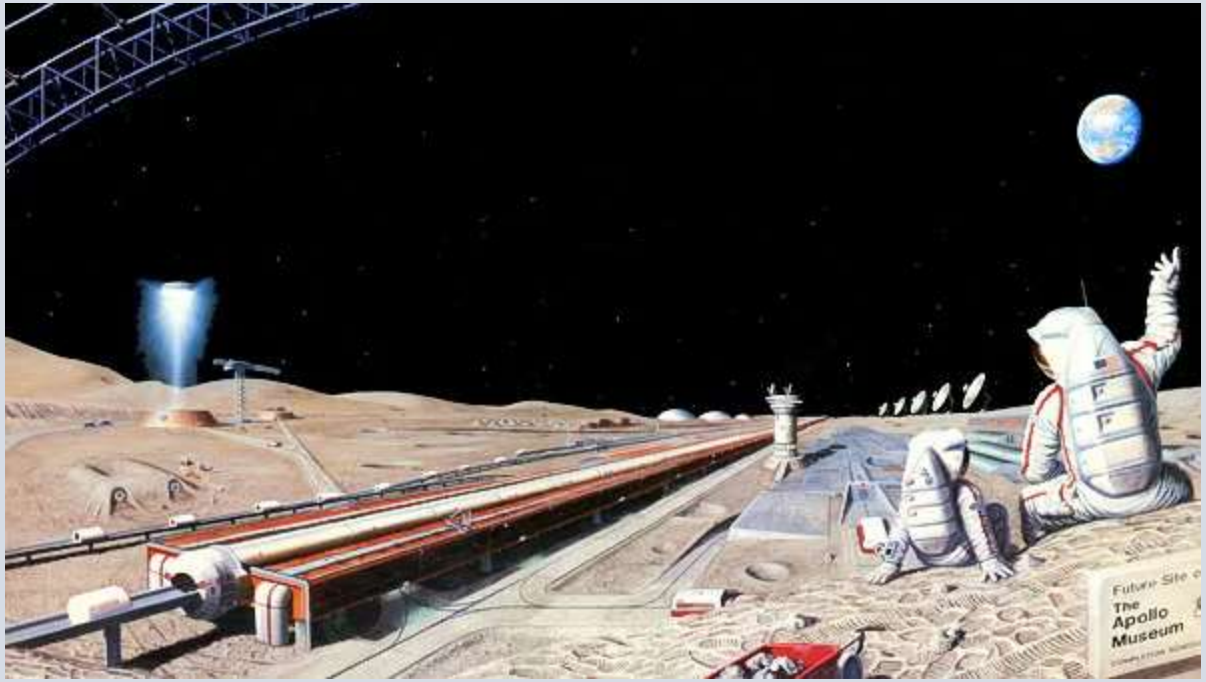


Review of NASA's Artemis Program

National Academies Aeronautics and Space Engineering Board

October 20, 2022

N. Wayne Hale, Jr.

NASA Advisory Council
Human Exploration & Operations Committee

- This discussion is not the official position of NASA, the NASA Advisory Council or the NAC HEO Committee

- This discussion is solely my own, informed partially by the information given to the NAC HEO committee which I am appointed to chair

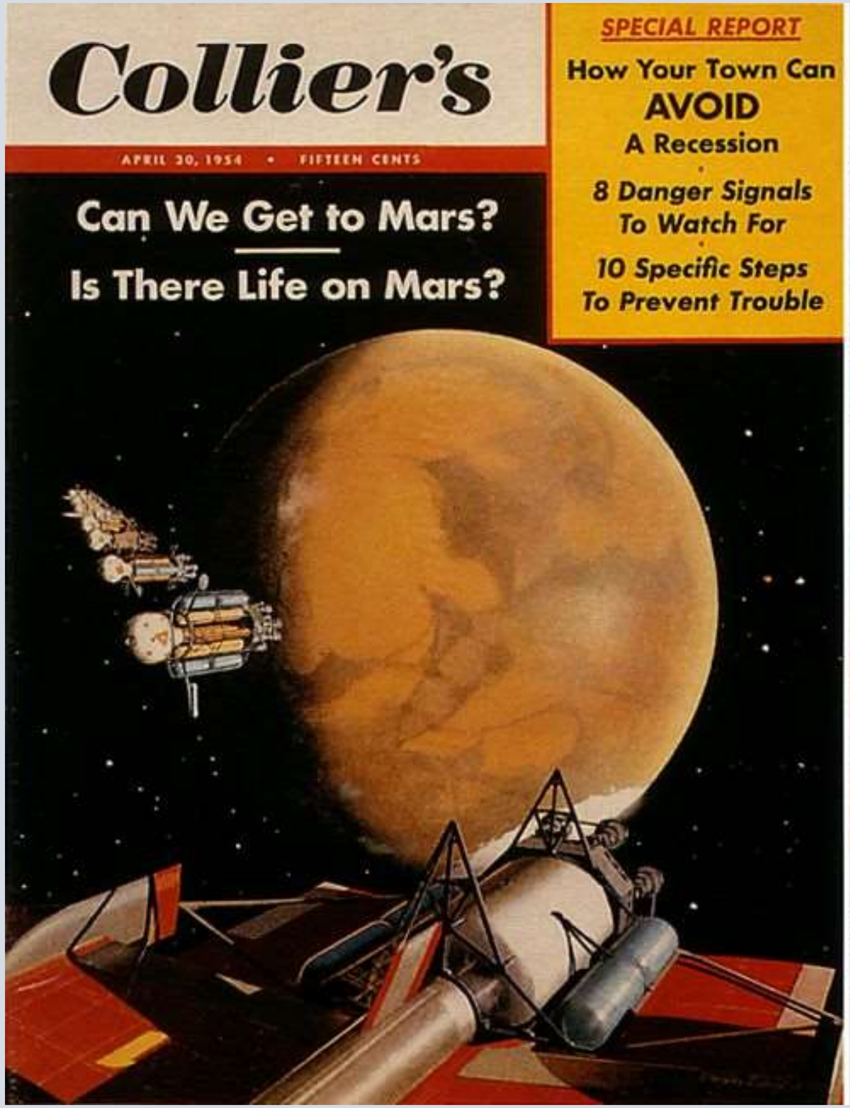
- ***All information in this presentation is from open source/public documents***

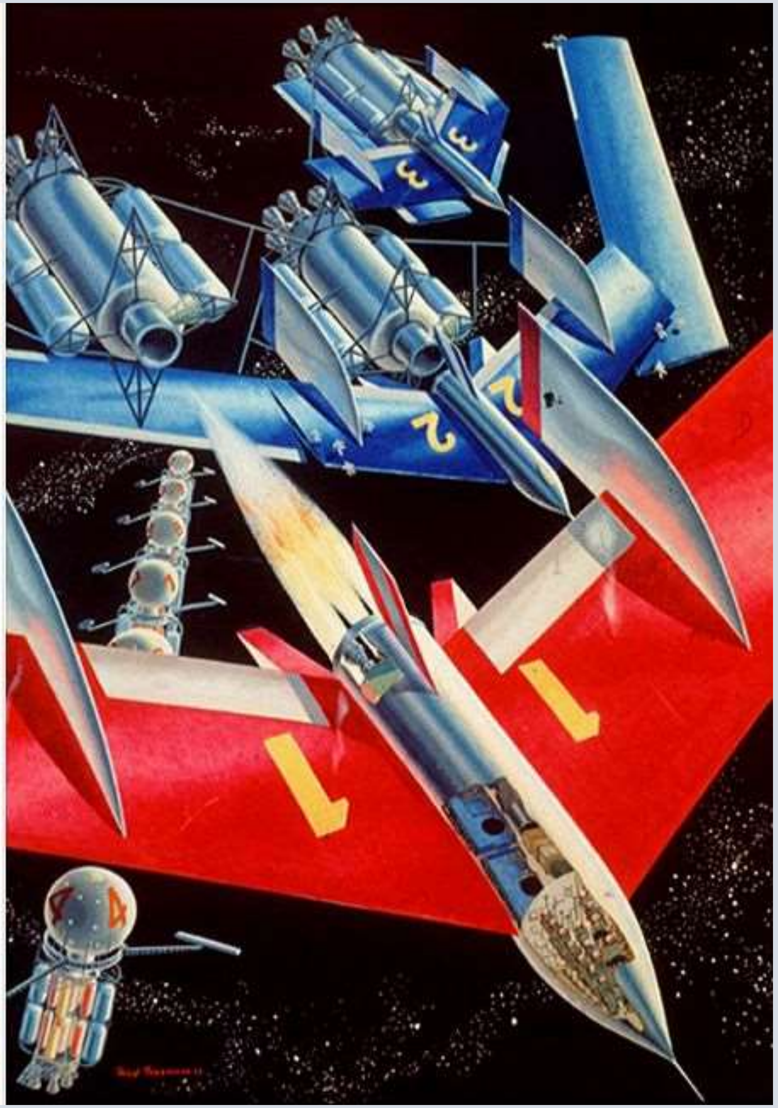
- HEO Committee membership

Wayne Hale (chair)
James Voss
Mark McDaniel
Pat Condon
Mike Lopez-Alegria
Nancy Ann Budden
Kwatsi Alibaruho
George Sowers
Doug Ebersole
Lynn Cline
Ellen Stofan (just appointed)
Pat Sanders (ex officio)

Expectations Driven by History

- In the 1950's Collier Magazine with Willy Ley and later Werner Von Braun with Walt Disney developed a plan that still resonates


Collier's
APRIL 30, 1954 • FIFTEEN CENTS
SPECIAL REPORT
How Your Town Can
AVOID
A Recession
8 Danger Signals
To Watch For
10 Specific Steps
To Prevent Trouble
Can We Get to Mars?
Is There Life on Mars?



