National Aeronautics and Space Administration

Presentation to 27th annual Ground System Architectures Workshop (GSAW)
March 1, 2023

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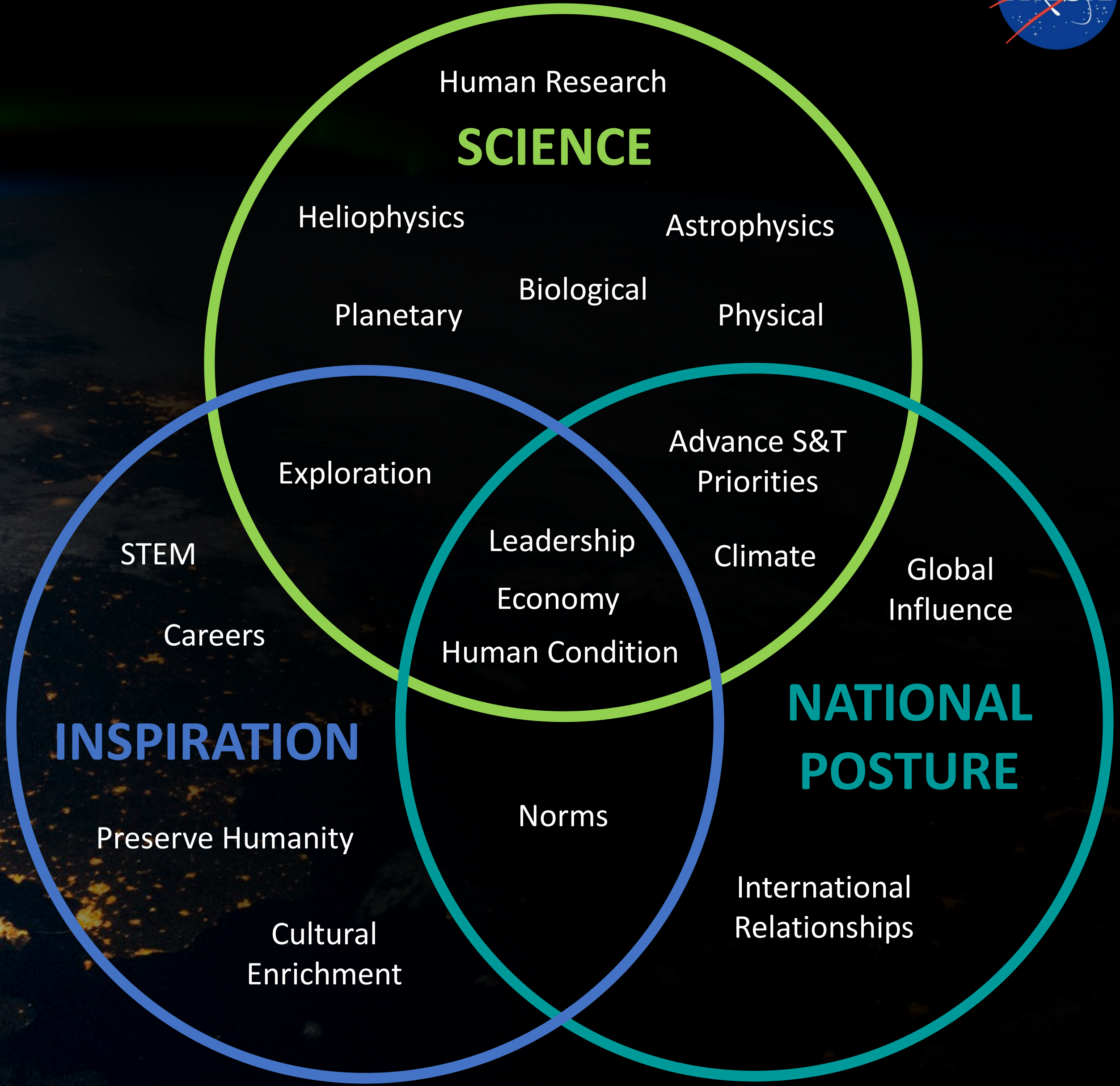
NASA

Why Go?

Benefit to Citizens



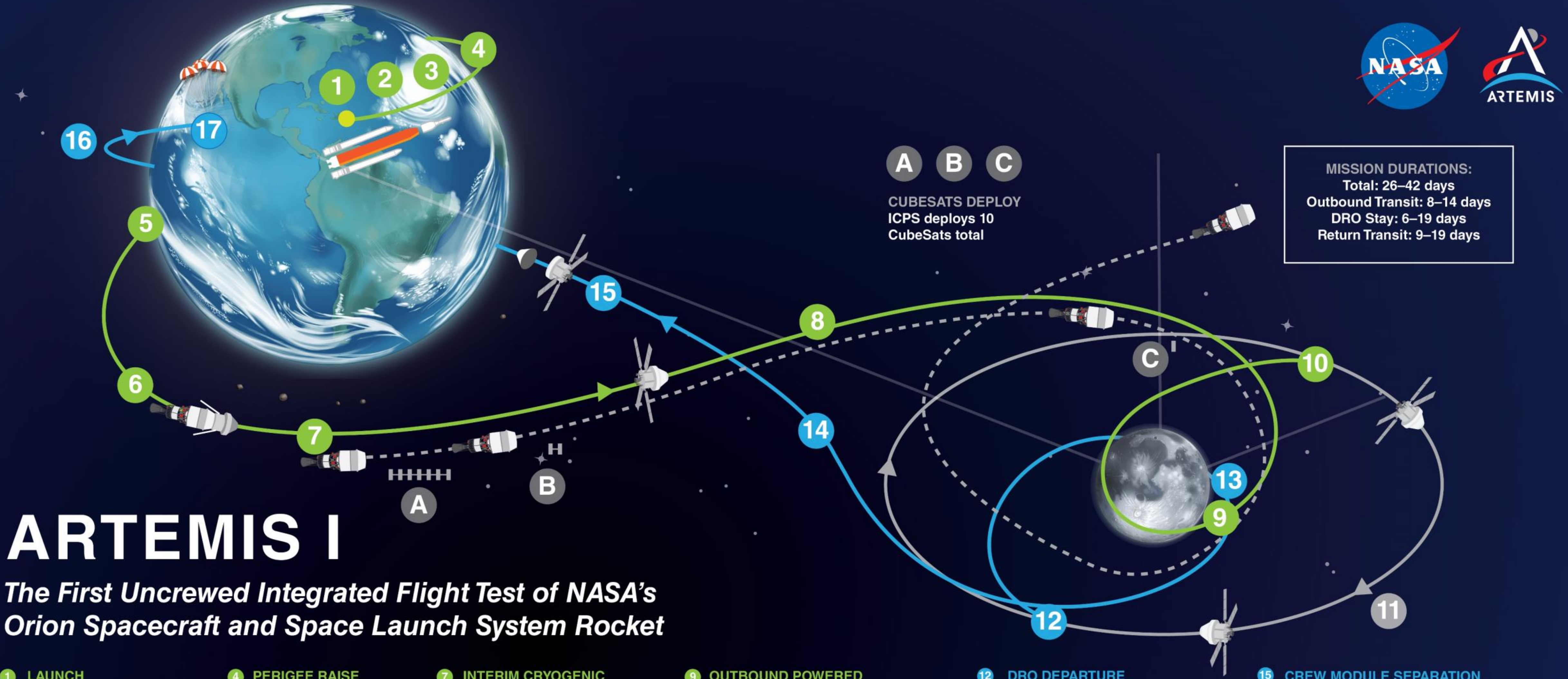
M2M Goals and Objectives

- **60+ Top-Level Objectives across 10 Top-Level Goals**
  - 26 Science (6 Goals)
  - 13 Infrastructure (2 Goals)
  - 12 Transportation & Habitation (1 Goal)
  - 12 Operations (1 Goal)

