



January 18-19, 2022

NASA Advisory Council (NAC)

# ARTEMIS

## Advanced Exploration Systems (AES)

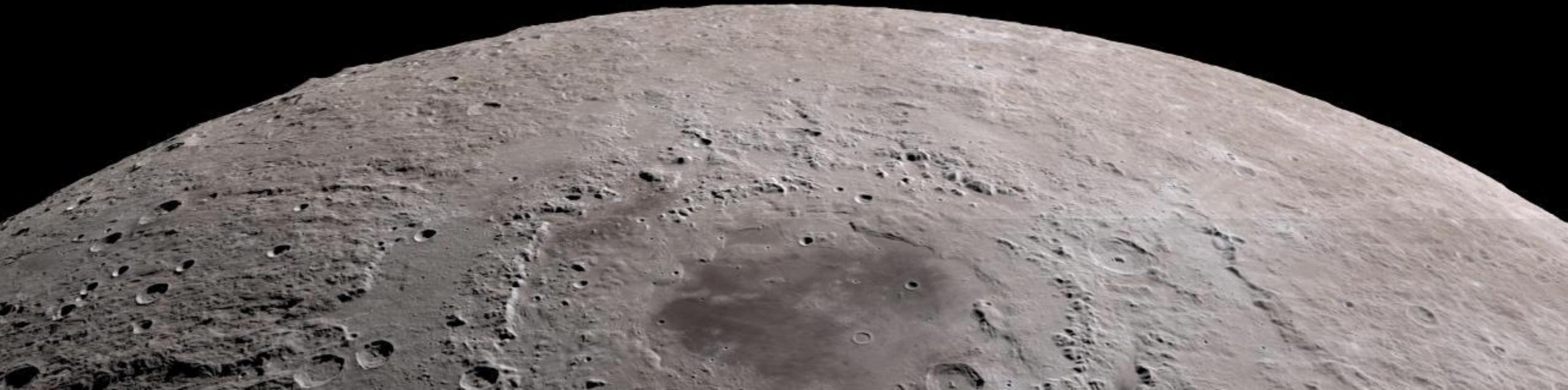
Mark Kirasich,  
Deputy Associate Administrator

# Advanced Exploration Systems (AES) Mission



Create a sustainable lunar and beyond human space exploration program

- HLS, Gateway, Exploration Suits, Lunar Terrain Vehicle and future Surface Mobility System Programs
- Plan and execute Artemis III+ Missions
- Develop advanced technology for long duration exploration missions





# ARTEMIS

Human Landing System (HLS)

# Human Landing System (HLS) Program Office



- The HLS Program Office is established at MSFC
- Business rhythm and governance established
  - Control boards, monthly element reviews, program quarterly reviews, risk boards
- Contract for the first crewed landing (Appendix H, Option A) in place
- Procurement planning for recurring landing services (Lunar Exploration Transportation Services) under way

<p>Nantel Suzuki HQ Program Executive</p>		<p>Heather Hall Program &amp; Management Analyst</p>		<p>Jason Turpin Deputy Project Manager</p>		<p>Lisa Watson-Morgan Program Manager</p>		<p>Lakiesha Hawkins Deputy Program Manager</p>		<p>Don Krupp Associate Manager</p>		<p>Lisa Hammond Associate Manager JSC</p>	
<p><b>HLS Technical Authority</b></p> <p>Rene Ortega HLS Chief Engineer</p>		<p><b>LP03 Program Planning &amp; Control Office</b> Mgr: Davey Jones (detail) Dep. Mgr: Joe Matus</p>		<p><b>LP10 Systems Engineering &amp; Integration Office</b> Mgr: Kent Chojnaki Dep. Mgr: Tom Percy (detail)</p>		<p><b>LP30 Space Vehicle Systems Office</b> Mgr: Ryan Whitley Dep. Mgr: Leo Barreda</p>		<p><b>LP40 Advanced Development Office</b> Mgr: Bill Jacobs Ast. Mgr: Alex Dominiguez</p>		<p><b>JSC Crew Compartment Office</b> Mgr: Steve Munday Dep. Mgr: Chuck Campbell</p>		<p><b>JSC Lander Flight Operations Office</b> Mgr: Cori Kerr Dep Mgr: Christie Bertels</p>	
<p><b>John Crisler</b> HLS Chief Safety Officer</p>		<p><b>KSC Lander Ground Operations Office</b> Mgr: Khoa Vo Dep. Mgr: Tracy Gill</p>		<p><b>LP20 Mission Systems Management Office</b> Tech Manager: Larry Gagliano Management Integration Lead: Daryl Woods</p>		<p><b>Debra Berdich</b> Chief Health &amp; Performance Officer</p>		<p><b>Jena Rowe</b> MSFC PAO</p>		<p><b>Joe Vermette</b> Strat Comm Lead</p>		<p><b>Laura Means</b> HLS Strat Comm</p>	

# Initial Human Landing System

## Appendix H Option A: Uncrewed Demo and first Crewed Landing

- APR 2021** ● SpaceX selected for Option A (DDT&E and first crewed demonstration mission)
- JULY 2021** ● Option A Contract Award
- NOV 2021** ● US Court of Federal Claims upholds SpaceX Selection, contract resumed
- First five SpaceX milestones complete; very strong data packages/reviews
  - Milestone schedule updated in the contract
  - Updated Integrated Master Schedule received and under evaluation
  - Site visits to Boca Chica and Hawthorne showed significant Starship progress
- TBD 2022** Upcoming Milestone: Orbital Flight Test