“The United States will Maintain its Leadership in Space Exploration and Space Science”

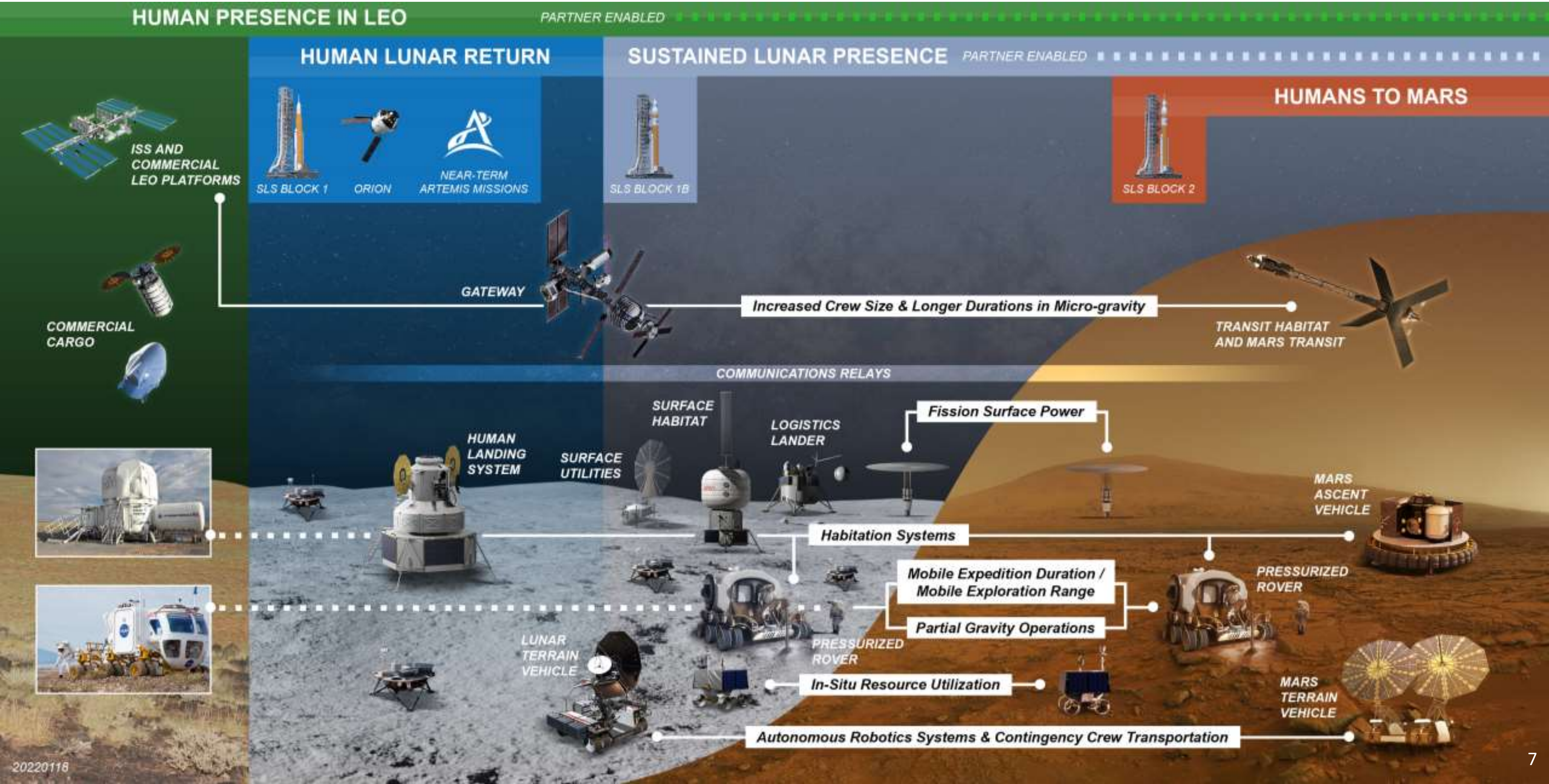
“Remain a global leader in science and engineering by pioneering space research and technology that propels exploration of the Moon, Mars, and beyond.”

“U.S. human and robotic space exploration missions will land the first woman and person of color on the Moon, advance a robust cislunar ecosystem, continue to leverage human presence in low-Earth orbit to enable people to live and work safely in space, and prepare for future missions to Mars and beyond.”

— The White House U.S Space Priorities Framework, Dec 2021

United States Space Priorities Framework
NASA 2022 Strategic Plan
2023 NASA Budget Request

Exploration Campaign & Segments



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NASA's Moon to Mars Objectives

A blueprint for future human exploration

SCIENCE

Conduct science on and around the Moon, using humans and robots to address scientific priorities about the Moon.

Demonstrate future science methods astronauts can use beyond Low Earth Orbit:

- Lunar/Planetary
- Heliophysics
- Biological/Physical
- Astrophysics

TRANSPORTATION AND HABITATION

Develop and demonstrate an integrated system to conduct human missions.

Live and work at deep space destinations and safely return to Earth.

LUNAR AND MARS INFRASTRUCTURE

Maintain continuous robotic and human presence on the Moon with multiple international and industry users to develop a robust lunar economy.

Create infrastructure to support initial human Mars demonstration and to continue exploring the solar system.

OPERATIONS

Conduct human missions on and around the Moon followed by missions to Mars.

Use a gradual approach to build, demonstrate, and operate new technologies to live and work on other planetary bodies.

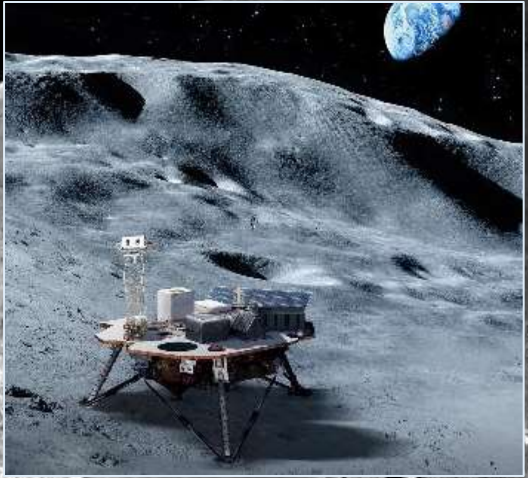
Requested feedback on these objectives in summer 2022 from the following key stakeholders:

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

Human Exploration Focus



SCIENCE	ANNUAL LUNAR SURFACE MISSIONS	MARS	EXPANDING PARTNERSHIPS
Connects all elements The "why"	**2025-2031** **2 Crew | 6.5-14 days**	**Analogs** **Space Station | Moon**	**International** **Existing and New Partners**
Enables architecture Ex: In-situ Resource Utilization	**2031+** **4 Crew | 30 days**	**Robotic Sample Return** **Volatiles**	**Industry** **Economic Development**
Incorporation of Decadal Level Science			**Other Government Agency Partners (DOE, NSF, NIH)**

Return to the Moon for the Long Term

- Not just Flags and Footprints /Cold War impetus like Apollo
  - A rapid trip to ‘beat the Chinese’ is not considered important
- Open Cis-Lunar Space for Human Activity for the Long term
  - Learning to work in deep space for extended periods of time
  - Extensive science from multiple areas of the Moon
  - Eventually turn over activities to the commercial sector in time
  - “Exist strategy” is complex but after a period allows for Mars activities
- ISRU Accelerates Mars Program
  - Water Ice ***potential*** at the Lunar South Pole would allow much cheaper and probably faster program to Mars
  - He3 may help solve Earth’s energy problems/Climate change
- Longer term goal is to open the Solar System to Human Activity
- All schedules are ‘Aspirational’

Cost is a problem

- SLS especially at low production rate is extremely expensive
- Starship Lander costs in the long term are yet to be determined
- Many development programs must take place for success
  - Cryogenic Propellant transfer in space/low rate boiloff storage
  - ‘Sustainable’ Lunar Lander
  - Lunar Surface EVA suits (and Mars Surface EVA suits)
  - Habitats and Transportation (LTV, Pressurized Rover, etc.)
  - Surface power
- Commercial ‘partnerships’ are seen as a panacea
- International contributions are also sought.
- NASA knows that cost killed Apollo

Why the Goofy Architecture?

- 1. SLS Block I cannot lift as much as Saturn V (no one-shot to the Moon).
- 2. SLS Block IB requires development of a more powerful upper stage, the Exploration Upper Stage, in work but not available now (schedule TBD)
- 3. The Orion service module, due to historic reasons, does not have the delta V capability that the Apollo service module had. Orion cannot insert and extract itself from low lunar orbit. Thus 'distant' orbit required.
- 4. The NHRO provides the best orbit to access the full lunar surface (rather than just equatorial sites) and is particularly good for landing at the south pole – where the water is supposed to be. (Apollo was only good for Equatorial sites)
- 5. The Gateway provides a logistics hub, an assembly point, and a safe haven in high lunar orbit as well as serves as a test bed for Mars mission technologies and mission techniques

Artemis Plans

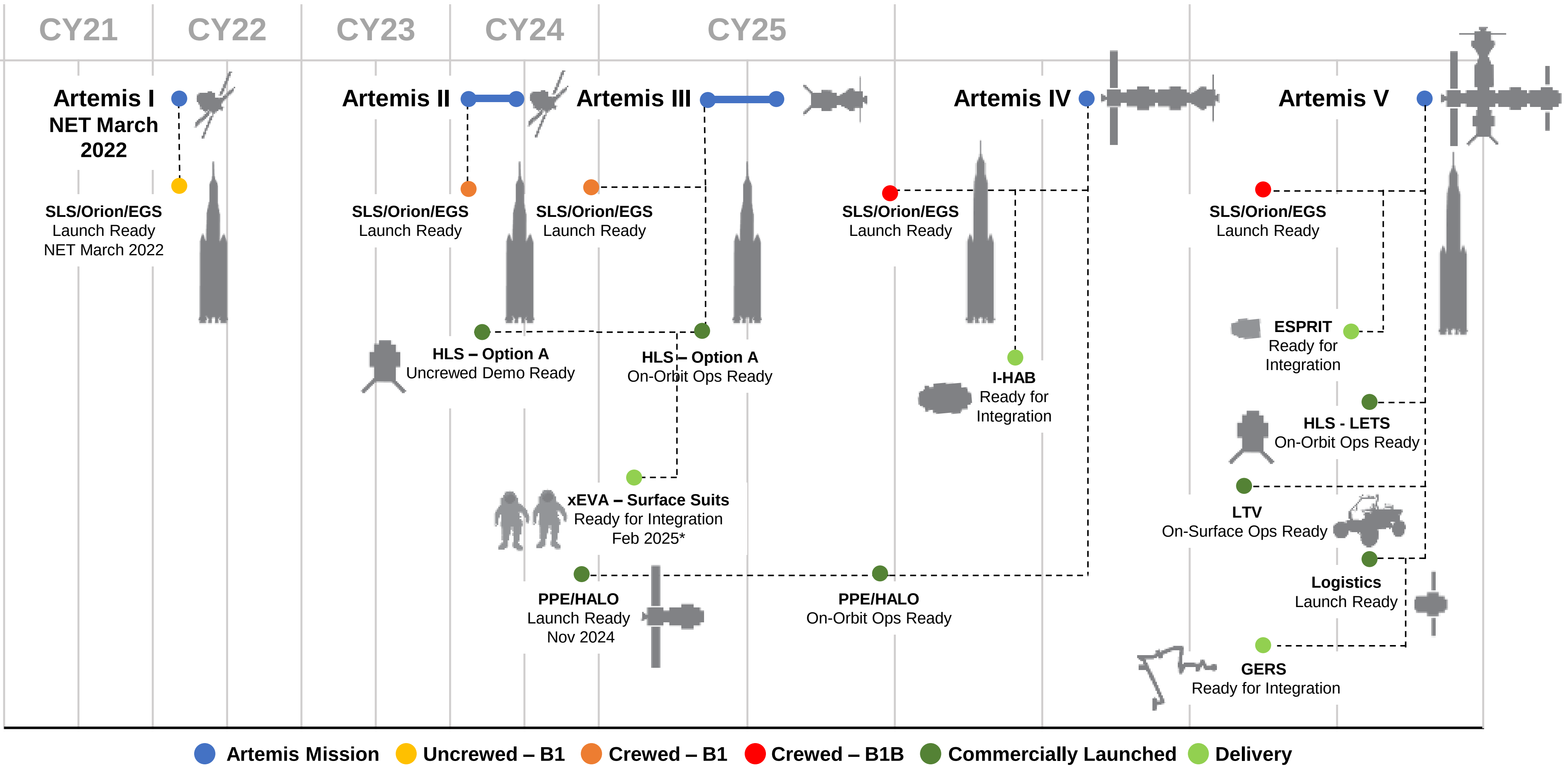
- Artemis I No Earlier Than November 14
  - Uncrewed mission to Lunar Distant Retrograde Orbit and return
  - Largely an engineering test but significant science objectives
- Artemis II 2024-ish
  - First crew mission, Lunar flyby with no orbit
  - Largely an engineering test but with significant science objectives
- On Orbit Demonstration of Cryo Prop transfer occurs in 2023 or 2024 (?)
- HLS (SpaceX) Demonstration uncrewed Lunar Landing approx. 2024
  - Launch from the Lunar surface is not a requirement for this demo
- Artemis III 2025 (current plan)
  - Demonstration Lunar Landing with 2 crew, short stay
- Gateway initial assembly 2026
- Regular ('Sustained') Human Lunar presence late 2020's
- Notional Mars campaign starting later