- **Recurring Tenets**
  - Common themes across objectives

ARTEMIS I

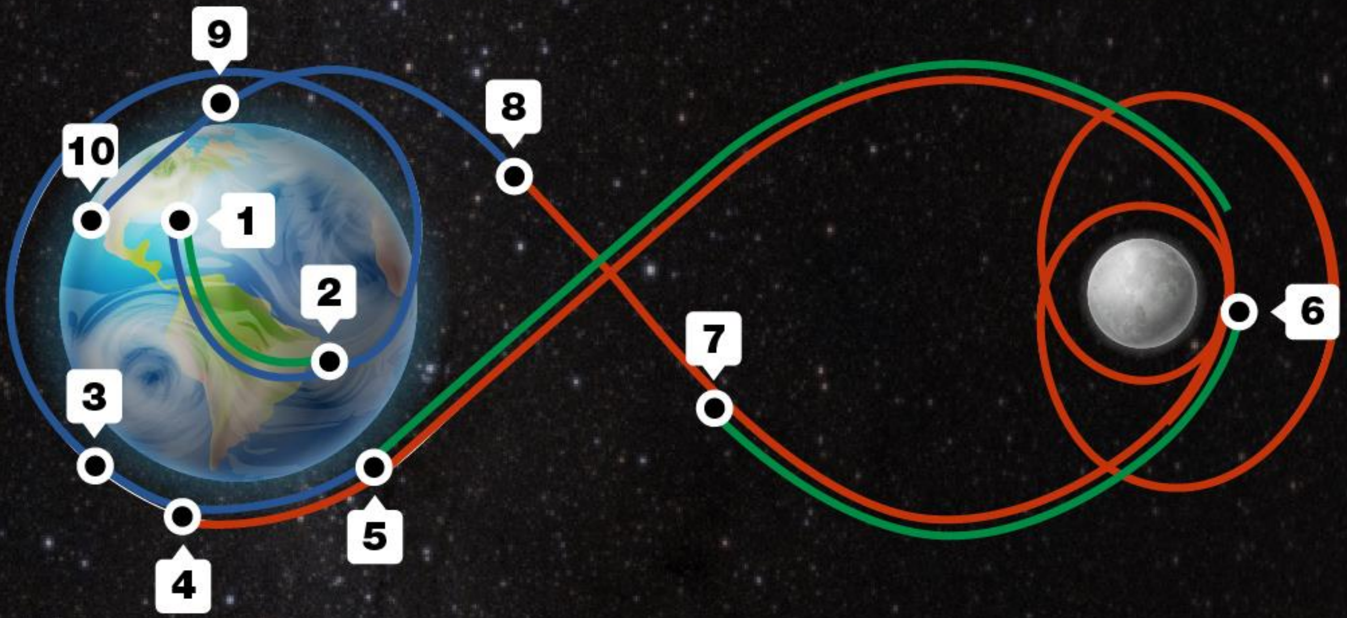
The First Uncrewed Integrated Flight Test of NASA's Orion Spacecraft and Space Launch System Rocket



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 I

COMMUNICATIONS AND NAVIGATION MILESTONES



NSN DTE / NSN TDRS — 1 Launch

Both the Launch Communications Segment and the constellation of Tracking and Data Relay Satellites will maintain communication between the Space Launch System and Orion.

NSN TDRS — 2 Low-Earth Orbit

In low-Earth orbit, NASA's Near Space Network TDRS will maintain continuous communications with Orion and the Interim Cryogenic Propulsion Stage (ICPS), which will accelerate Orion fast enough to overcome the pull of Earth's gravity and set it on a precise trajectory to the Moon.

NSN TDRS — 3 ICPS Separation

Once Orion no longer needs the ICPS, the Near Space Network will monitor telemetry from the ICPS until it is out of range. The ICPS will continue towards the Moon on a heliocentric trajectory, deploying small satellites that provide additional science in translunar orbit.

NSN TDRS / DSN — 4 Handover to DSN

As Orion prepares to leave the area of near-Earth space covered by the Near Space Network, network engineers will pass communications services to the Deep Space Network.

DSN / NSN DTE — 5 Journey to the Moon

En route to the Moon, the Deep Space Network will be the primary method of communication with Earth, with Near Space Network ground stations providing supplementary tracking and navigation data.

DSN — 6 Distant Retrograde Orbit

When Orion arrives at the Moon, it will enter a distant retrograde orbit, a highly stable orbit in which Orion travels opposite the direction the Moon travels around Earth. There, NASA will continue to test and demonstrate Orion's capabilities.

DSN / NSN DTE — 7 Return Transit

Returning from the Moon, the Deep Space Network will be the primary method of communication with Earth, with Near Space Network ground stations providing supplementary tracking and navigation data.

DSN / NSN TDRS — 8 Return Trajectory Correction Burn

During the final engine burn that places Orion on target to safely enter Earth's atmosphere, the Near Space Network will join the Deep Space Network, ultimately taking over communications for the remainder of the mission.