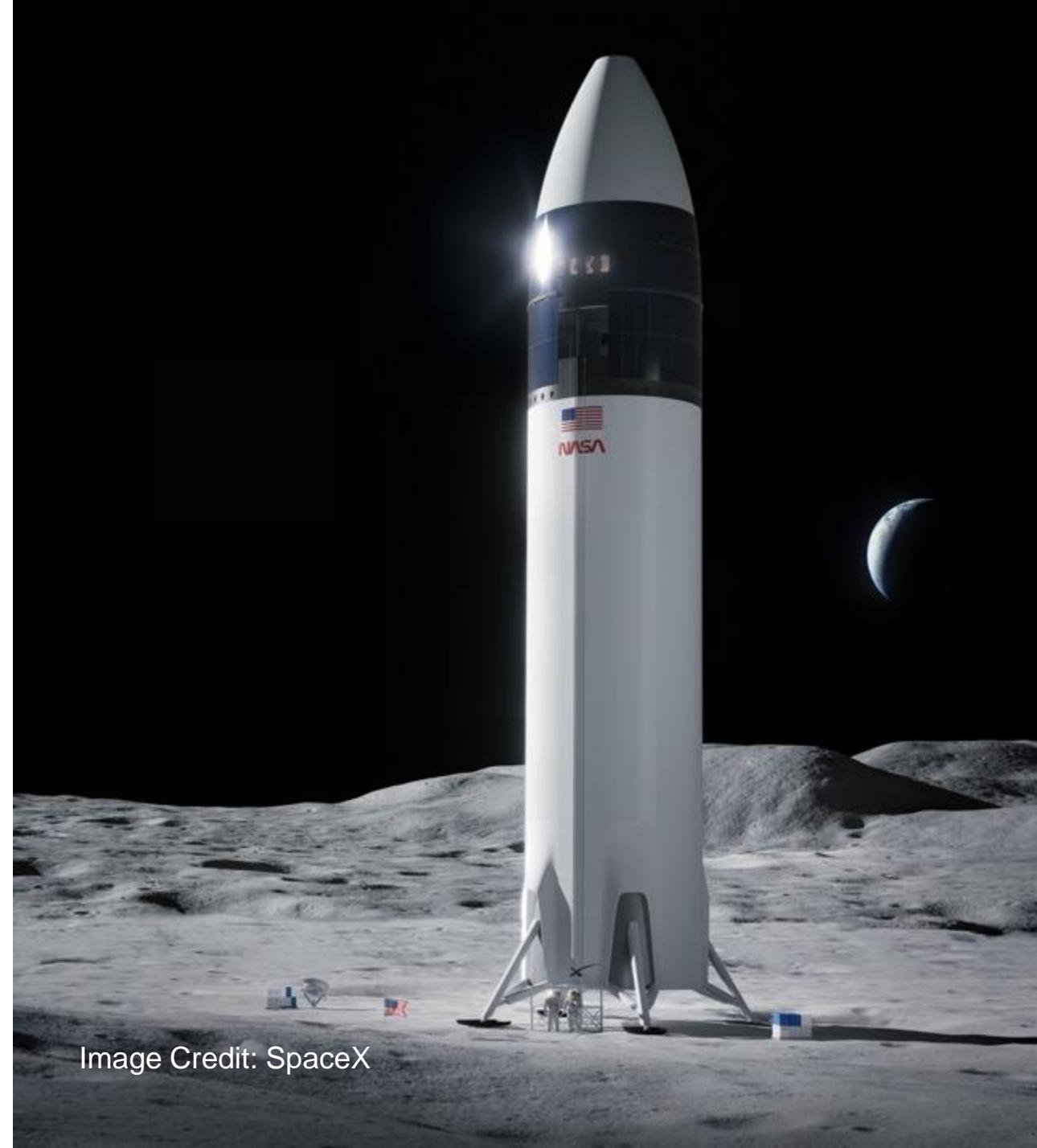


Image Credit: SpaceX

# SpaceX HLS Progress



SN11



B4 and S20 stacked | Aug 2021



S20 static fires | Oct – Nov 2021

# Additional HLS Procurement Actions



## Appendix N

- Prepares industry for the transportation services competition (also called a “bridge”)
- Initial awards to five companies: Blue Origin, Dynetics, Lockheed Martin, Northrup Grumman, and SpaceX
- CLIN 1 completed Nov 2021: Industry assessment of draft sustaining lander requirements
- Initially awarded CLIN 2 Risk Reduction work under way (initial awards based upon available funding)
- Additional work (CLINs 2, 3 and 4) may be awarded based upon available funding

## HLS Lunar Exploration Transportation Services (LETS)

- Develop and certify at least one affordable lunar landing solutions for sustained transportation services
- Two Request for Information (RFI) cycles completed to date in addition to App N
- DDT&E through Certification
  - Includes an uncrewed test of the human landing system
  - Contractor/Provider responsible for obtaining the launch vehicle
  - CLINS (severable) for Large Cargo missions; (not competing with GLS or CLPS)
- Services
  - Schedule: Recurring missions beginning 2028
  - IDIQ task orders for NASA determined mission assignments (includes flight readiness, post-flight review, etc.)
- Draft RFP to be available Spring, 2022