Working Manifest for Technical Integration

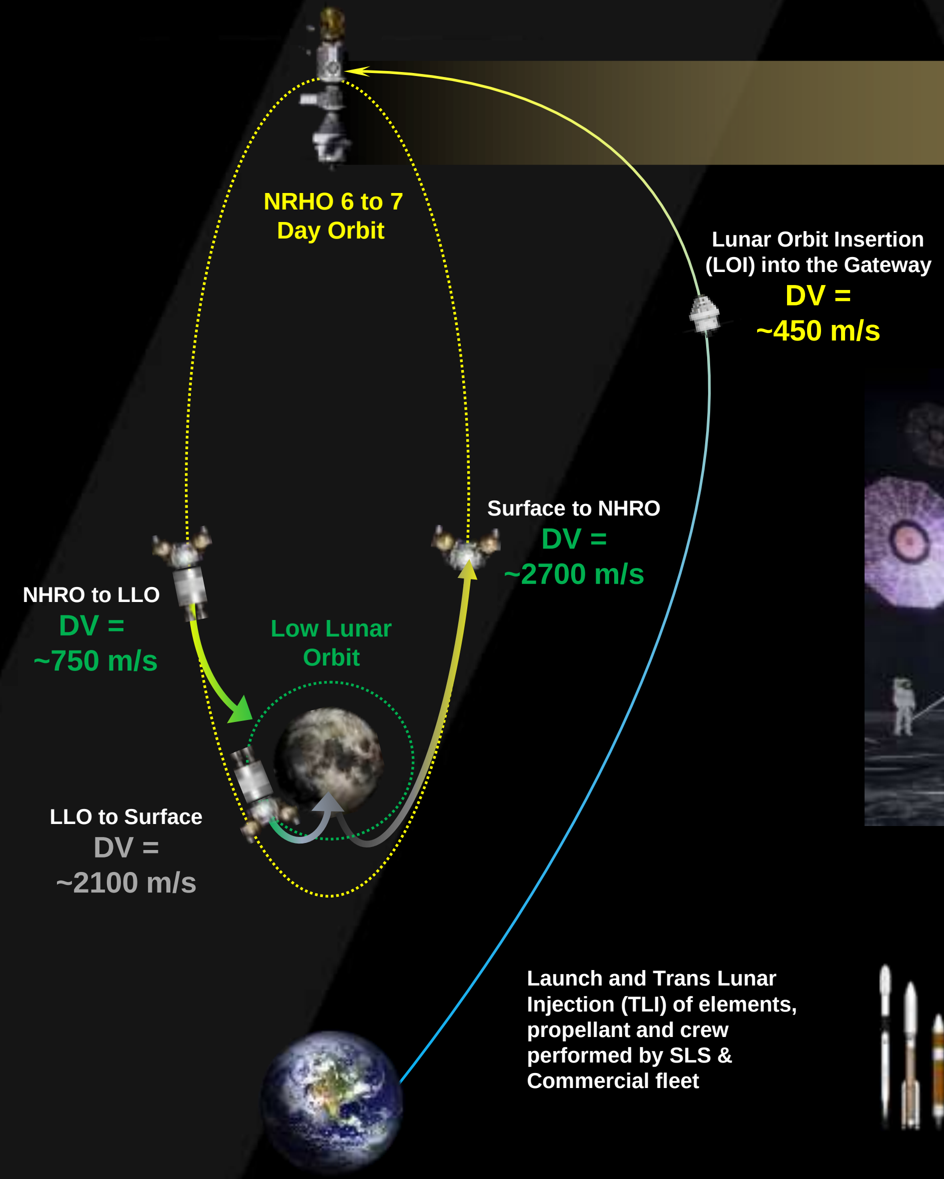
Key Terminology:

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**



The Physics Driving Lunar Architecture Choices



Crewed lunar surface missions to polar regions require 6,390 m/s roundtrip through Gateway.

ΔV for equivalent Direct to LLO mission is approximately 5% lower but requires slightly more mass for first mission. However, for subsequent missions, the Gateway approach significantly reduces mass and cost

Gateway approach allows for ΔV to be distributed across multiple elements reducing mass per launch

Commercial Launch Vehicles projected to be capable of sending up to 15 mT to TLI (using upper stage for TLI burns and service module or integrated propulsion for NRHO insertion burn).

SLS projected to be capable of sending 10 mT (Block 1B, co-manifested with Orion) to 40 mT (Block 1B cargo) to TLI.

Mission Risk Comparison to NRHO

Orbit Selection				Crew Risk				
	Orbit Period	Time in Orbit	MET	Abort Time (Surface to Orion, Does not include RPOD)	Abort Time (Orion to Earth)	Delay for missed Earth return window	Critical Maneuvers (Number of HLS maneuvers consistent)	Communication Outage to Orbit
Baseline NRHO	~6.5 days	~13-18 days	~25-34 days	0.5 to 2.5 days	~5-8 days ~1-2 day window per NRHO rev (some NRHO arrival conditions allow for aborts with METs <21 days total)	~4.5 days	OPF, NRI, RPODUs*, NRD, RPF	N/A
Elliptical Polar Orbit (EPO) with CoLA (6500 x 100 km)	~9 hours	~4.5-10.5 days	~20.5-23.5 days	11-13 hours	3.5-10 days Continuous abort window during orbit phase	~17 days	3 burn LOI Sequence 3 burn TEI Sequence (these occur in front of the Moon) RPODUs*	Comm losses due to occultation behind the Moon
Elliptical Lunar Orbit (ELO) Coplanar Posigrade ***[Equatorial- No Polar Access]*** (5500 x 100 km)	~8 hours	~7 days	~17.5 days	11 - 13 hours	3-8 days 5 day window	~20-21 days	3 burn LOI Sequence 3 burn TEI Sequence (these occur in front of the Moon) RPODUs*	Comm losses due to occultation behind the Moon

<u>Color compares to NRHO</u>
Blue – better than NRHO
Orange – worse than NRHO
Red – not viable

* All missions have Orion RPOD, HLS undock, HLS RPOD, and Orion undock


D. Davis 7/2017

ARTEMIS I

The First Uncrewed Integrated Flight Test of NASA's Orion Spacecraft and Space Launch System Rocket

1. **LAUNCH**
SLS and Orion lift off from pad 39B at Kennedy Space Center.

2. **JETTISON ROCKET BOOSTERS, FAIRINGS, AND LAUNCH ABORT SYSTEM**

3. **CORE STAGE MAIN ENGINE CUT OFF**
With separation.

4. **PERIGEE RAISE MANEUVER**

5. **EARTH ORBIT**
Systems check with solar panel adjustments.

6. **TRANS LUNAR INJECTION (TLI) BURN**
Maneuver lasts for approximately 20 minutes.

7. **INTERIM CRYOGENIC PROPULSION STAGE (ICPS) SEPARATION AND DISPOSAL**
ICPS commits Orion to moon at TLI.

8. **OUTBOUND TRAJECTORY CORRECTION (OTC) BURNS**
As necessary adjust trajectory for lunar flyby to Distant Retrograde Orbit (DRO).

9. **OUTBOUND POWERED FLYBY (OPF)**
60 nmi from the Moon; targets DRO insertion.

10. **LUNAR ORBIT INSERTION**
Enter Distant Retrograde Orbit.

11. **DISTANT RETROGRADE ORBIT**
Perform half or one and a half revolutions in the orbit period 38,000 nmi from the surface of the Moon.

12. **DRO DEPARTURE**
Leave DRO and start return to Earth.

13. **RETURN POWERED FLYBY (RPF)**
RPF burn prep and return coast to Earth initiated.

14. **RETURN TRANSIT**
Return Trajectory Correction (RTC) burns as necessary to aim for Earth's atmosphere.

15. **CREW MODULE SEPARATION FROM SERVICE MODULE**

16. **ENTRY INTERFACE (EI)**
Enter Earth's atmosphere.

17. **SPLASHDOWN**
Pacific Ocean landing within view of the U.S. Navy recovery ship.