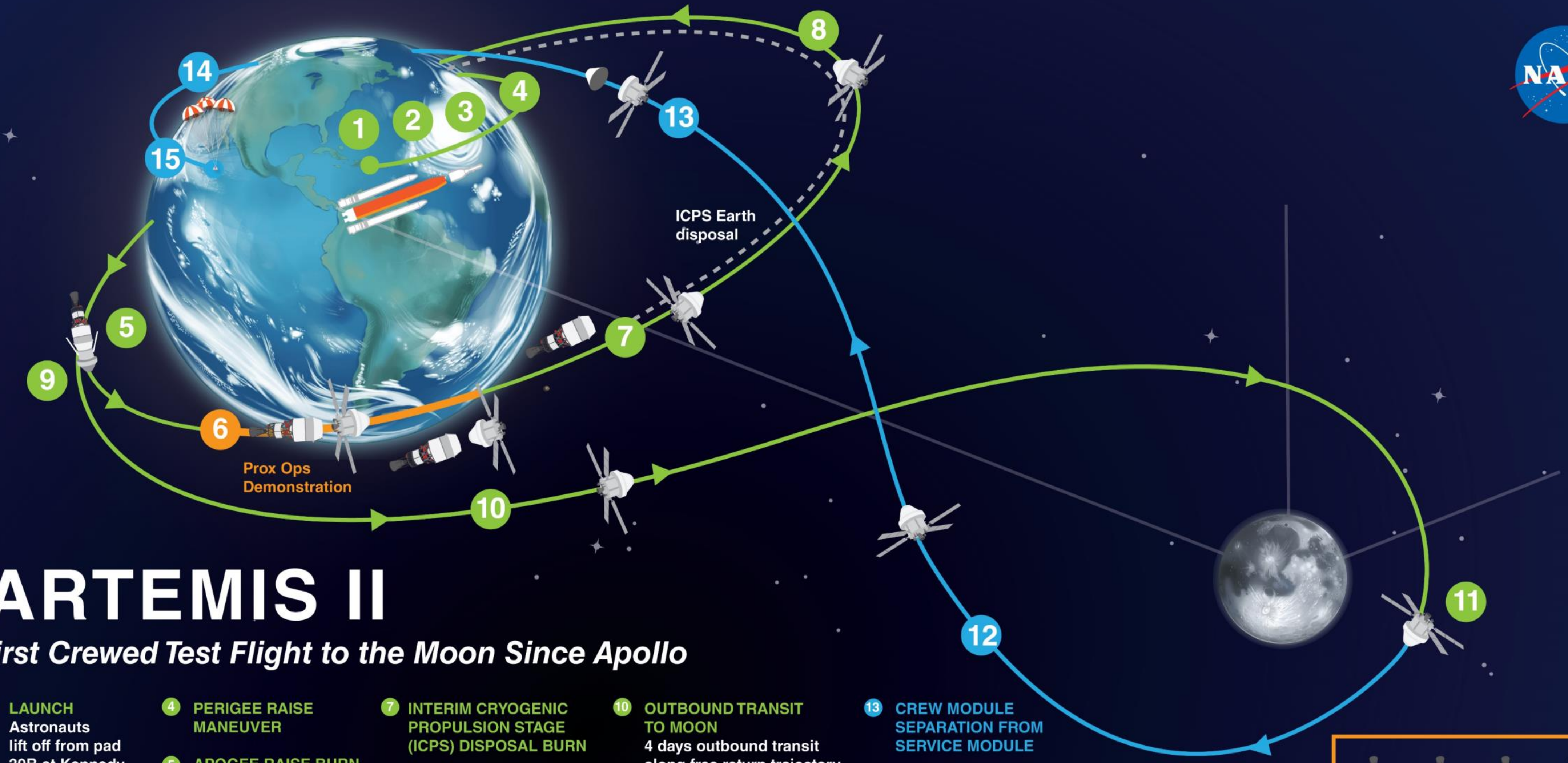
NSN TDRS — 9 Re-entry

During re-entry, the enormous heat generated as Orion encounters the atmosphere turns the air surrounding the capsule into plasma. Until it dissipates, this can disrupt communications with the spacecraft.

NSN TDRS — 10 Splashdown and Recovery

The Near Space Network maintains communications through the unfurling of parachutes, splashdown in the Pacific Ocean, and recovery of the capsule by military and NASA professionals.

NSN NEAR SPACE NETWORK — NSN DTE — NSN TDRS — **DSN** DEEP SPACE NETWORK

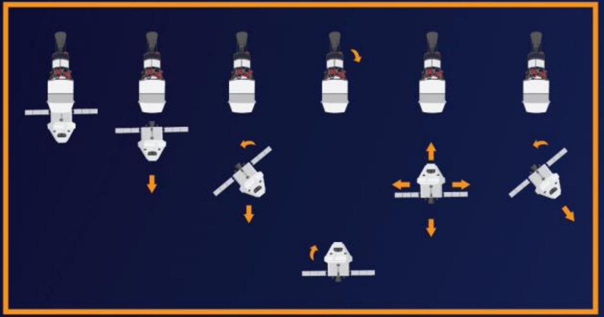


ARTEMIS II

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



Artemis III Candidate Landing Regions

KEY LANDING REGION CHARACTERISTICS

Close proximity to the geographic South Pole

Gentle slope for landing and moonwalks

Constant view to Earth for communications

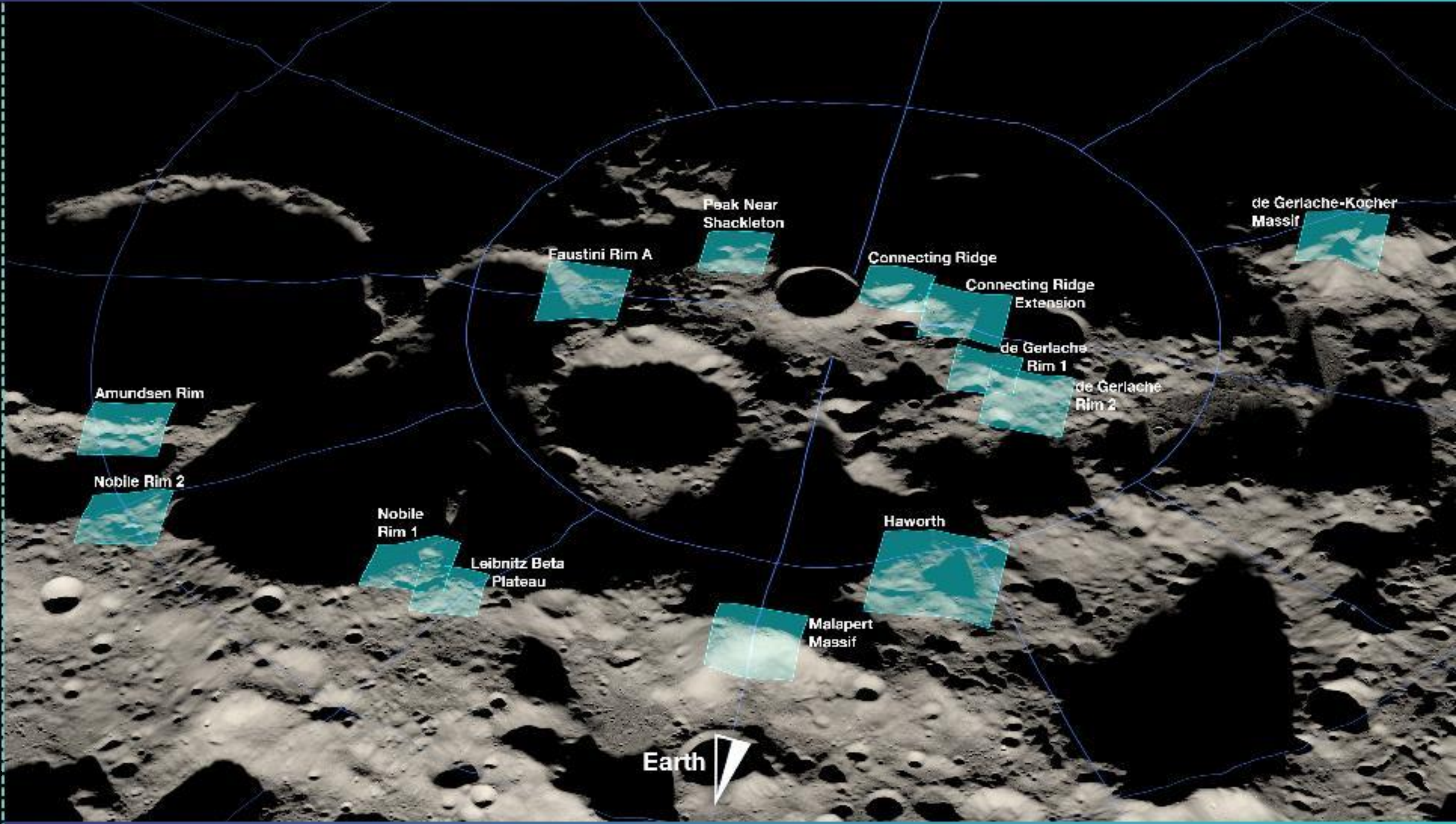
Continuous sunlight throughout the surface expedition of about 6.5 days