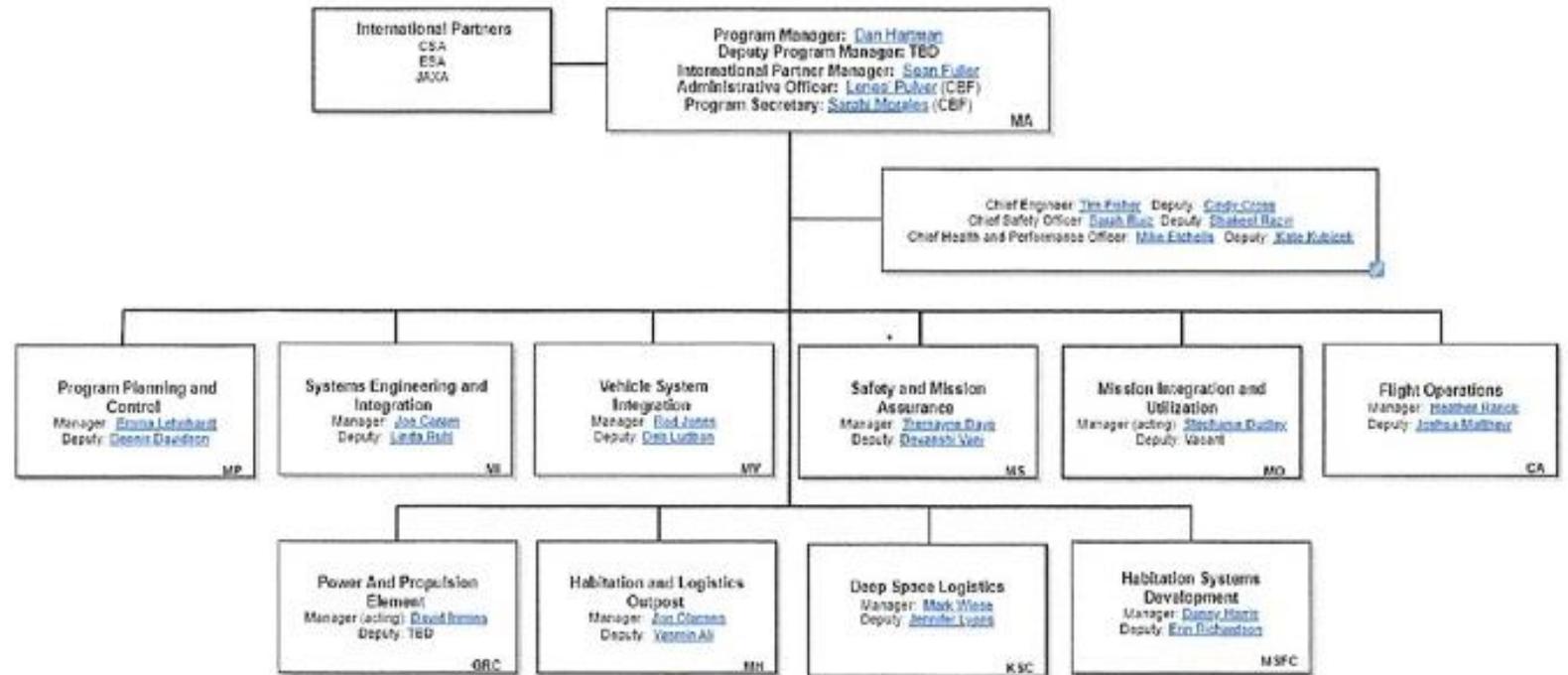
# ARTEMIS

Gateway

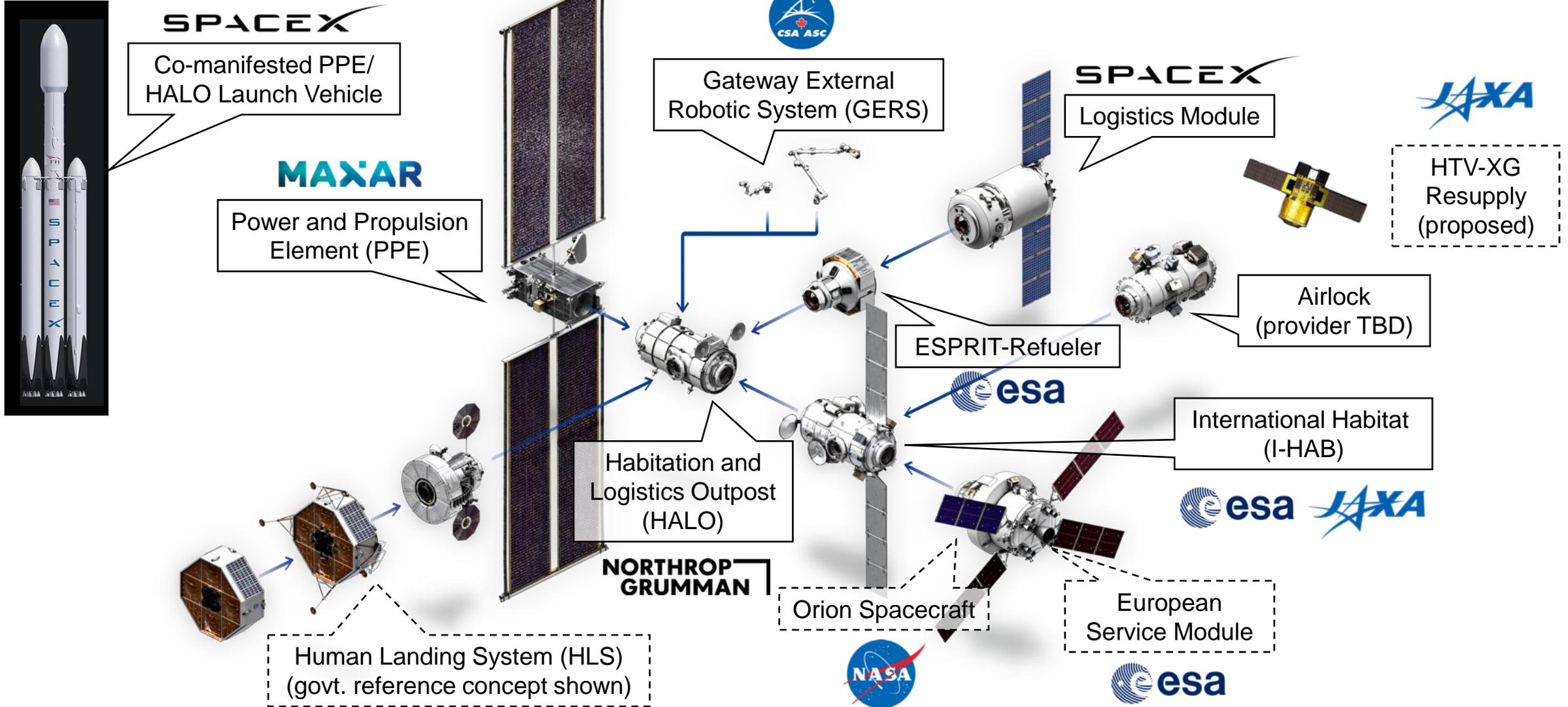
# Gateway Program Office



- The Gateway Program Office was established at JSC in Feb 2019
- International Partner MOUs with ESA, CSA, and JAXA signed in Dec 2020 - defining agency roles with contributions and benefits
- Business rhythm and governance established
  - Control boards, monthly element reviews, program quarterly reviews, risk boards
  - Relationships/Integration with International Partners, Prime contractors, Orion, and HLS well defined
- All early element contracts in place (less airlock)



# Gateway Integrated Spacecraft



# Gateway Program Major Accomplishments

Calendar Year 2021



- FEB** ● PPE/HALO Launch Vehicle contract award
- FEB** ● HALO primary structure assembly initiated in Italy
- MAR** ● Gateway Program SDR Delta Sync Review
- APR** ● Gateway Program Key Decision Point 0
- APR** ● 6 kW solar electric propulsion (SEP) subsystem test by PPE, Maxar, Busek
- MAY** ● HALO Preliminary Design Review (PDR) Close-out
- JUNE** ● Gateway Integrated Analysis Cycle (IAC) #7 kicked off
- JUL** ● Northrop Grumman awarded HALO contract (fixed price)
- AUG** ● Live ISS/HALO Q&A event
- NOV** ● International Habitat (I-HAB) PDR Part 2 Close-out
- DEC** ● Gateway PPE Maxar PDR Part 2



# Gateway Program Upcoming Major Events

Calendar Year 2022



- Block update to Maxar requirement set and PPE Base Completion Review
- Gateway Program Preliminary Design Review (PDR)-informed Sync Review and Key Decision Point (KDP) 1
- Gateway External Robotics System (GERS) System Requirements Review (SRR)
- PPE Maxar Systems and Integrated CDR
- HALO Systems and Integrated CDR
- Falcon Heavy Extended Fairing CDR
- Ship and delivery of the HALO habitable element, manufactured by Thales Alenia Space Italia (TASI)
- Ship refueling breadboard test rig to ESA for ESPRIT testing
- Continue GLS special studies in advance of first mission ATP
- Initiation of ~ 12 GFE items required for initial capability and delivery of NDS passives/S-Band radios for HALO
- Continued build-out of Lab facilities (power, com, avionics/software)
- Design Analyses Cycle 8 kickoff
- Focused area on ICD development and detailed verification objectives across the program