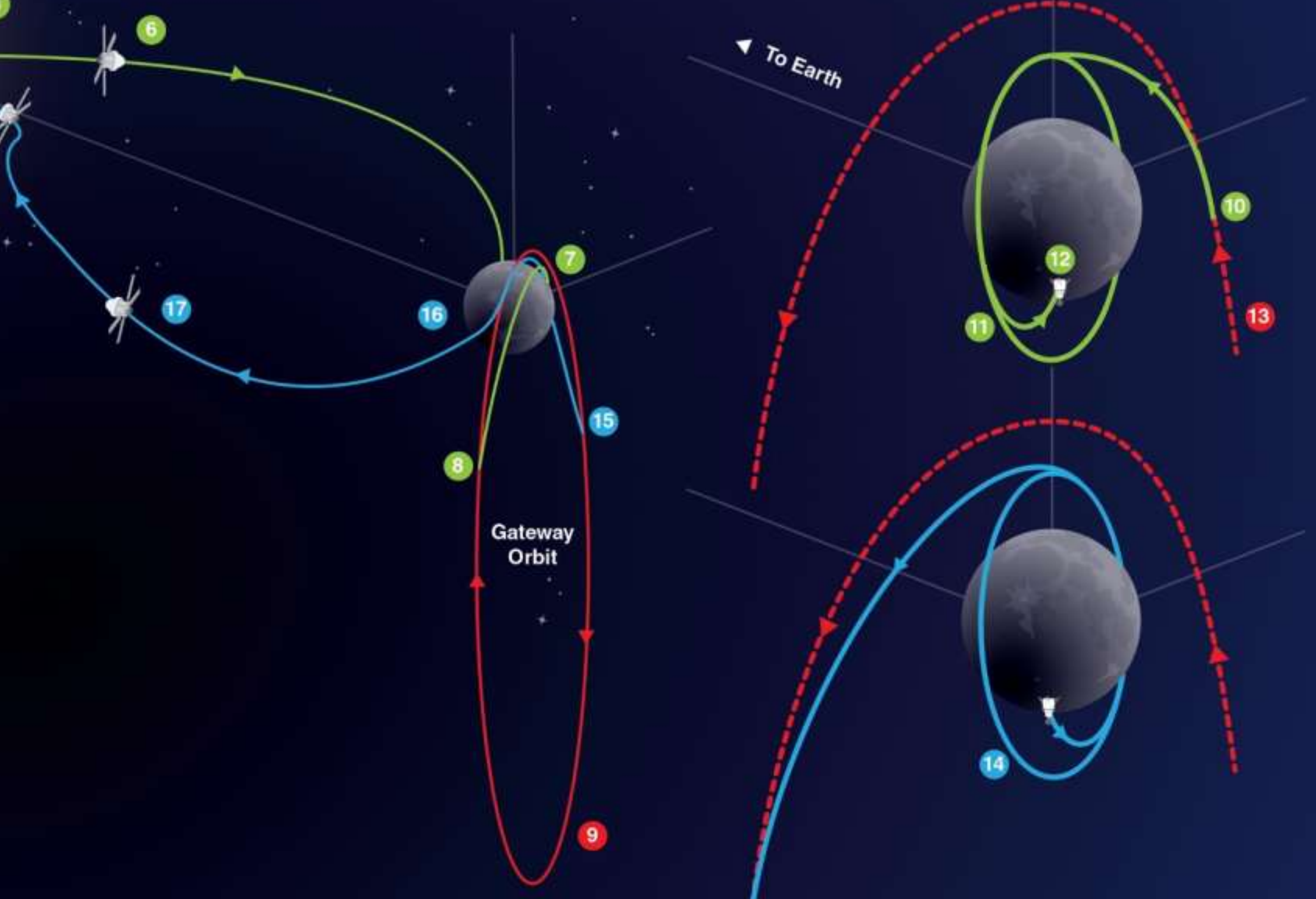
ARTEMIS II

First Crewed Test Flight to the Moon Since Apollo

1. **LAUNCH**
   Astronauts lift off from pad 39B at Kennedy Space Center.
2. **JETTISON ROCKET BOOSTERS, FAIRINGS, AND LAUNCH ABORT SYSTEM**
3. **CORE STAGE MAIN ENGINE CUT OFF**
   With separation.
4. **PERIGEE RAISE MANEUVER**
5. **APOGEE RAISE BURN TO HIGH EARTH ORBIT**
   Begin 24 hour checkout of spacecraft.
6. **PROX OPS DEMONSTRATION**
   Orion proximity operations demonstration and manual handling qualities assessment for up to 2 hours.
7. **INTERIM CRYOGENIC PROPULSION STAGE (ICPS) DISPOSAL BURN**
8. **HIGH EARTH ORBIT CHECKOUT**
   Life support, exercise, and habitation equipment evaluations.
9. **TRANS-LUNAR INJECTION (TLI) BY ORION'S MAIN ENGINE**
   Lunar free return trajectory initiated with European service module.
10. **OUTBOUND TRANSIT TO MOON**
    4 days outbound transit along free return trajectory.
11. **LUNAR FLYBY**
    4,000 nmi (mean) lunar farside altitude.
12. **TRANS-EARTH RETURN**
    Return Trajectory Correction (RTC) burns as necessary to aim for Earth's atmosphere; travel time approximately 4 days.
13. **CREW MODULE SEPARATION FROM SERVICE MODULE**
14. **ENTRY INTERFACE (EI)**
    Enter Earth's atmosphere.
15. **SPLASHDOWN**
    Ship recovers astronauts and capsule.

PROXIMITY OPERATIONS DEMONSTRATION SEQUENCE

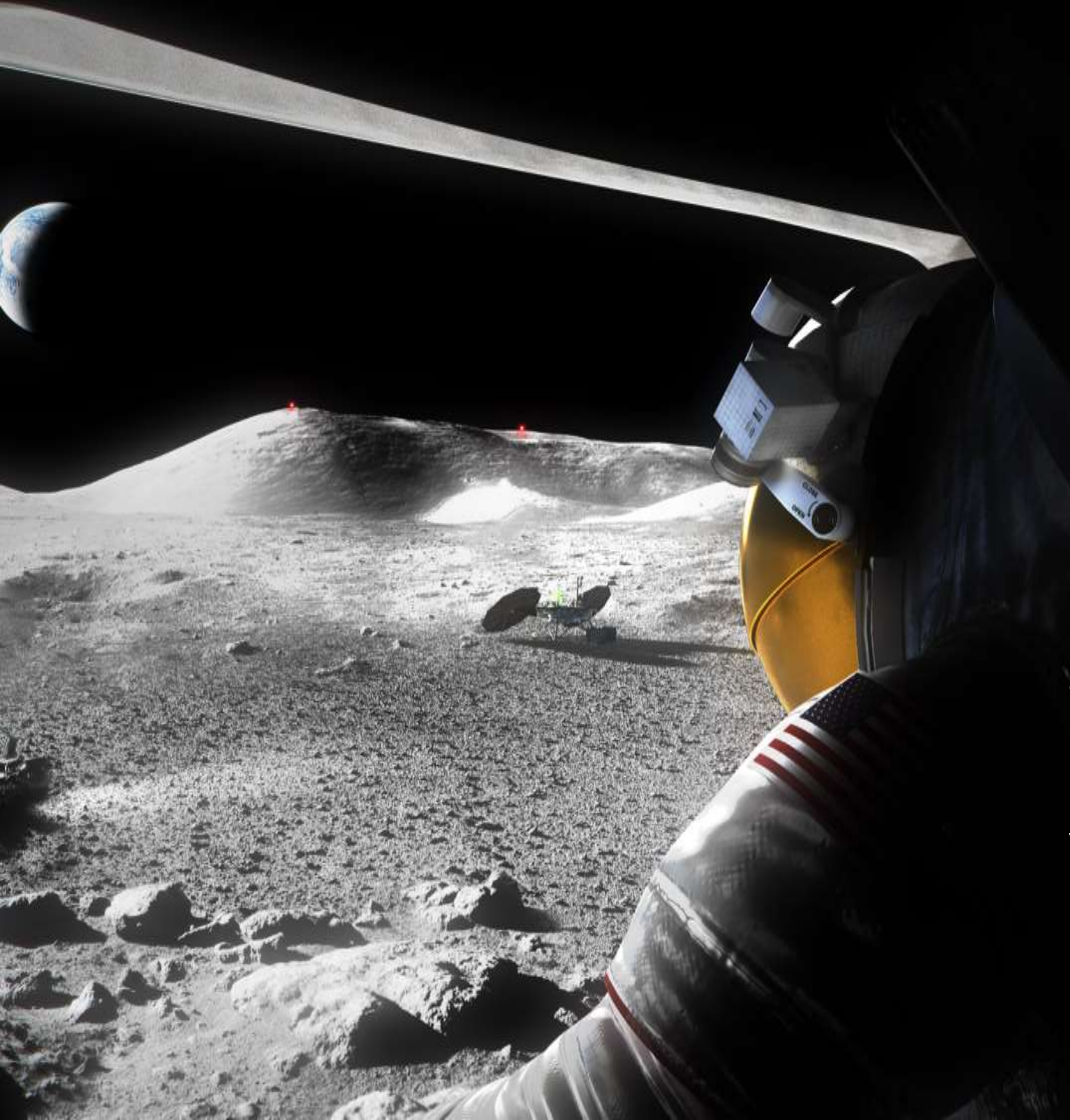
National Aeronautics and
Space Administration



ARTEMIS III

Landing on the Moon

1. **LAUNCH**
   SLS and Orion lift off from Kennedy Space Center
2. **JETTISON ROCKET BOOSTERS, FAIRINGS, AND LAUNCH ABORT SYSTEM**
3. **CORE STAGE MAIN ENGINE CUT OFF**
   With separation
4. **ENTER EARTH ORBIT**
   Perform the perigee raise maneuver. Systems check and solar panel adjustments
5. **TRANS LUNAR INJECTION BURN**
   Astronauts committed to lunar trajectory, followed by ICPS separation and disposal
6. **ORION OUTBOUND TRANSIT TO MOON**
   Requires several outbound trajectory maneuver burns.
7. **ORION OUTBOUND POWERED FLYBY**
   60 nmi from the Moon
8. **GATEWAY ORBIT INSERTION BURN**
   Orion performs burn to establish rendezvous ppint to Gateway, performs rendezvous and docking
9. **LUNAR LANDING PREPARATION**
   Crew transfers to Gateway, activates Lander staged at Gateway, prepares for Lander departure
10. **LANDER UNDOCKING AND SEPARATION FROM GATEWAY**
11. **LANDER ENTERS LOW LUNAR ORBIT**
    Descends to lunar touchdown
12. **LUNAR SURFACE EXPLORATION**
    Astronauts conduct week long surface mission and extra-vehicular activities
13. **GATEWAY/ORION REMAIN IN LUNAR GATEWAY ORBIT**
    During lunar surface mission
14. **LANDER ASCENDS LOW LUNAR ORBIT**
    Lander performs rendezvous and docking with Gateway
15. **CREW RETURNS IN ORION**
    Orion undocks from Gateway, performs orbit depprture burn
16. **ORION PERFORMS RETURN POWERED FLYBY**
    60 nmi from the Moon
17. **FINAL RETURN TRAJECTORY CORRECTION (RTC) BURN**
    Precision targeting for Earth entry
18. **ENTRY INTERFACE (EI)**
    Enter Earth's atmosphere
19. **SPLASHDOWN**
    Pacific Ocean landing within view of the U.S. Navy recovery ships



Human Landing System

HLS

Sustaining Lunar Transport

Using proven commercial partnership strategies, NASA is working with U.S. industry to build towards regular human lunar landings.

Companies will develop human landing systems and NASA will purchase transport services, while maintaining oversight to ensure safety standards are met.