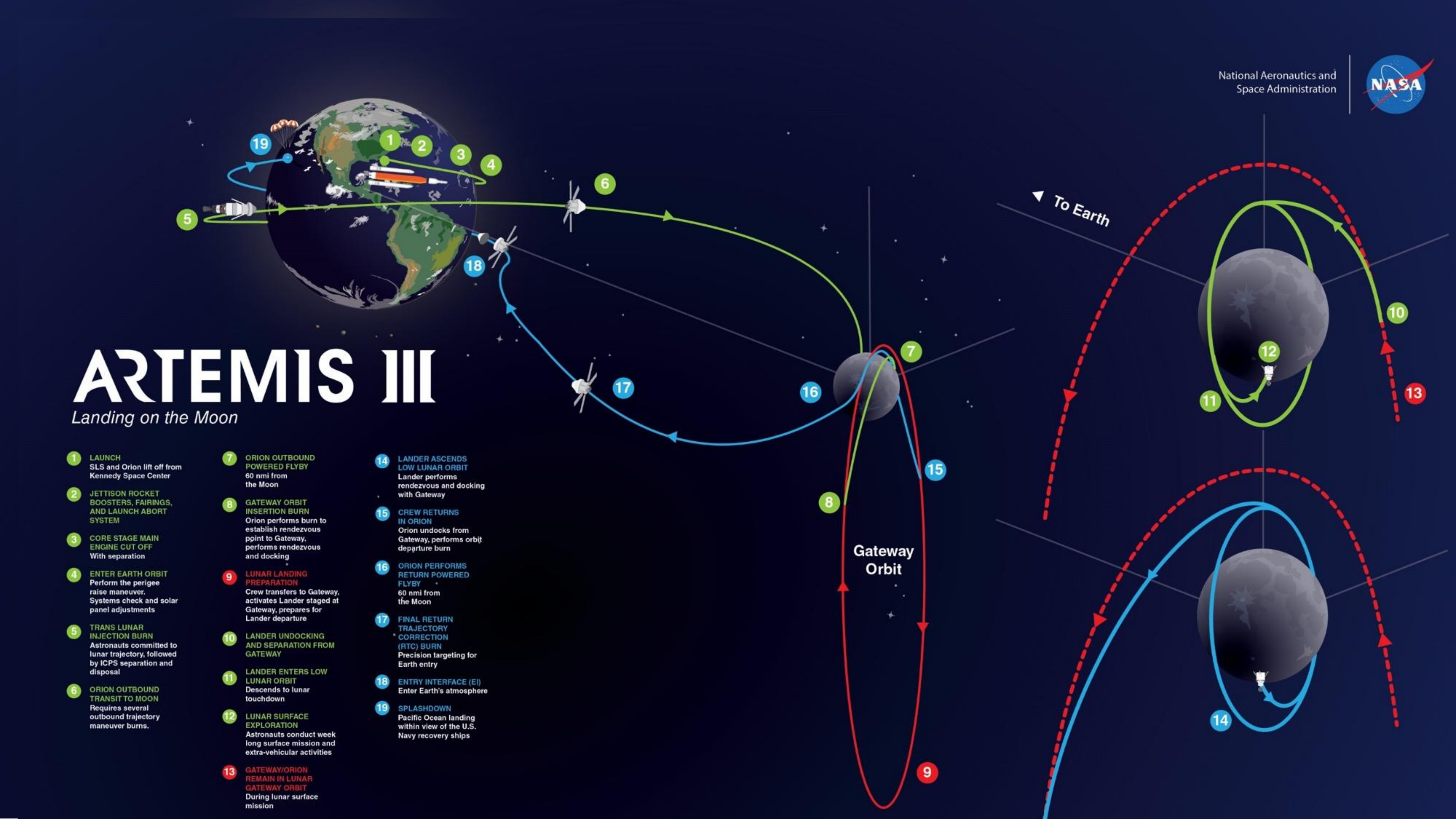
Landing Accuracy

Surface data resolution

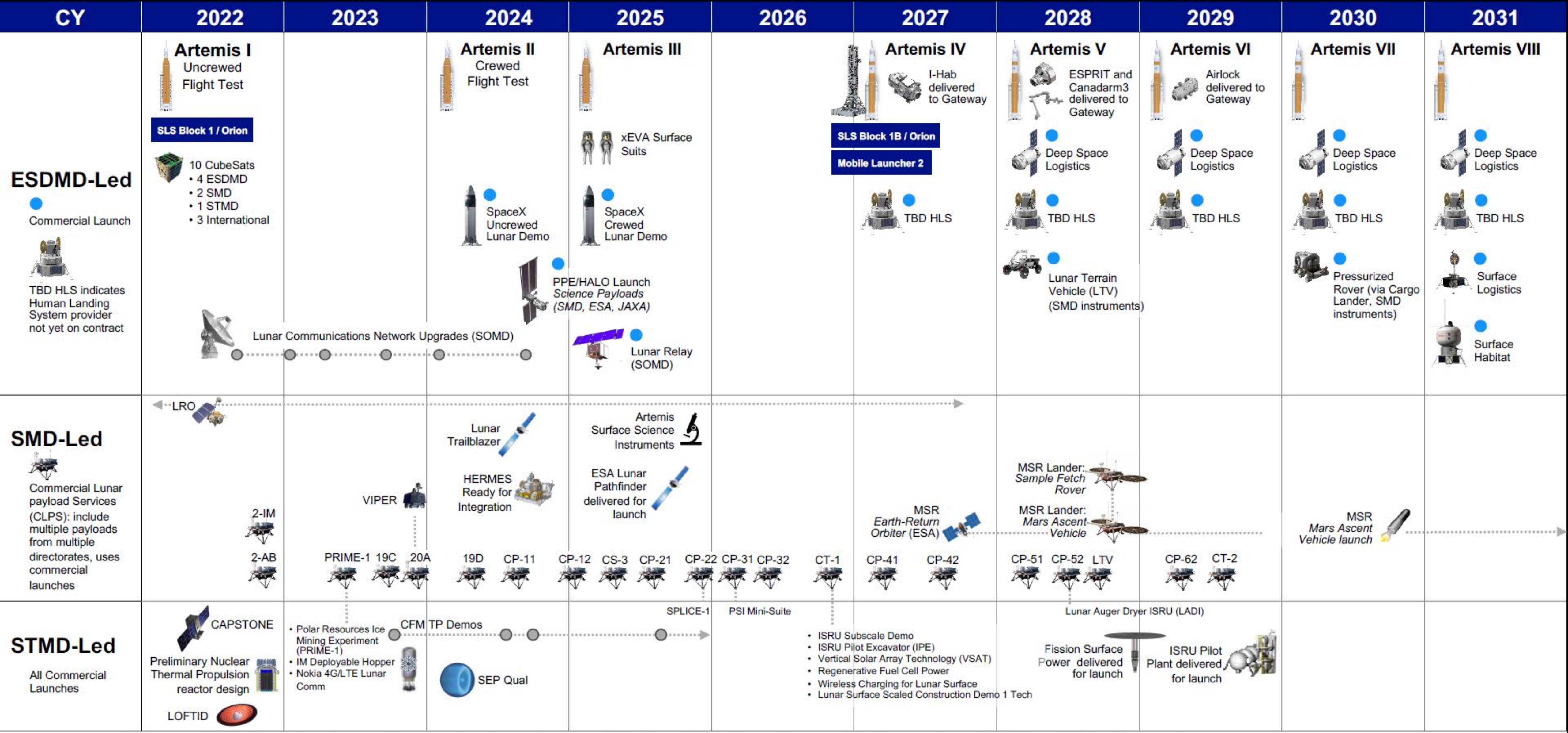
Combined mission vehicle capabilities: Space Launch System, Orion spacecraft, Starship Human Landing System

A landing *region* is approximately 15 km^2. Each landing region includes multiple potential landing sites.