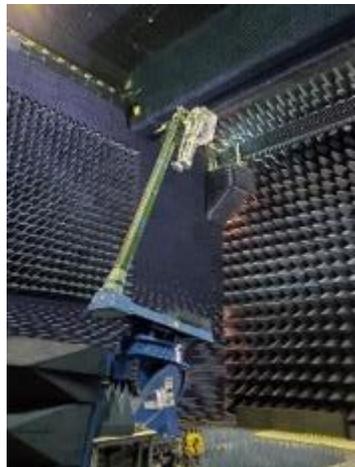
# ARTEMIS

Spacesuits and  
Human Surface Mobility Systems

# Exploration Extravehicular Activity (xEVA) Status



**xEMU DVT Helmet  
Light Testing**



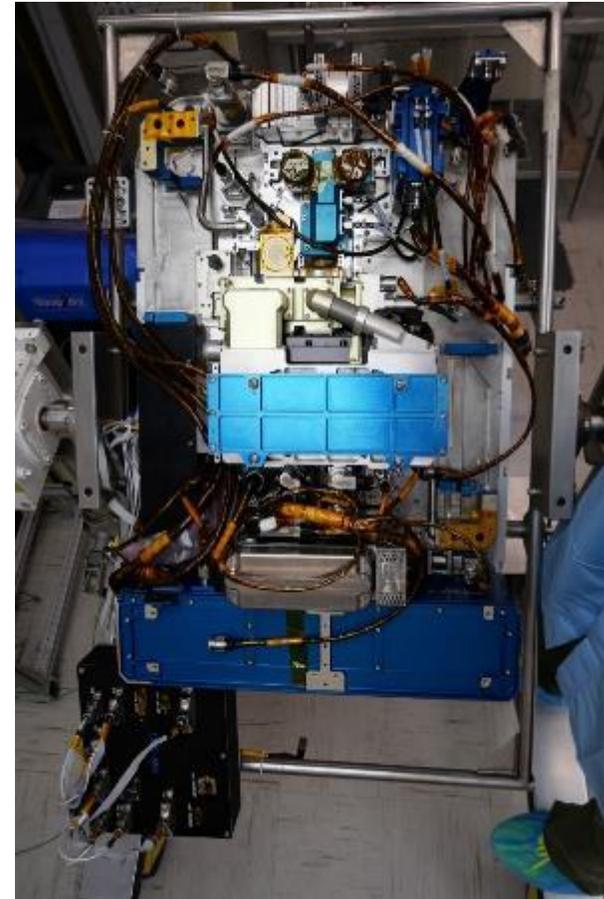
**xEMU Antenna Testing**

- xEVA Services (xEVAS) procurement to provide suits for ISS, Gateway and the lunar surface
  - Proposals received on Dec 14<sup>th</sup>, 2021
  - Targeting contract award April 2022
- Continued strong government-based risk reduction work
  - Initiated exploration Extravehicular Mobility Unit (xEMU) design verification testing (DVT) of the pressure garment subsystem (PGS) and portable life support subsystem (PLSS)
    - Primary and auxiliary Thermal Control Loop testing
    - Helmet light and camera assembly vibration testing
    - Antenna pattern testing
    - PGS partial gravity mobility evaluations at Active Response Gravity Off-load System facility (ARGOS)
  - Successfully completed first human-in-the-loop test series in upgraded 20ft Chamber test facility
  - Successfully completed fifth of six planned on-orbit simulated EVA series with the Spacesuit Evaporation Rejection Flight Experiment (SERFE) following a planned 210d dwell period
  - Test data and reports will be added to EVA Technical Library to reduce risk for future xEVAS partner(s)

# Exploration Extravehicular Mobility Unit (xEMU) Design Verification Testing (DVT) and Project Technical Review (PTR)



- **xEMU DVT unit is an extremely high-fidelity EDU**
  - xEMU DVT's purpose is to reduce the risk of failure during Qual, post CDR, late in the development cycle
  - DVT testing will assess majority of requirements by evaluating adequacy of component and assembly level performance
  - DVT results anchor analytical models
  - DVT validates alternate components acceptability where parallel suppliers have been developed
- **xEMU PTR will be a tailored internal review of CDR-level design products**
  - Among several outcomes, PTR allows NASA to clearly rank the fidelity/maturity of the xEMU design products available at time of xEMU closeout, prior to transition to xEVAS
  - To avoid unnecessary overhead, xEMU PTR will not be a formal CDR
  - Focus is on technical content, not process



**xPLSS DVT Assembly as of ~May '21**  
Vent Loop Assembly underway

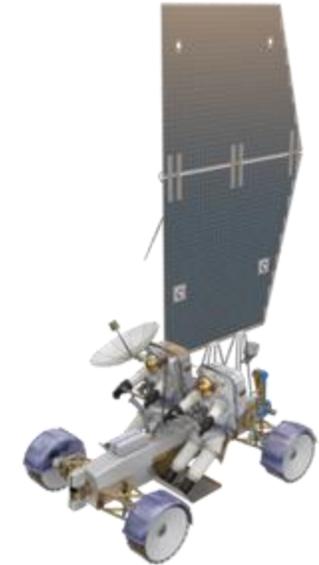


**xPGS DVT Assembly as of ~May '21**  
Pressure Checks underway

# Human Surface Mobility (HSM) Status



- Released a second Lunar Terrain Vehicle (LTV) Request for Information in September 2021
  - Received 21 responses containing feedback on approaches to surviving the extended lunar night, supporting 10 years of operation, delivery service preference, and interest in providing LTV as a commercial service.
  - Responses are feeding updates to the Survive the Night assessment and informing LTV procurement strategy.
- Completed initial draft of requirements and initial standards tailoring to support upcoming LTV Mission Concept Review (MCR), including those for LTV system and interfaces to xEVA, HLS, communication systems, and payloads.
- Investigated strategies for changes to LTV Reference Design power and thermal subsystems for surviving longer periods of lunar night
- Held a three-day TIM with JAXA to discuss Pressurized Rover high-level system requirements and concepts of operation, as a part of the ongoing feasibility study
- Initiated an AES cross-program analysis to assess impacts of incorporating a suitport requirement for sustained lunar surface operations.
  - A final decision on the requirement is expected in early spring and programmatic documentation will be updated accordingly