Starship HLS development in work


SPACEX

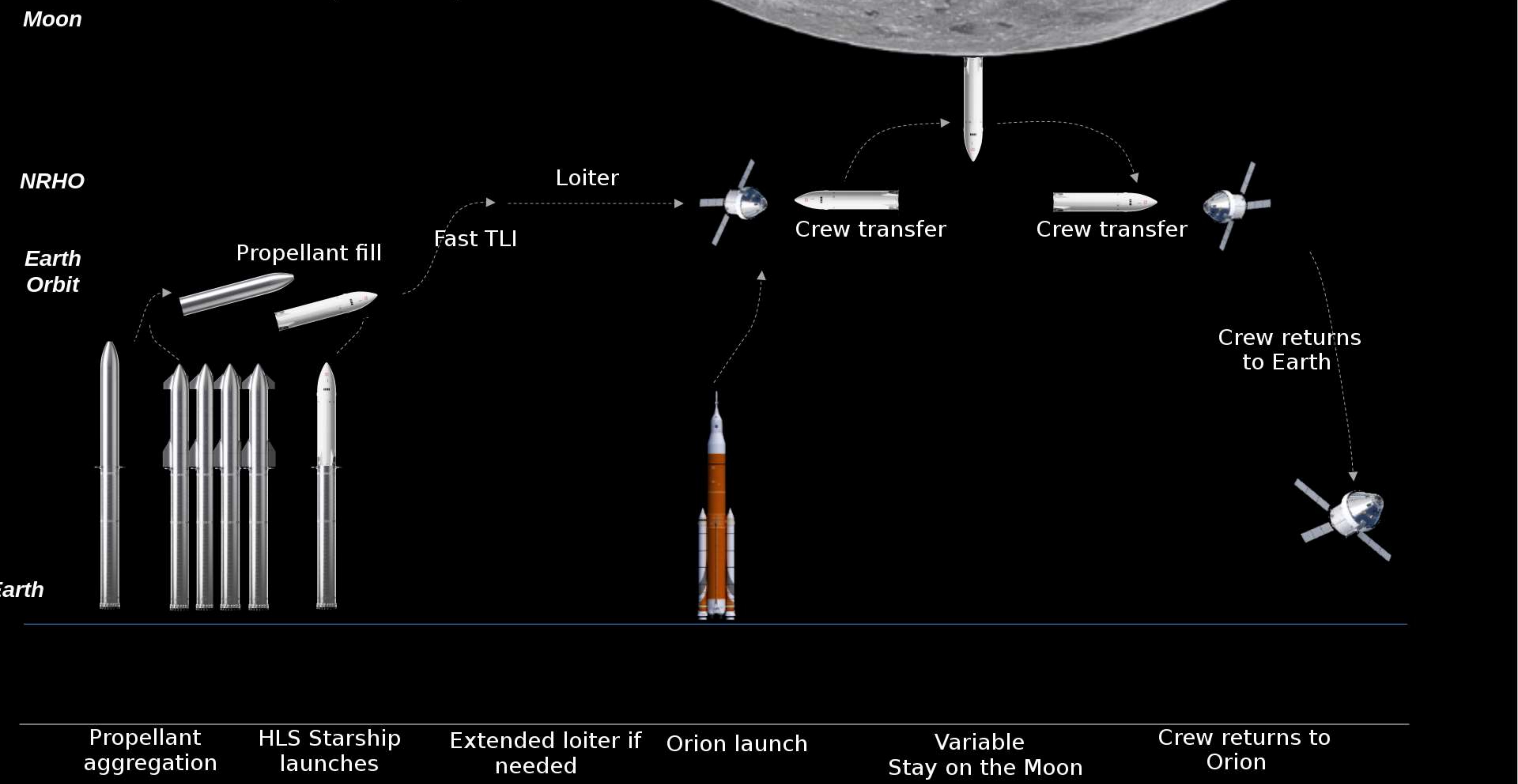
Microgravity Cryogenic Propellant Transfer is Key Technology Development

- Multiple (3 to 8 reported) tanker missions required for a single SpaceX landing mission
- Development of the Starship Super Heavy Launch Vehicle in work but not demonstrated
  - Required to launch the HLS, LEO Prop Depot, and Tanker vehicles
- LOX/Methane stage is much higher Isp (327-380) than Storables and temperatures between propellants are compatible
- Cryo Transfer in Space Technology Demonstrators are funded – but not yet flown
- Details of the design are considered proprietary

Lunar Landers

- SpaceX selected to develop the first demonstration lander. Requires a on-orbit cryogenic propellant transfer demonstration, an uncrewed landing demonstration on the moon (no ascent, no return), and one short term (6.5 day) 2-person lunar landing (Artemis III).
- SpaceX has been selected to develop a second-generation lunar lander ("sustainable lander") which can carry 4 people and stay on the surface up to 30 days. Schedule goal for Artemis V and subsequent.
- NASA has opened a competition for other providers to also develop second generation 'sustainable lunar landers' as well. Schedule goal for Artemis V and subsequent flights

Artemis III Concept of Operations



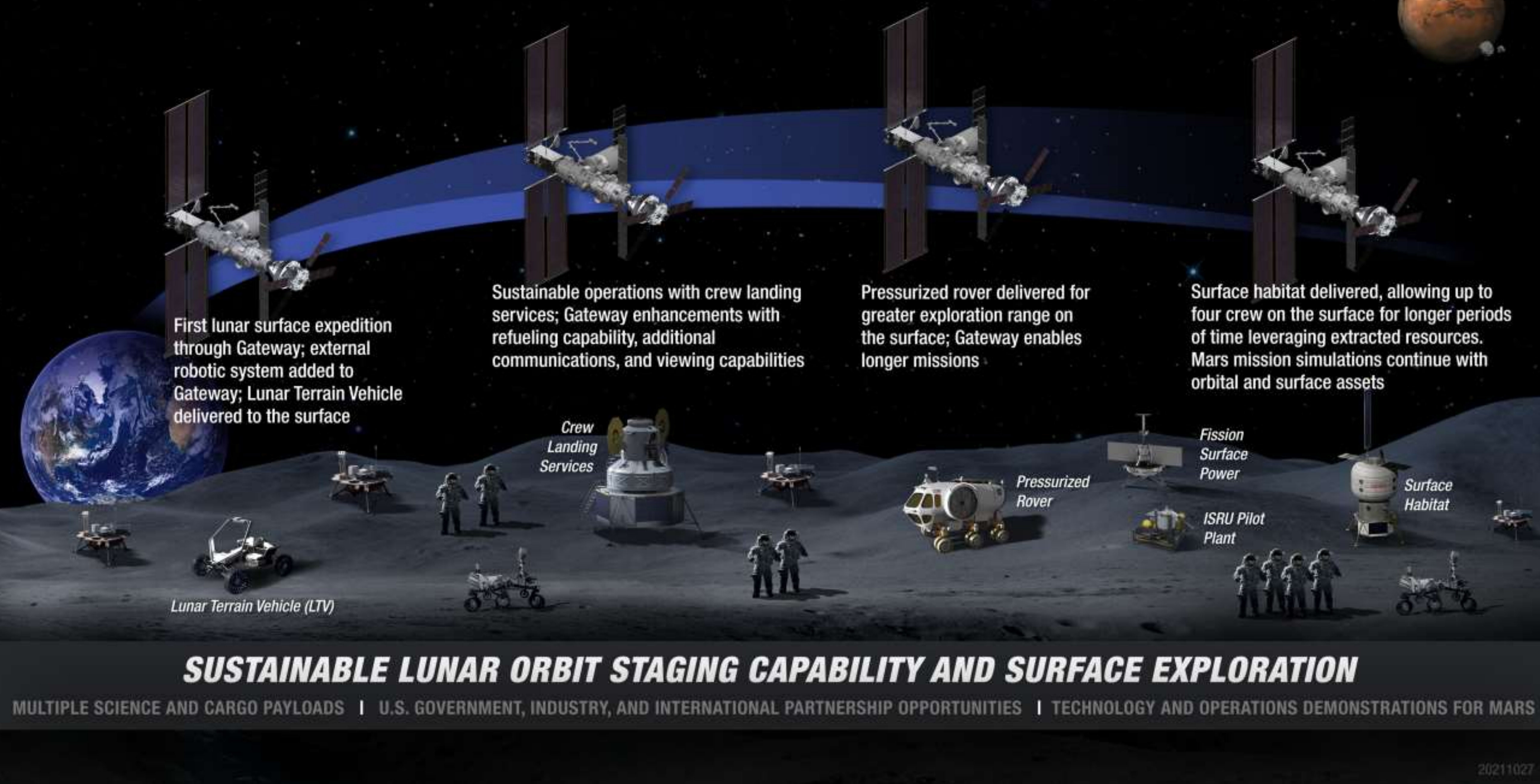
Details are Few

- Design Options are in work
- Much of the Starship HLS is considered proprietary
- Sustainable Lander competition just started (RFP released)

- NASA cannot discuss costs until approved by OMB
- NASA negotiates with Congress over costs

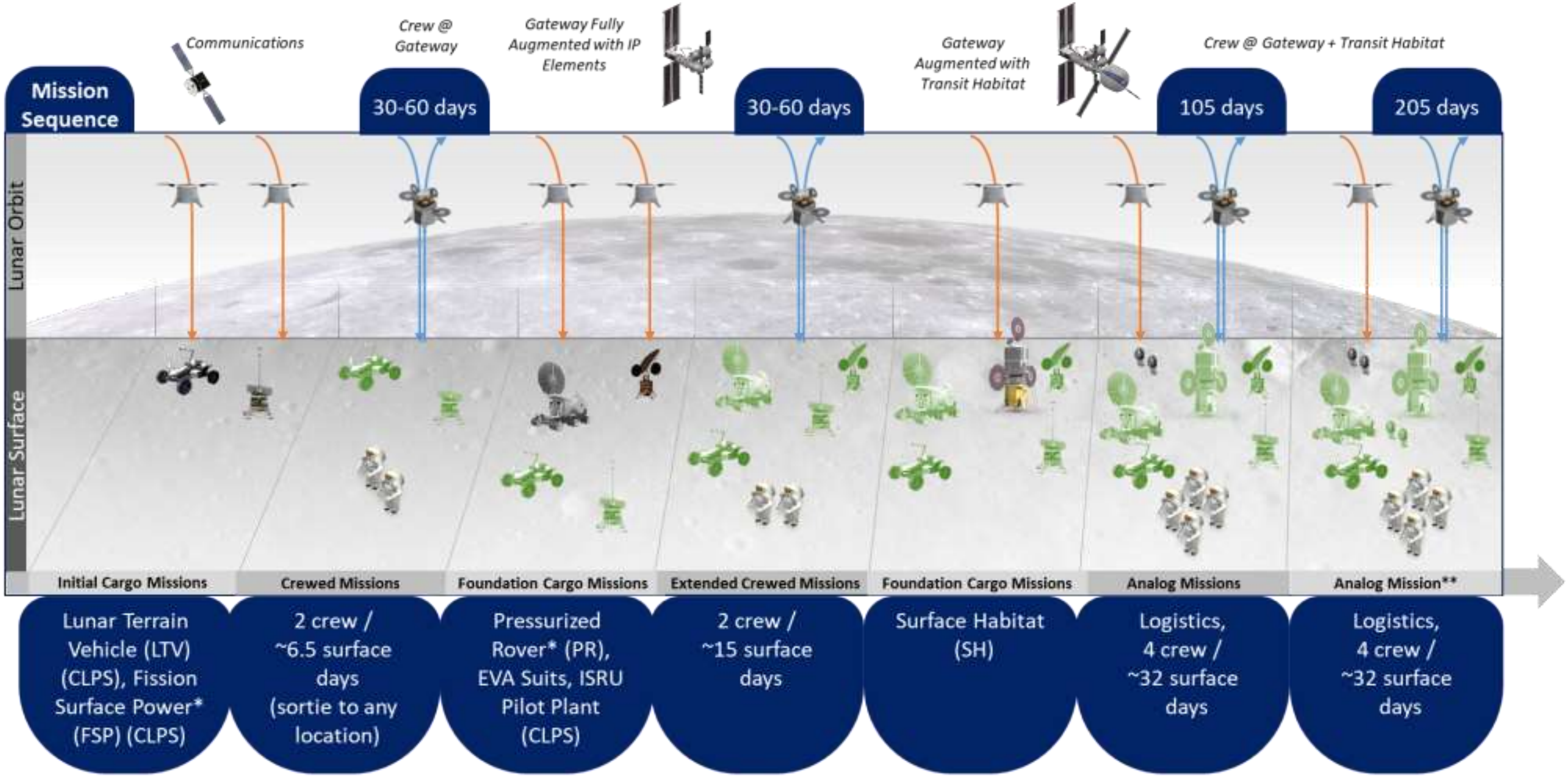
- Bottom Line: Don't expect details any time soon