National Aeronautics and Space Administration
NASA
ARTEMIS III
Landing on the Moon
To Earth
Gateway Orbit
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 departure 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

Artemis Planning Manifest



Icons represent the calendar year in which the launch occurs. | Based on FY23 Presidents budget request. | Does not include impact from FY22 appropriations. | Selected Mars forward elements in SMD and STMD included for context.

UPDATED 20221024

Starship HLS development in work

Initial Human Landing System

HLS

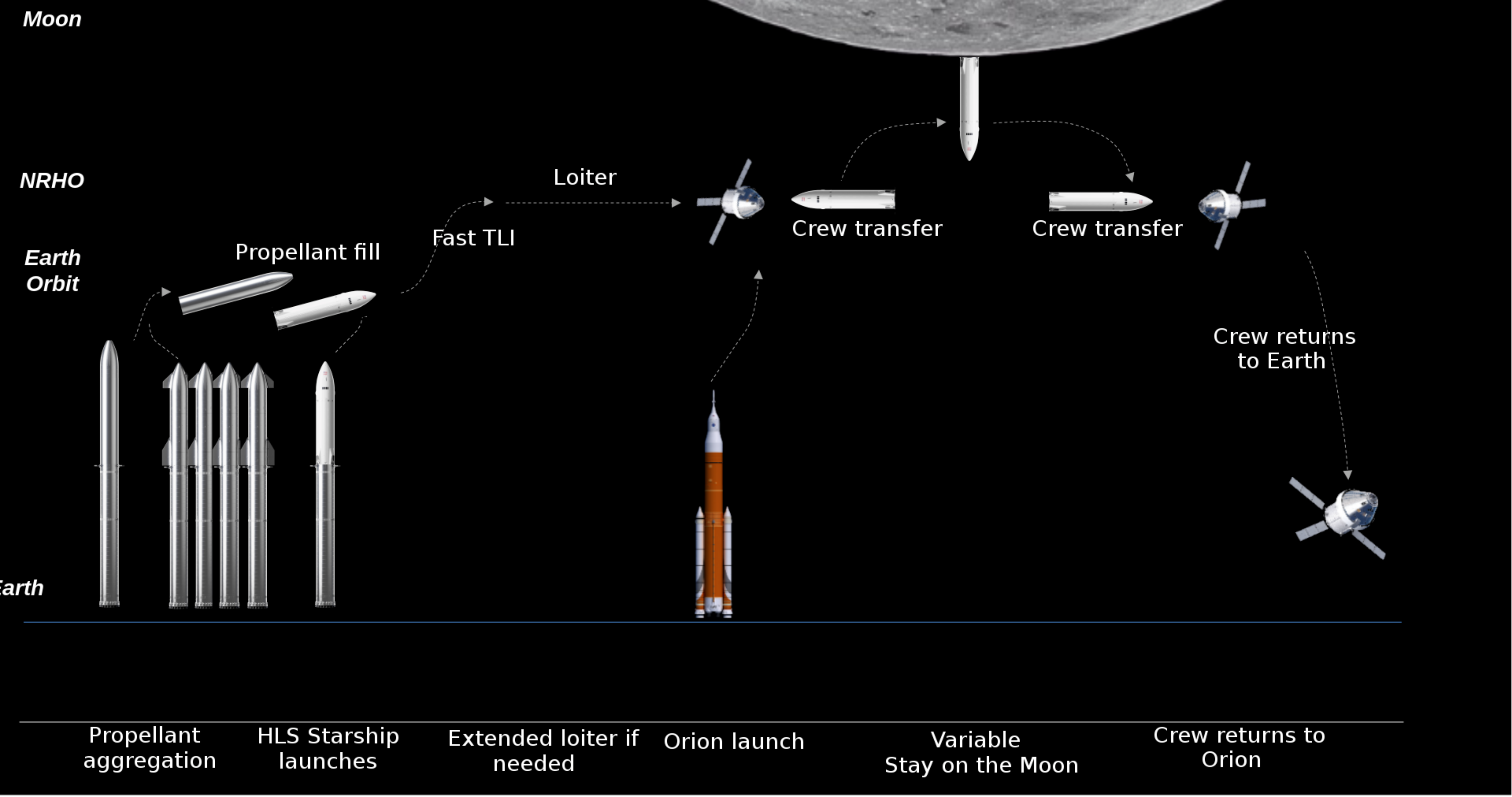
NASA will use the HLS Starship for use on Artemis III, the mission that will put the next two Americans on the surface of the Moon.

The SpaceX Option A contract includes two lunar surface missions:

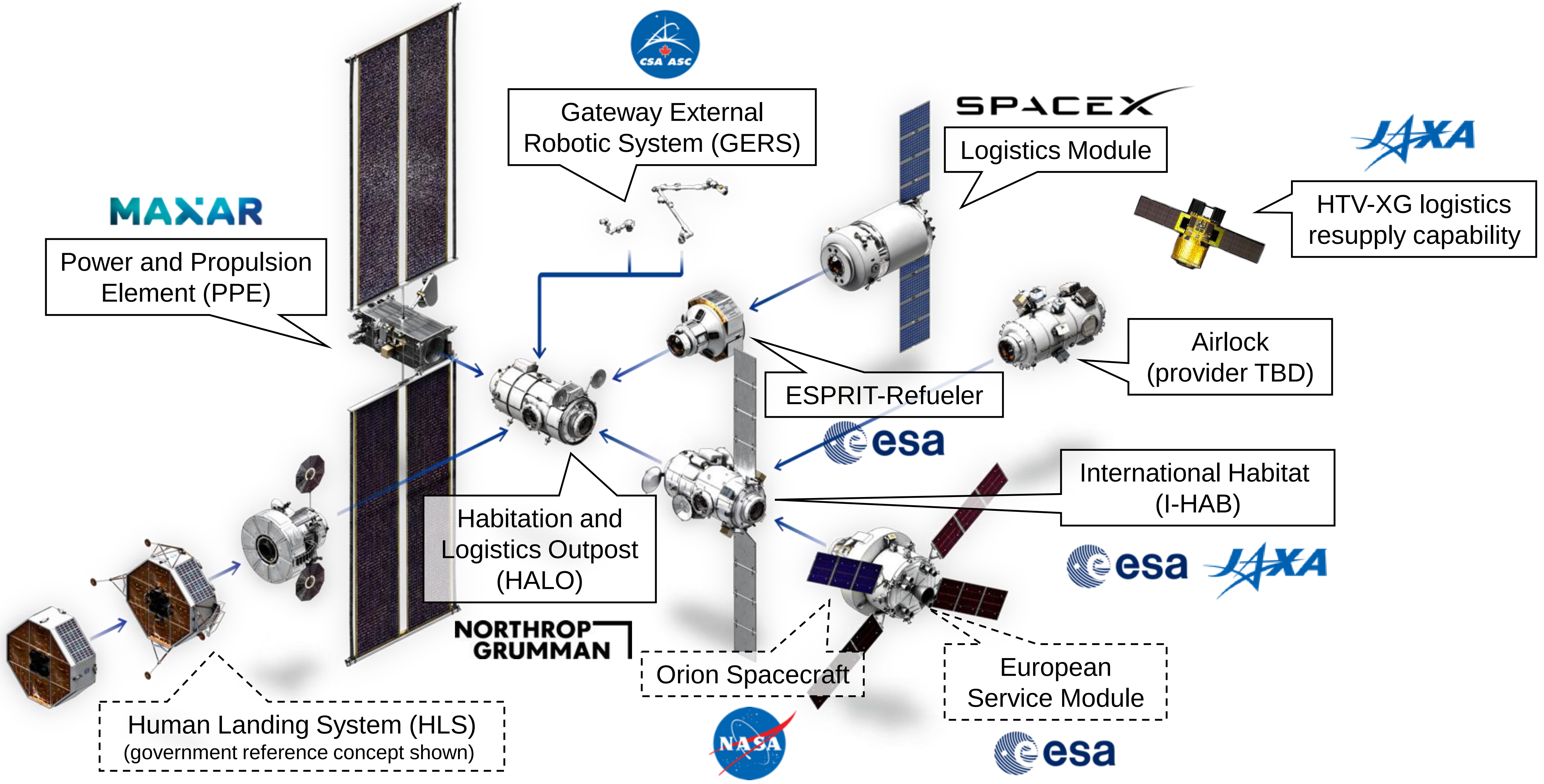
- SpaceX Uncrewed Lunar Demo-A
- SpaceX Crewed Lunar Demo-A