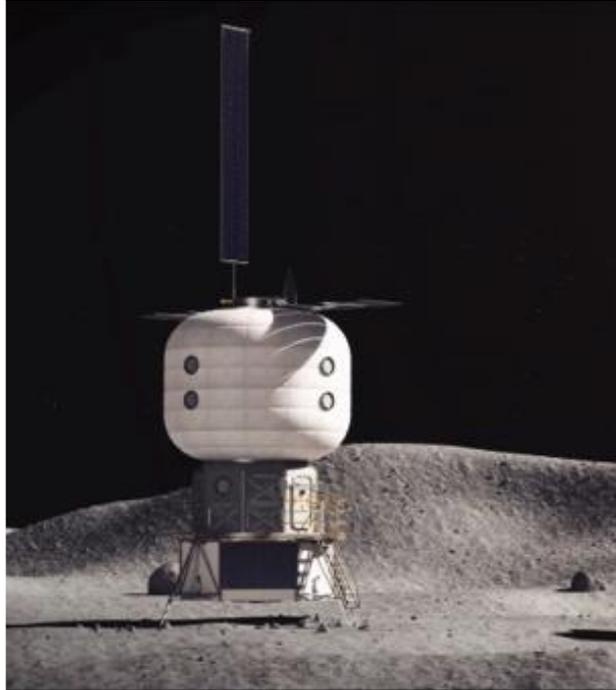




# ARTEMIS

Exploration Capabilities

# Exploration ECLSS/Human Habitability Needs



## Lunar Surface Habitat

2 to 4 crew for 30 to 60 days

- High pressure oxygen generation for EVA
- Wastewater and urine processing > 98% water recycled



## Mars Transit Habitat

4 crew for 1,100 days

- Highly reliable regenerative environmental control and life support systems (ECLSS)
- Includes brine recovery, Sabatier + Plasma Pyrolysis Assembly (PPA), lightweight trash disposal and ejection system

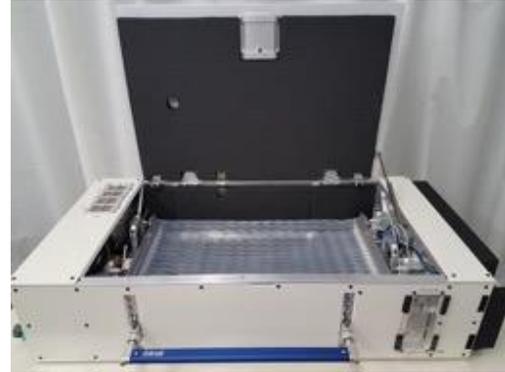
# Testing Exploration ECLSS and Crew Safety with ISS



CO<sub>2</sub> Scrubbers will recover > 75% of oxygen



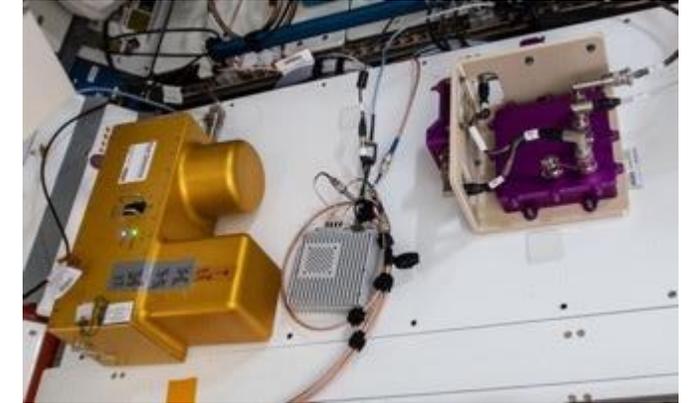
Thermal Amine Scrubber



Brine Processor Assembly will recycle 98% of water.



Spacecraft Atmosphere Monitor



Radiation Sensors  
Right: Hybrid Electronic Radiation Assessor (HERA)  
Left: ISS Radiation Assessment Detector



4-Bed CO<sub>2</sub> Scrubber



Universal Waste Management System



Advanced Oxygen Generator will produce high pressure O<sub>2</sub> for EVA



Saffire Fire Safety Flight Experiments

# Crew Health and Performance Systems Development



**Food Systems:** Reducing water content, increasing shelf life, and growing food crops in space (Sierra Space AstroGarden)



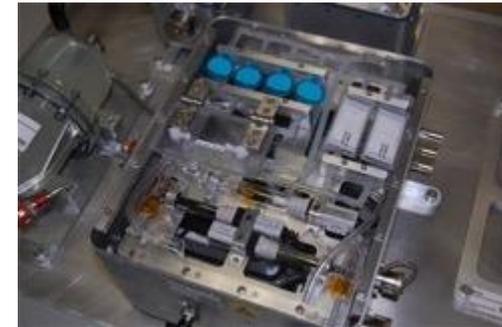
**EVA Physiology:** Investigating the physiological effects of EVA on the crew to prevent injuries, and informatics to improve crew performance.