Artemis Base Camp Buildup



Exploration Campaign Segment – Sustained Lunar Presence

- Includes all activities on or around the Moon that contribute to both the establishment of a sustained human lunar presence and to risk reduction for human Mars exploration.



NOTE: Crew mission duration driven by budget and mission objectives

Representative Sequence

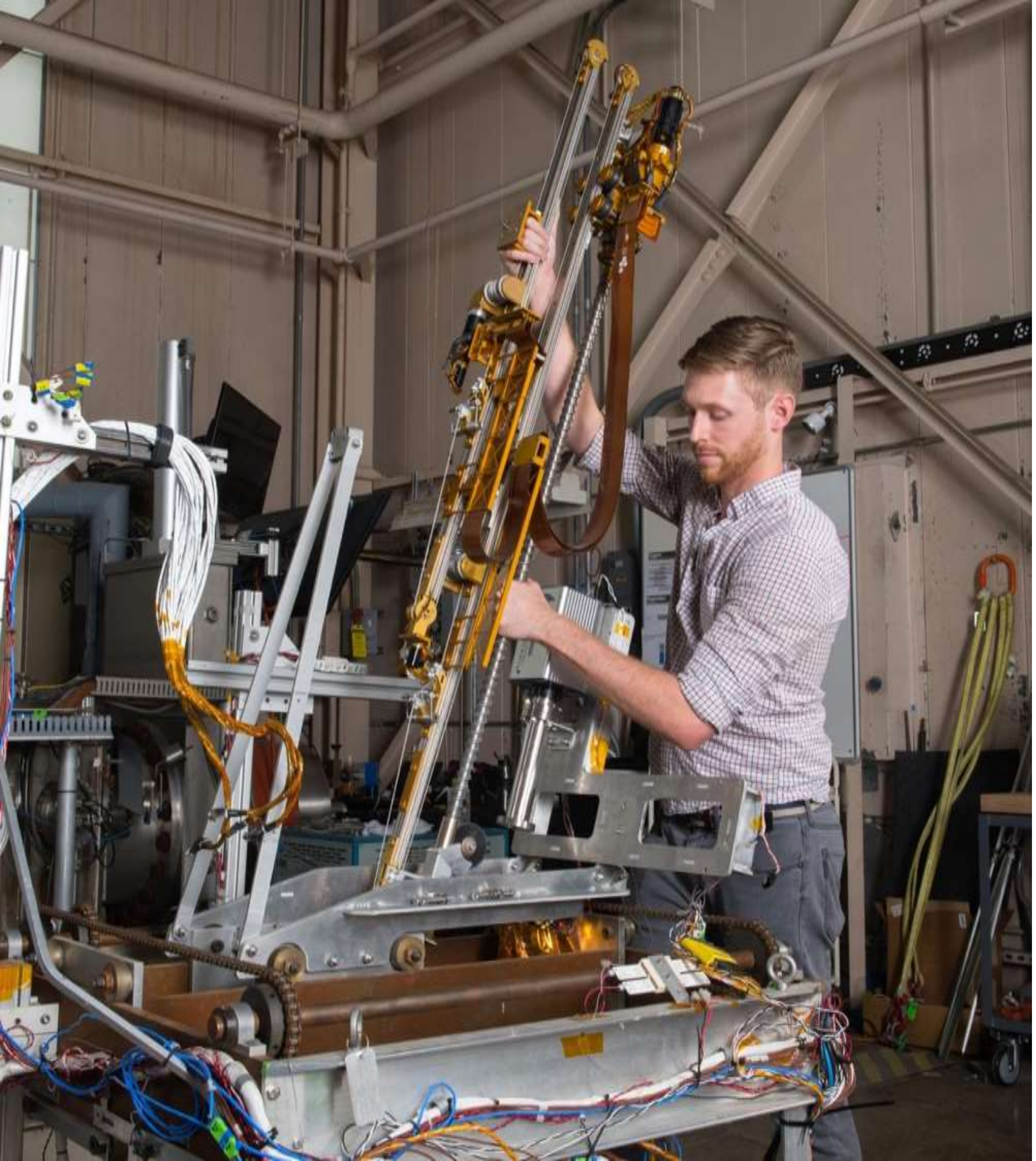
* *Robotic deployment of the FSP and Pressurized Rover operations are critical Mars-forward tests*

** *Initial emphasis on Mars Analog missions transitioning to lunar sustained missions; Sustained Human Lunar Surface missions continue indefinitely*

Artemis Science Objectives

- Understand planetary processes
- Understand the character and origin of lunar polar volatiles
- Interpret impact history of Earth-Moon system
- Reveal the record of the ancient sun and our astronomical environment
- Observe the universe and the local space environment from a unique location
- Conduct experimental science in the lunar environment
- Investigate and mitigate exploration risks

Pictured left: NASA astronaut candidates and field instructors hike during geology training in Arizona



Artemis Technology Objectives

The **Lunar Surface Innovation Initiative (LSII)** works across industry, academia and government through in-house efforts and public-private partnerships to develop transformative capabilities like:

- In-situ resource utilization (ISRU)
- Surface power
- Dust mitigation
- Extreme environment
- Extreme access
- Excavation and construction

Pictured left: A Honeybee Robotics systems engineer installs The Regolith and Ice Drill for Exploring New Terrain (TRIDENT) on a trolley for thermal vacuum chamber testing. TRIDENT will drill up to three feet deep, extracting lunar soil and demonstrating a critical capability for future ISRU.

Exploration Extravehicular Activity (xEVA) Systems Development: Not Just Spacesuits

Advanced suits (Exploration Extravehicular Mobility Units or xEMUs)

- Portable Life Support Subsystem (xPLSS) which contains CO_2 removal and thermal control
- Pressure garment subsystem (xPGS)

Vehicle interfaces (VISE)

- Physical interfaces and support equipment such as don/doff fixtures, launch enclosures, umbilicals, battery chargers, and maintenance equipment

Tools and equipment

- Geology equipment for sample collection
- Construction tools for maintenance activities
- Translation support like handrails

Pictured left: ARGOS Suit and tong tool
Pictured right: NASA Astronaut Jessica Meir in an xEMU

GATEWAY

Capability

NASA and its international partners will add modules and capabilities, evolving a robust orbiting laboratory and a home away from home for astronauts on their way to and from the lunar surface. The Gateway will serve as a test bed and staging point for future human exploration into deep space.

Power and Propulsion Element (PPE)

- High-power solar electric propulsion spacecraft
- Transfers the initial capability to lunar orbit
- Establishes a communications relay with Earth
- Maintains the Gateway's orbit

Habitation and Logistics Outpost (HALO)

- Houses up to 4 crew for up to 30 days (with Orion)
- Provides high-rate lunar communication relay to support lunar surface activities and command and control systems for Gateway
- Docking port for visiting spacecraft and future modules

Canadian Space Agency (CSA):
External robotics system, robotic interfaces, and end-to-end robotic operations

European Space Agency (ESA):
International Habitat (I-HAB) and refueling modules, along with enhanced lunar communications

The Japan Aerospace Exploration Agency (JAXA):
I-HAB's environmental control and life support system, batteries, thermal control, and imagery components

Gateway is Key for Multiple Lunar Missions

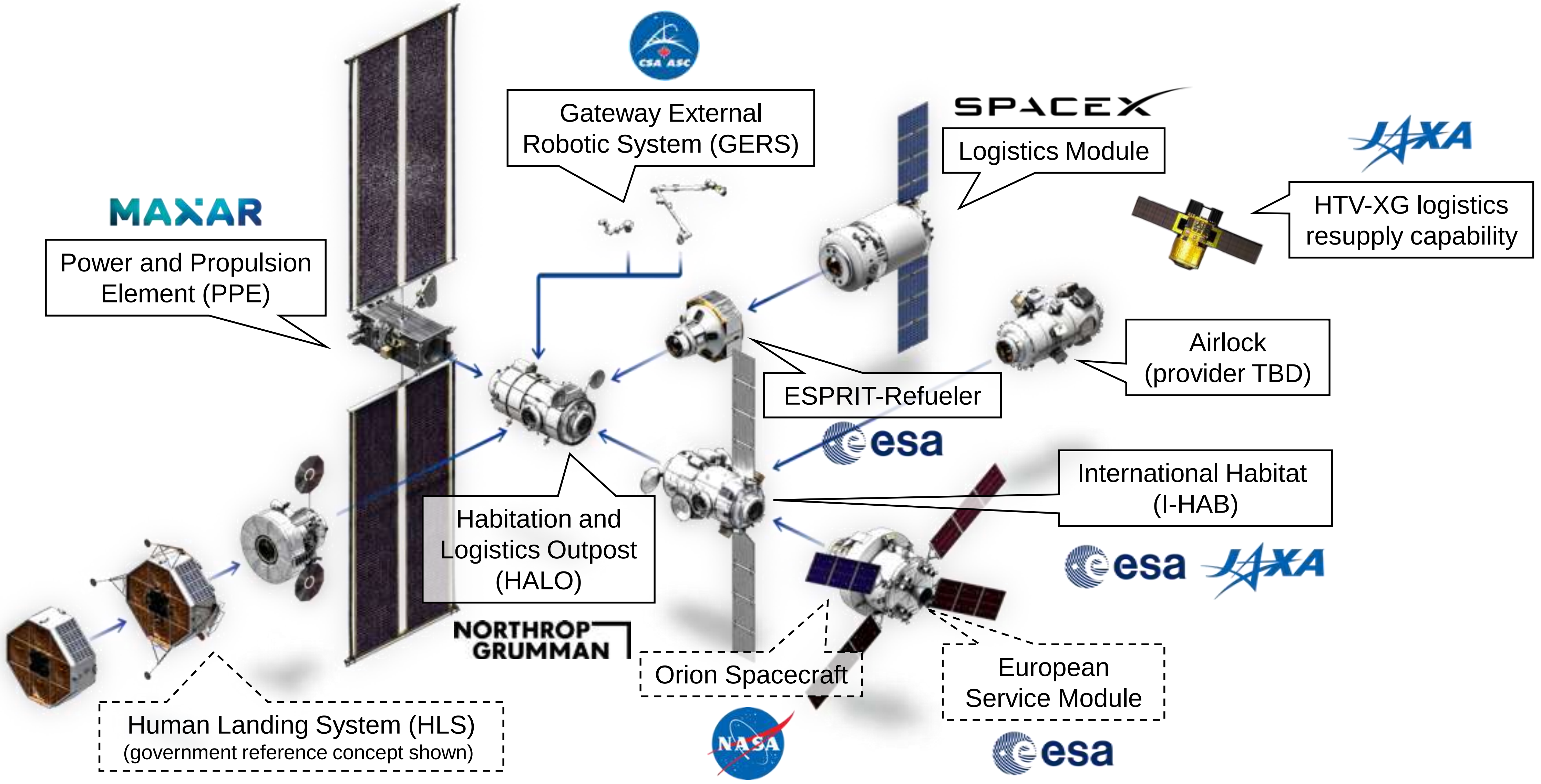
- Artemis/Orion lunar orbit capability is limited

