The combined PPE and HALO vehicle is termed the Co-Manifested Vehicle (CMV)

HALO Primary Subsystems

- CDH – Command & Data Handling
- FSW – Flight Software
- CBCS – Computer Based Control System
- EPS – Electrical Power Systems
- TCR – Telemetry, Commanding & Ranging
- TCS – Thermal Control System
- ECLSS – Environmental Control Life Support System
- CS – Crew Systems
- Struc/Mech – Structures & Mechanism
- Cargo/Utilization – both interior/exterior payloads
- FTA – Fluid Transfer Assembly



HALO Internal View



- Includes Crew workstations to operate HALO or payloads
- Radial ports support crew access to logistics visiting vehicle and Lunar lander
- Stowage of logistics cargo, tools, emergency equipment, etc.
- Exercise area in the aft end of HALO

HALO Flight Hardware

- The first pieces of flight hardware for Gateway's Habitation and Logistics Outpost (HALO) have arrived at Thales Alenia Space Italy (TASI) sent by NASA's HALO contractor Northrop Grumman
- These forgings are the base metal that is used to create the pressure shell, barrel sections, and interface rings for HALO
- The manufacturing process is based on the same process employed by TASI in support of Northrop Grumman's Cygnus spacecraft, which is currently being used to deliver cargo to the International Space Station

Summary

- Following HALO SDR, NASA informed NG team to proceed with comanifest mission
  - Reduced launches from two to one
  - Eliminated remote rendezvous and docking between PPE and HALO
  - Allows opportunity for most of the PPE/HALO integrated testing to occur on the ground vs. in NRHO follow rendezvous
- CMV team of NASA, Maxar and NG are working together to develop mission concepts of operations
  - Prelaunch Ops and flight phases for comanifest mission
- CMV go for launch in late 2023
- CMV supports Phase 2 of Gateway and the Artemis Program


The Gateway (Phase 2)


And on to Mars
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