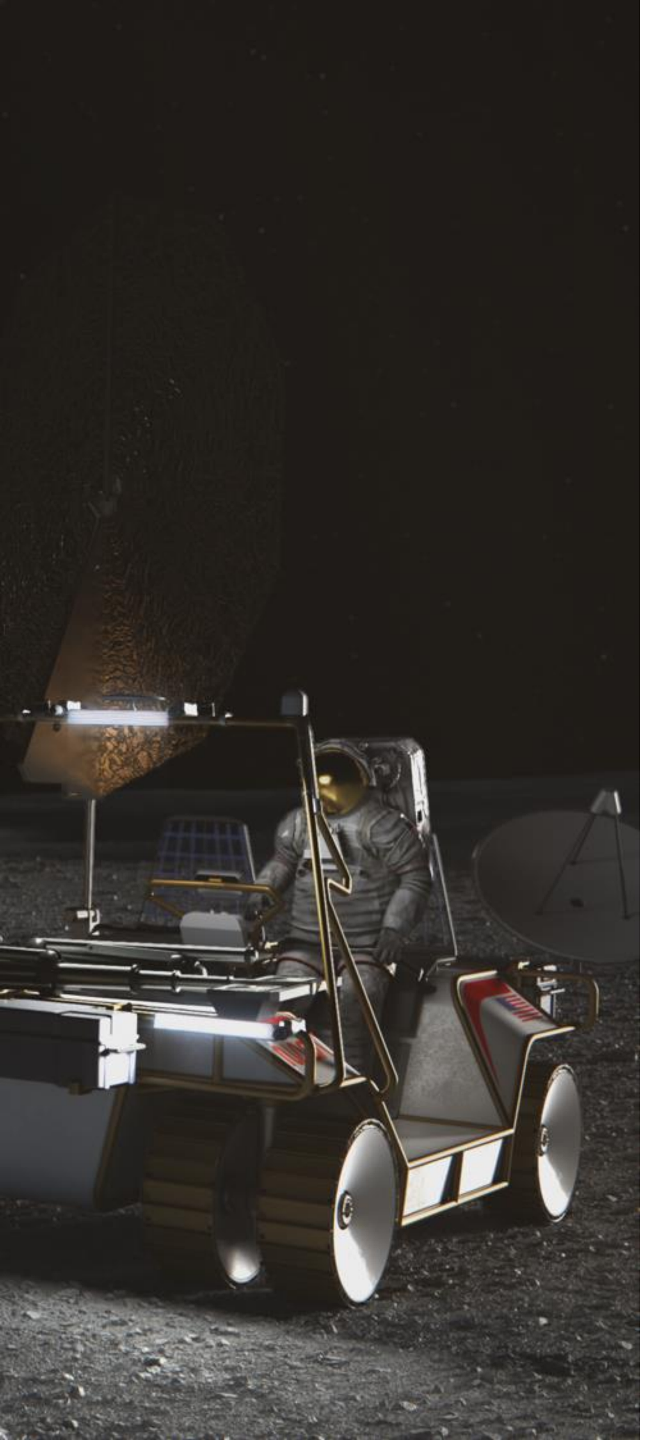
Image Credit: SpaceX

Artemis III Concept of Operations



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

SPACE TECHNOLOGY PORTFOLIO

EARLY STAGE INNOVATION AND PARTNERSHIPS

- Early Stage Innovation
  - Space Tech Research Grants
  - Center Innovation Fund
  - Early Career Initiative
  - Prizes, Challenges & Crowdsourcing
  - NASA Innovation Advanced Concepts
- Technology Transfer

SBIR/STTR PROGRAMS

- Small Business Innovation Research
- Small Business Technology Transfer

TECHNOLOGY MATURATION

- Game Changing Development
- Lunar Surface Innovation Initiative

TECHNOLOGY DEMONSTRATION

- Technology Demonstration Missions
- Small Spacecraft Technology
- Flight Opportunities

STMD Strategic Framework

STMD rapidly develops, demonstrates, and transfers revolutionary, high pay off space technologies, driven by diverse ideas

Lead

Ensuring American global leadership in Space Technology

- Advance US space technology innovation and competitiveness in a global context
- Encourage technology driven economic growth with an emphasis on the expanding space economy
- Inspire and develop a diverse and powerful US aerospace technology community