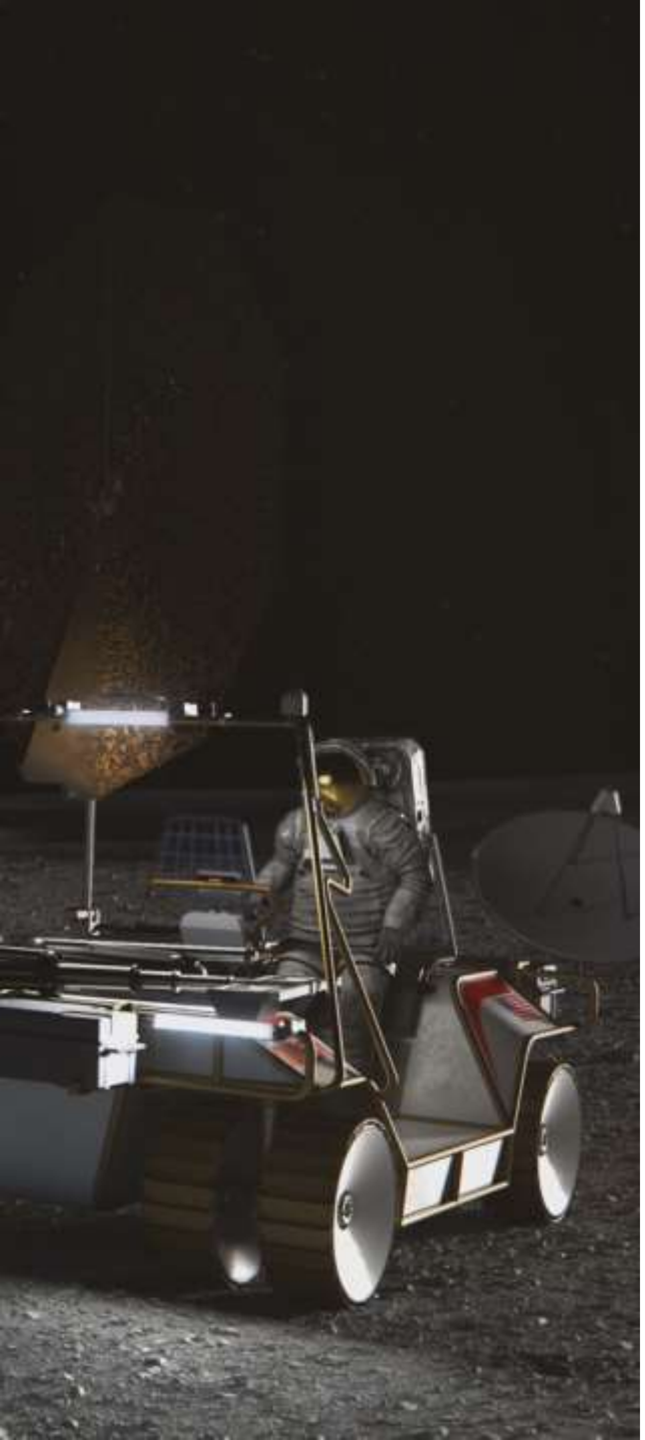
- Logistics (and assembly) node is needed
  - Multiple logistics missions to Gateway needed to stockpile equipment for long duration lunar sorties/outposts

- Safe Haven for contingencies is needed

- Gateway is a key technology demonstrator for long term Mars missions
  - ECLSS, Comm, Radiation Protection, etc.

Gateway Integrated Spacecraft





Lunar Terrain Vehicle

LTV

Requirements definition is in-work

- Ability to traverse from one landing zone to another and increase exploration range beyond maximum suited walking distance
- Reusable and rechargeable for approximate 10-year service life
- Remote operation from Human Landing System, Gateway, and Earth
- Interface with future science instruments and payloads for utilization or pre-deployment of assets
- Ability to survive eclipse periods

Developing LTV: Survive the Night

- The lunar South Pole is massively cratered, with areas bathed in sunlight and shrouded in darkness
- The craters are brutally cold but elevated areas can grow extremely hot
- NASA has initiated a new study to identify options for addressing lunar night survival
- Potential design solutions will be generated by an internal team and industry partners
- LTV will need to survive up to 100 hours of darkness with at least a 10-year lifespan

Pictured left: Artist’s render of LTV on the lunar surface

Pressurized Rover

Artist’s illustration

Provides pressurized mobile habitation to enable long-range surface exploration in shirtsleeve environment and access to surface.

- Habitation for 30 days for 2 crew
- Ability for crew to analyze samples in-situ and prioritize materials for return to Earth
- Provides volume for spares and logistics
- Power generation and energy storage for lunar environment
- Dust and radiation protection
- Reuse for multiple missions of 10-year lifetime
- Capability also identified in current concepts for first human mission to Mars

Surface Habitat

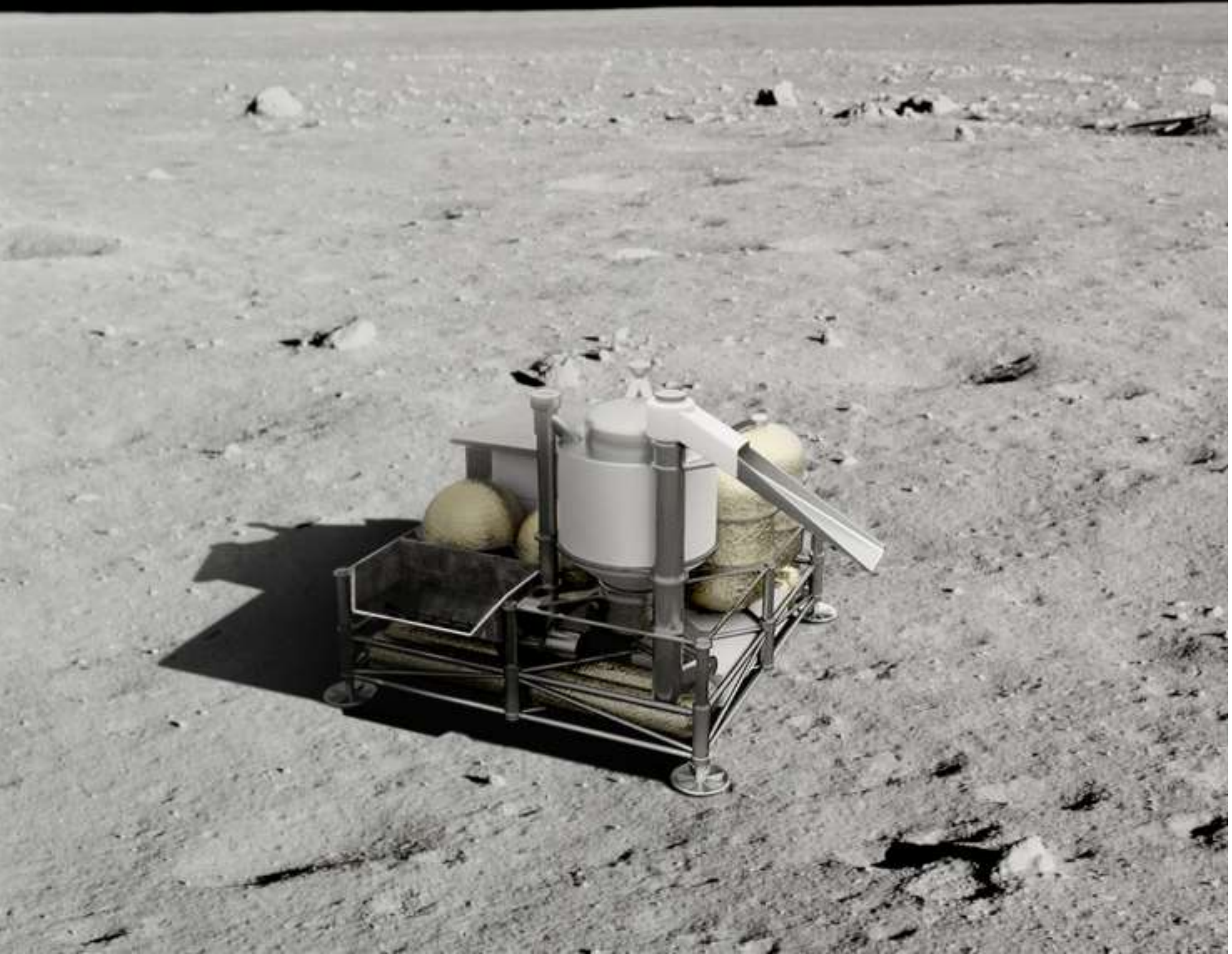
Artist's illustration

Envisioned as a primary asset to achieve a sustained lunar presence.

NASA is working with industry to develop conceptual designs for the Surface Habitat.