**Crew Health and Performance Exploration Analog (CHAPEA):** Simulated 1-year Mars mission in 3D-printed habitat.



**Exercise Countermeasures:** Developing exercise equipment to keep the crew fit and healthy during long missions in deep space (ESA)



**Exploration Medicine:** Intravenous Fluid Generation (IVGEN) Mini

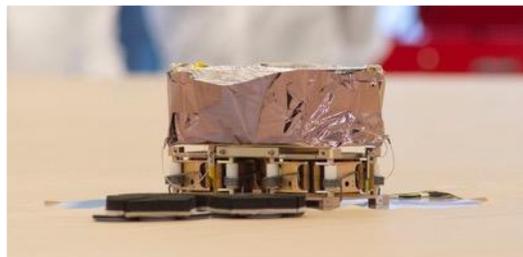
# AES Artemis I CubeSats



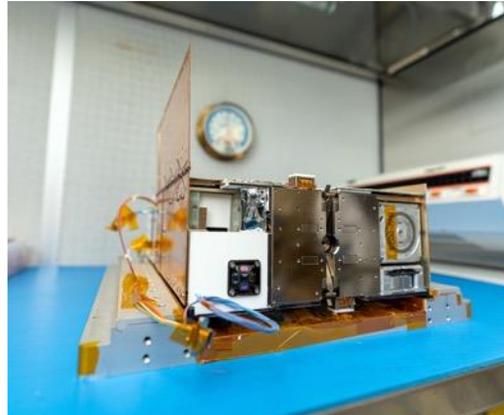
## BioSentinel



Use yeast as a biosensor to evaluate the effects of ambient space radiation on DNA.



## Lunar IceCube



Search for water (and other volatiles) in ice, liquid and vapor states using infrared spectrometer.

## Near-Earth Asteroid (NEA) Scout



Detect target NEA, perform reconnaissance and close proximity imaging.

## LunIR



Use a miniature high-temperature Mid-Wave Infrared (MWIR) sensor to characterize the lunar surface.



# ARTEMIS

Mission Integration

# Top AES Integration Accomplishments



Highlights since September 2021

- Released Working Artemis Manifest to allow mission analysis and technical integration
- Kicked-Off Enterprise Mission Analysis Cycle 3.1 Part 2 for Artemis III
- Completed First AES Top Risk Review
- Completed Artemis In-Space Communications Architecture Trade
- Vetted Future Artemis mission requirements to support Human Landing System (HLS) sustained lander draft Request for Proposal (RFP) efforts
- Kicked-Off AES Requirements Analysis Cycle 2

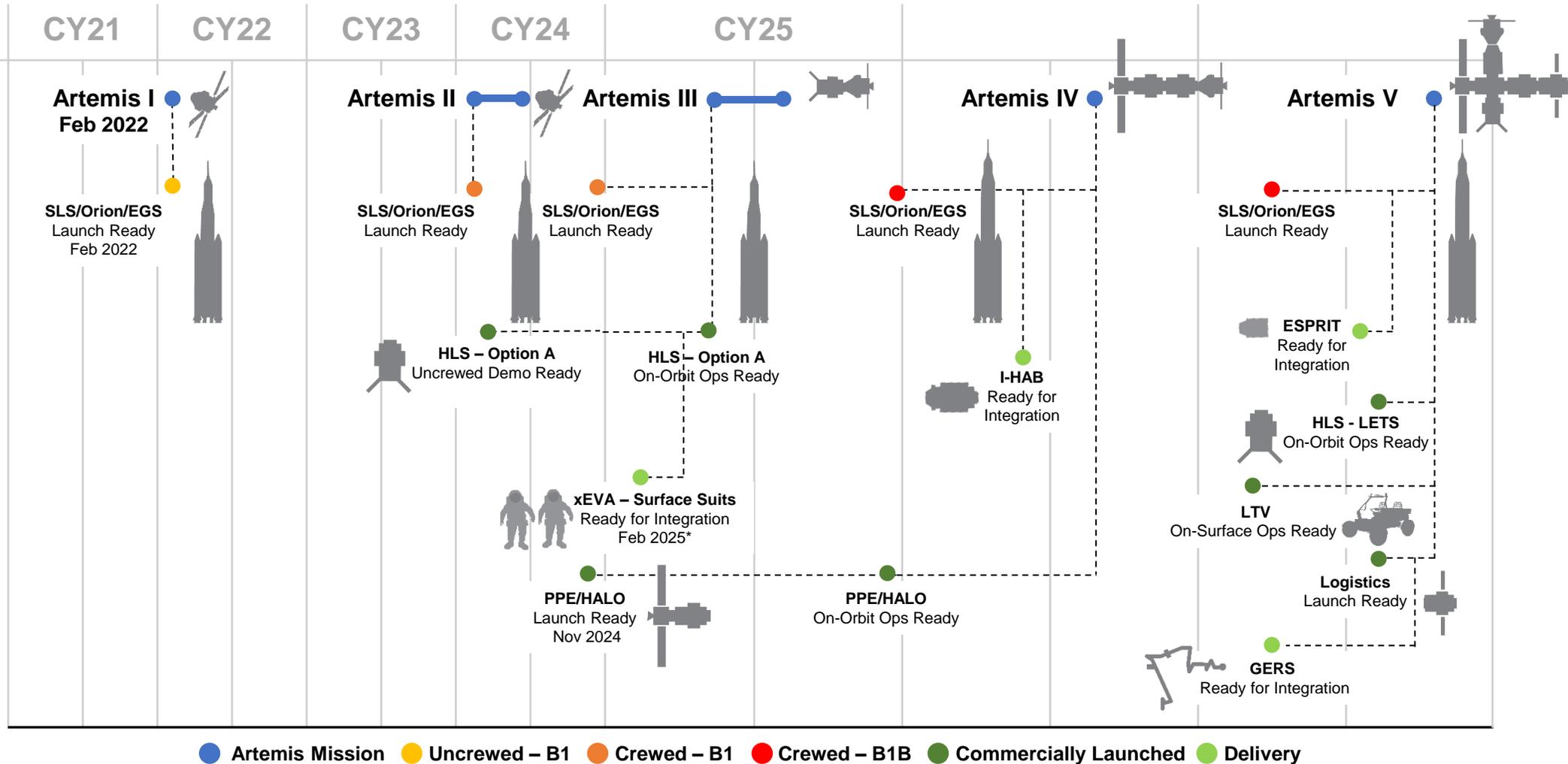
# Working Manifest for Technical Integration