Transforming Space Missions

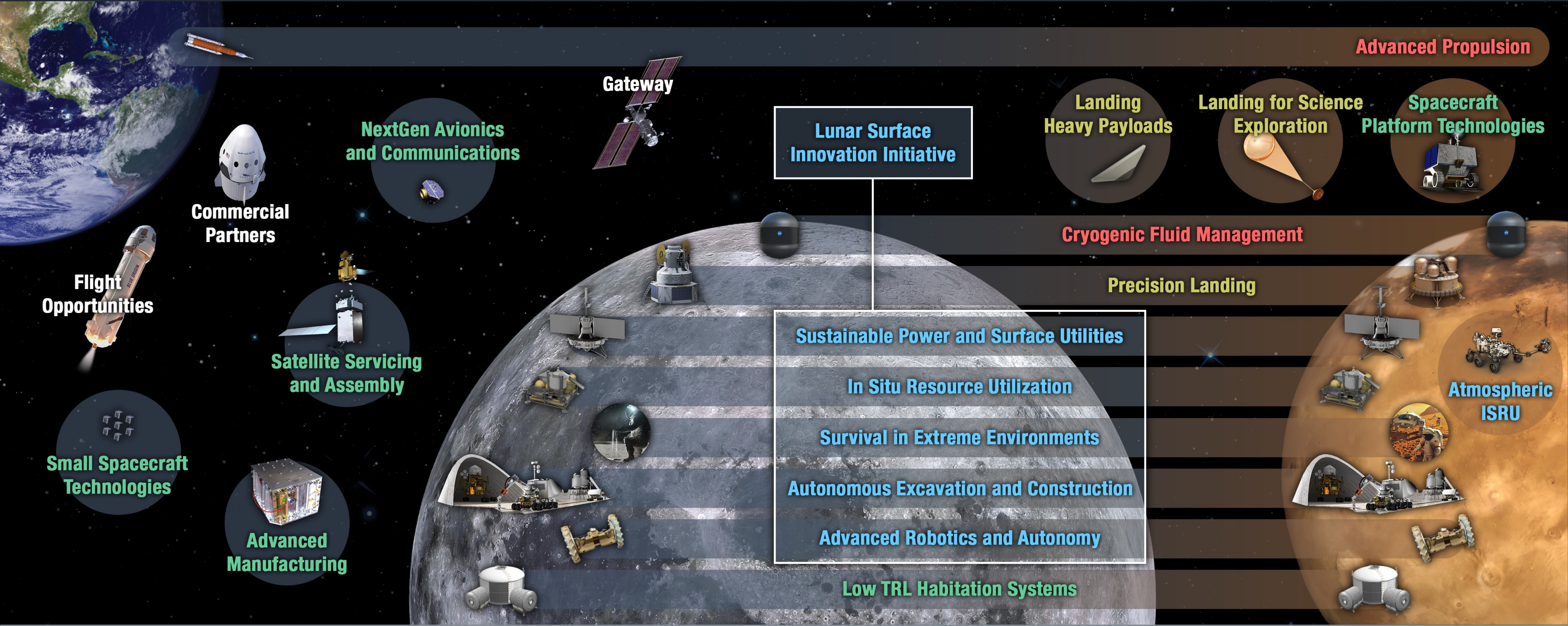
Thrusts	Outcomes	Primary Capabilities
Go Rapid, Safe, and Efficient Space Transportation	• Develop nuclear technologies enabling fast in space transits. • Develop cryogenic storage, transport, and fluid management technologies for surface and in space applications. • Develop advanced propulsion technologies that enable future science/exploration missions.	• Nuclear Systems • Cryogenic Fluid Management • Advanced Propulsion
Land Expanded Access to Diverse Surface Destinations	• Enable Lunar/Mars global access with 20t payloads to support human missions. • Enable science missions entering/transiting planetary atmospheres and landing on planetary bodies. • Develop technologies to land payloads within 50 meters accuracy and avoid landing hazards.	• Entry, Descent, Landing, & Precision Landing

Live
Sustainable Living and Working Farther from Earth
	• Develop exploration technologies and enable a vibrant space economy with supporting utilities and commodities
	  ◦ Sustainable power sources and other surface utilities to enable continuous lunar and Mars surface operations.
	  ◦ Scalable ISRU production/utilization capabilities including sustainable commodities on the lunar & Mars surface.
	  ◦ Technologies that enable surviving the extreme lunar and Mars environments.
	  ◦ Autonomous excavation, construction & outfitting capabilities targeting landing pads/structures/habitable buildings utilizing in situ resources.
	• Enable long duration human exploration missions with Advanced Habitation System technologies. [Low TRL STMD; Mid High TRL SOMD/ESDMD]
		• Advanced Power
		• In Situ Resource Utilization
		• Advanced Thermal
		• Advanced Materials, Structures, & Construction
		• Advanced Habitation Systems

Explore Transformative Missions and Discoveries	• Develop next generation high performance computing, communications, and navigation. • Develop advanced robotics and spacecraft autonomy technologies to enable and augment science/exploration missions. • Develop technologies supporting emerging space industries including: Satellite Servicing & Assembly, In Space/Surface Manufacturing, and Small Spacecraft technologies. • Develop vehicle platform technologies supporting new discoveries. • Develop technologies for science instrumentation supporting new discoveries. [Low TRL STMD/Mid High TRL SMD. SMD funds mission specific instrumentation (TRL 1 9)] • Develop transformative technologies that enable future NASA or commercial missions and discoveries	• Advanced Avionics Systems • Advanced Communications & Navigation • Advanced Robotics • Autonomous Systems • Satellite Servicing & Assembly • Advanced Manufacturing • Small Spacecraft • Rendezvous, Proximity Operations & Capture • Sensor & Instrumentation

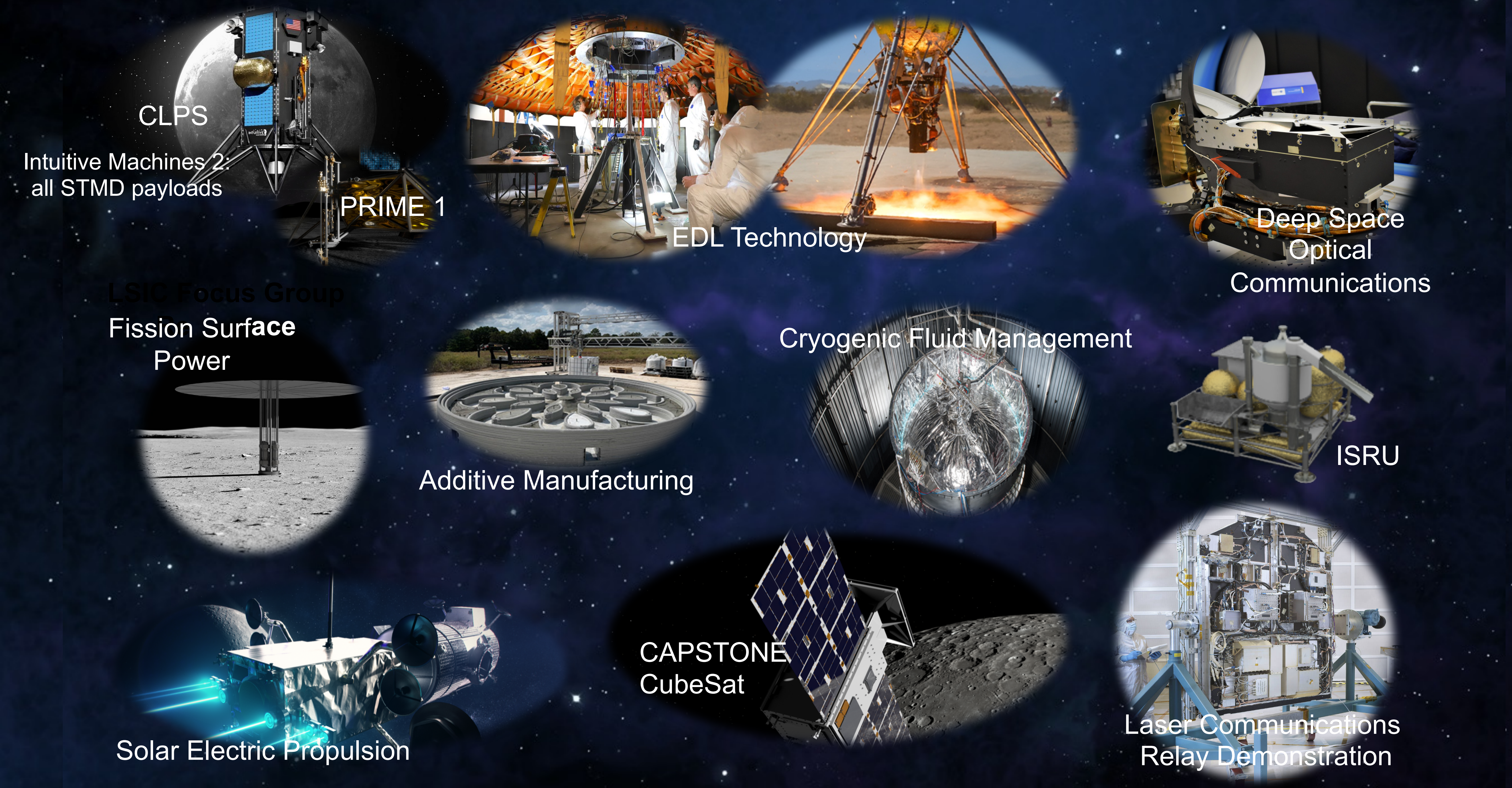
Ensuring American Global Leadership in Space Technology