- 2-4 crew – medical, exercise, galley, crew quarters, stowage
- 30-60 day capable habitat
- EVA capable with suit maintenance capability
- Recharge capability for surface assets
- Communication hub for surface assets
- Reuse for multiple missions of 15 year lifetime

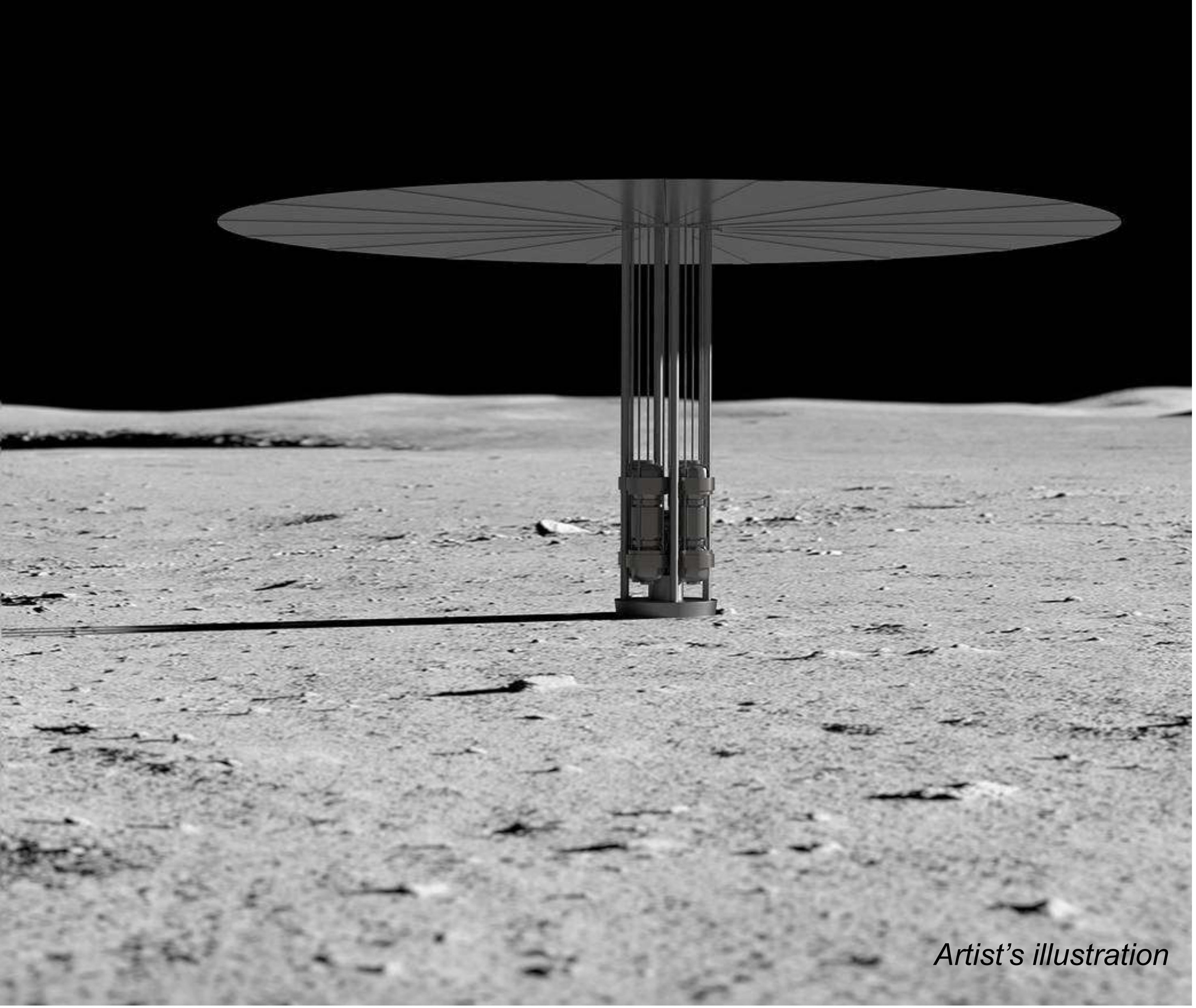
In-Situ Resource Utilization



An Artemis ISRU Pilot Plant to demonstrate a scalable capability to extract and use lunar-based resources.

- **Resource Identification / Mapping:** Perform evaluation of lunar regolith to identify composition for science, future exploration and commercial use. Enable global and detailed local and subsurface mapping of lunar resources and terrain, especially for water in permanently shadowed craters, for science, future exploration, and commercial use
- **Oxygen Extraction:** Enable extraction and production of oxygen from lunar regolith to provide 10's of metric tons per year, for up to 5 years with little human involvement and maintenance, for reusable surface and ascent/descent transportation.
- **Water Mining:** Enable cislunar commercial markets through extraction of water resources to provide 100's of metric tons of propellant per year for reusable landers and cislunar transportation systems.
- **Lunar Surface Construction:** Building of roads, launch/landing pads, dust free zones, foundations, blast protection, radiation shielding, shade structures, unpressurized shelters, and even pressurized habitats.

Fission Surface Power



Artist's illustration

Modular nuclear fission power source

Common requirement for an
initial human missions to Mars

- Surface architecture depends on power capability delivered with landers
- Power level dependent on propellant type and transfer strategy
- Near-term demonstration on the lunar surface can provide reliable power to human landers, habitats, and ISRU systems continuously through eclipse periods and provide a proving ground to extend the capability as a power source that will enable Mars exploration

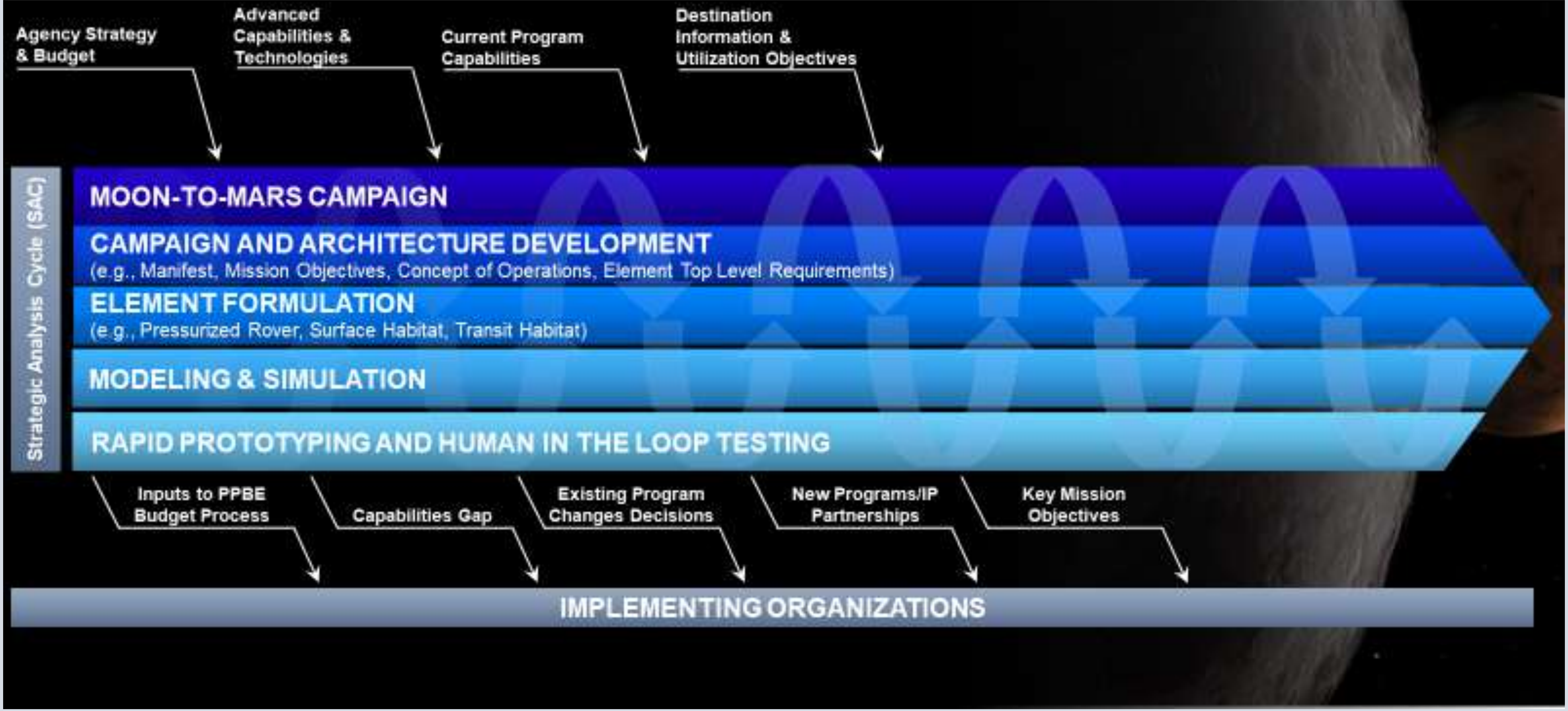
Transit Habitat

Artist's illustration

Reused element with 15-year lifetime for multiple missions

- Keep crew healthy and productive during long duration, deep space stays including:
  - Shakedown missions at Gateway and while free-flying with interim propulsion
  - Lunar-Mars analogs
  - Up to 1100-day Mars transit and orbital stays
- Demonstrate needed capabilities to live for long durations beyond low Earth orbit
- Build on ISS and commercial investment in deep space habitation

Moon to Mars Architecture and Element Development and Refinement

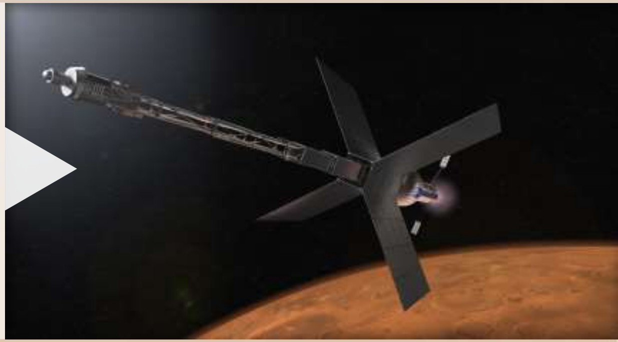


First Conceptual Mars Mission

Reference architecture for *analysis purposes only.*

TRANSIT HABITAT AND HYBRID PROPULSION STAGE

- Supports four crew on the long mission to Mars
- Two crew remain in orbit while two crew visit the Mars surface



1 **PRE-DEPLOYED CARGO**

- 25-ton class payload Mars lander
- Ascent vehicle propellant, Surface Power, and surface mobility/propellant transfer system

2 **PRE-DEPLOYED CREW ASCENT VEHICLE**

3 **CREW**

- Two crew land/live in pressurized rover
- Provides habitation and mobility for 30 days
- Supports science and exploration operations

My Conclusions

- Artemis appears to be the best architecture given goals and the near-term capabilities (e.g., launch vehicles)

- Cost will be a factor
  - Must be spread out over many years to be ‘sustainable’

- Commercial partnerships promise to bring down costs

- Detailed design options still in trade

- Recommendation: ASEM address release of ‘proprietary’ information
  - The taxpayers have a stake and need to know.