## Key Terminology:

- B1:** Block 1 (SLS with ICPS)
- B1B:** Block 1B (SLS with EUS)
- EGS:** Exploration Ground Systems
- ESPRIT:** European System Providing Refueling, Infrastructure & Communications
- EUS:** Exploration Upper Stage
- GERS:** Gateway External Robotics System
- HALO:** Habitation and Logistics Outpost
- HLS:** Human Landing System
- ICPS:** Interim Cryo Propulsion Stage
- I-HAB:** International Habitat
- LETS:** Lunar Exploration Transportation Services
- LTV:** Lunar Terrain Vehicle
- PPE:** Power & Propulsion Element
- SLS:** Space Launch System
- xEVA:** Exploration Extravehicular Activity

\*Date based on Government planning and estimates; not contract informed



# AES Integration End-to-End Products



## AES SE&I

### Safety & Mission Assurance

<b>Probabilistic Risk Assessment</b>
Mission LOC and LOM analyses
<b>Crew Survivability Assessment</b>
Artemis Mission Crew Survival Analysis Report
<b>System Safety Plans</b>
Artemis Mission Mishap Response & Contingency Action Plan S&MA Plan
<b>System Safety Analysis</b>
Integrated Hazards Analysis

### AES PP&C

Schedule Integration  
CM/DM  
Risk Management  
AES Implementation Plan

### AES Baseline Definition

AES V&V Plan (design Cert)  
AES Req'ts, Standards, Constraints  
AES CONOPS  
AES MBSE Model  
AES Architecture/ Configuration  
AES Waivers & Deviations Records  
AES Certification Metrics

### Flight Certification

AES COFR Plan  
AES eCOFR System

### Imagery

AES Imagery Req'ts/V&V  
AES Imagery ConOps  
AES Imagery Post-Flight Report  
AES Ground Video Distribution  
AES GFE Handheld Cameras

### Data Integration

AES Tool Development

### Technical Management

AES SEMP, Sync Point Plans  
AES Technical Risks and Issues  
AES TPMs  
AES Integrated SEI Schedule  
AES IT Tools and Data Requirements

### ETE Mission Performance (EMPT)

AES E2E Performance GRA  
AES Conceptual Flight Profile (Artemis III/IV)  
AES Integrated Performance TPM Report

### Integrated Avionics & Software

AES End To End Avionics & Software Integration Plan  
AES IAS V&V Assessment Report  
AES IAS Integrated Schedule  
IAS Post Flight Assessment Report  
AES End to End Validation Test Plan  
AES Integrated Avionics & Software Config Matrix

### Communications/Network Infrastructure

AES Comm, Network, Tracking Architecture  
AES Integrated Comm, Network & Tracking (ICAN) Test Plan  
AES Cross Program Spectrum Management  
Advanced Encryption Standard Key Production Spec

### Aborts

AES Abort Cert Strategy  
Abort Timelines  
Abort Analysis Methodology  
Abort Conditions/Triggers  
Abort Design and Performance

### Human Rating

AES HRCP  
AES Human Error Analysis  
AES Usability Report

### Mission Design & Planning

AES EMAC Plan and Outcomes  
AES Off-nominal and Contingencies  
AES Mission Planning  
AES GR&A  
AES Mission Design Matrix  
AES Mission Manager Data Book  
AES Surface Mission Data Book

### Crew Interfaces & Interoperability

AES Interoperability (Crew I/F) Plan  
AES GFE Plans

### Mission Operations & Integration

#### Artemis Mission Integration

AES Mission Implementation Plan  
Mission Definition Baseline  
AES Manifest & Flight Plan

#### Artemis Mission Operations

AES Flight Rules Artemis III+

#### Payloads

AES Payload Selection/Manifest  
AES Payload Utilization Plan

#### Lunar Logistics & Resupply Manifesting

AES Logistics Manifest

# AES Summary



- Initial HLS under contract and planning for sustaining HLS services procurement is underway
- All initial Gateway capability elements are under contract and proceeding to system-level Preliminary Design Review (PDR); module-level Critical Design Reviews (CDRs) planned for calendar year 2022
- Exploration suit procurement underway, targeting April 2022 award
- LTV formulation activities underway and Pressurized Rover pre-formulation effort continues
- Artemis mission planning and integration processes defined and being executed



Follow the missions

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