Rapid, Safe, and Efficient Space Transportation | **Expanded Access to Diverse Surface Destinations** | **Sustainable Living and Working Farther from Earth** | **Transformative Missions and Discoveries**

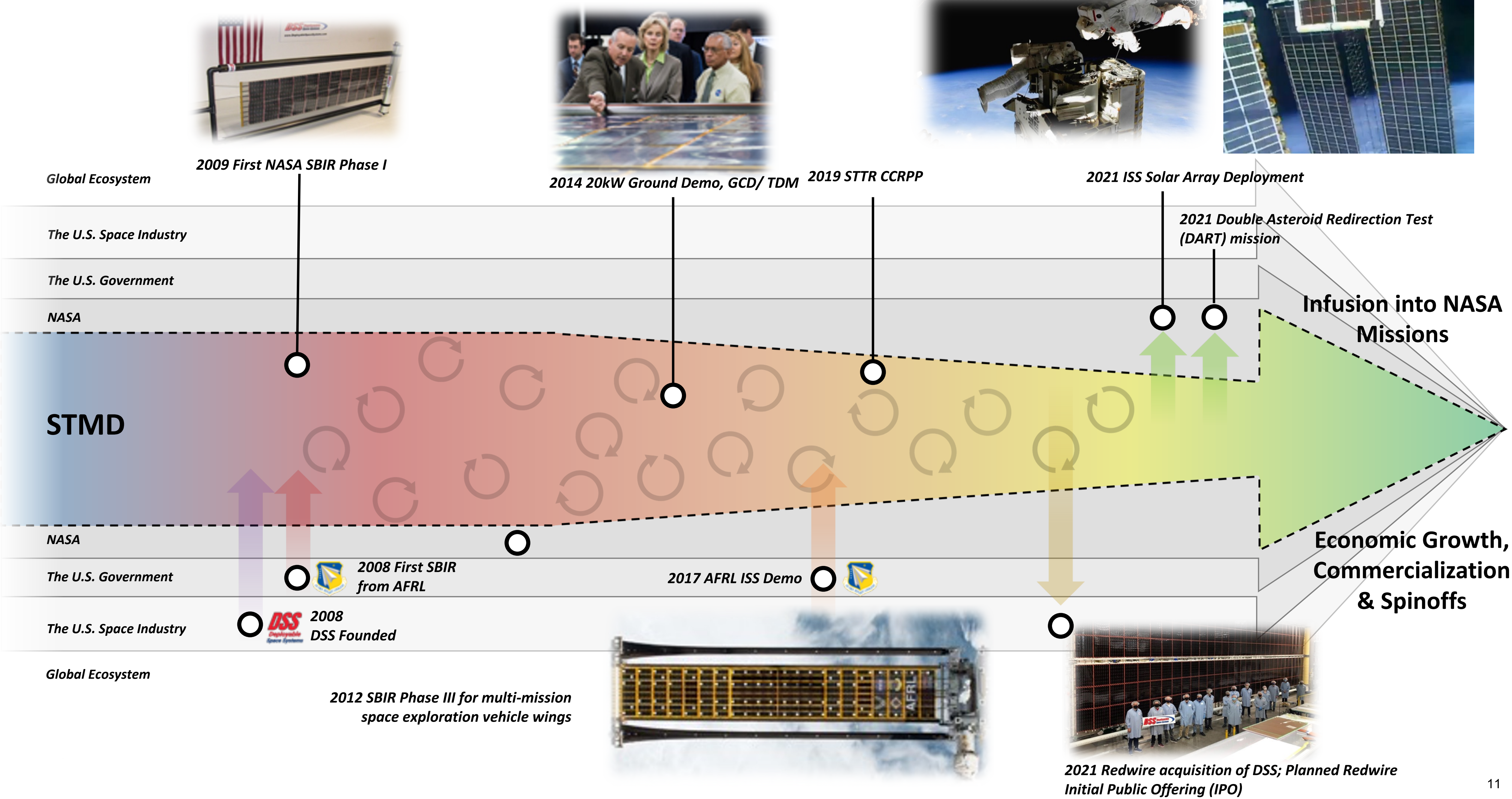


Technology Drives Exploration

Enabling Technologies for Future Science & Exploration Missions



Impact Story: Roll-Out Solar Array (ROSA)

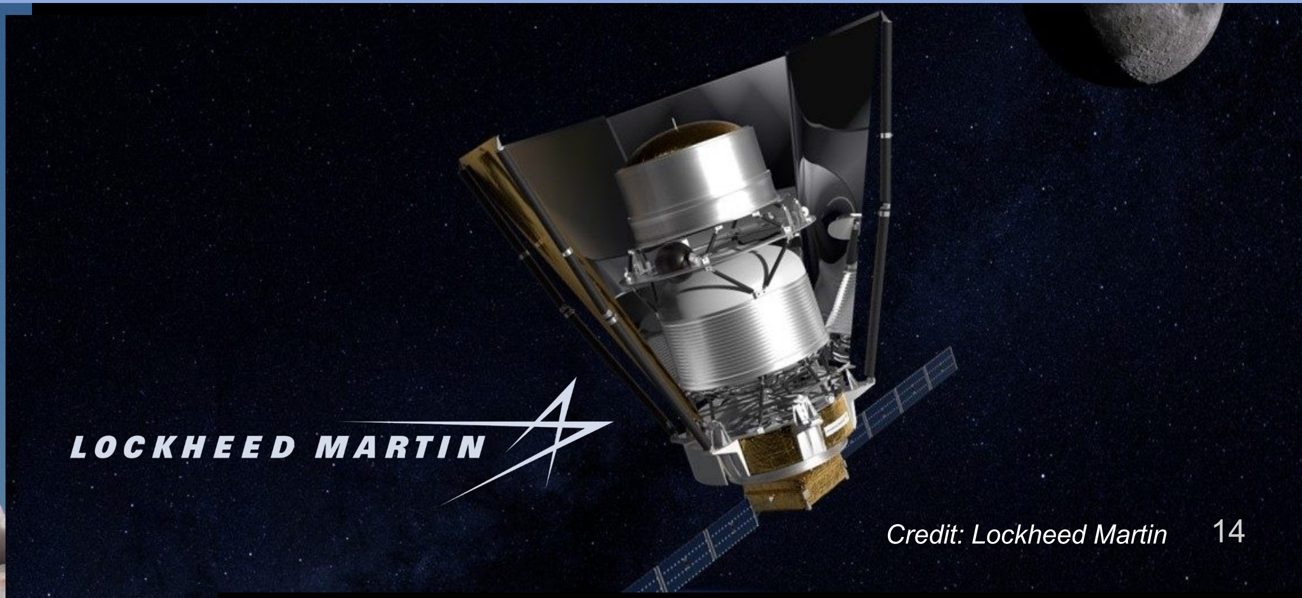


Credit: SpaceX

Credit: ETA Space

Via NASA Tipping Point partnerships, four unique cryogenic fluid management flight demonstrations will take place from fiscal years 2023 to 2025.

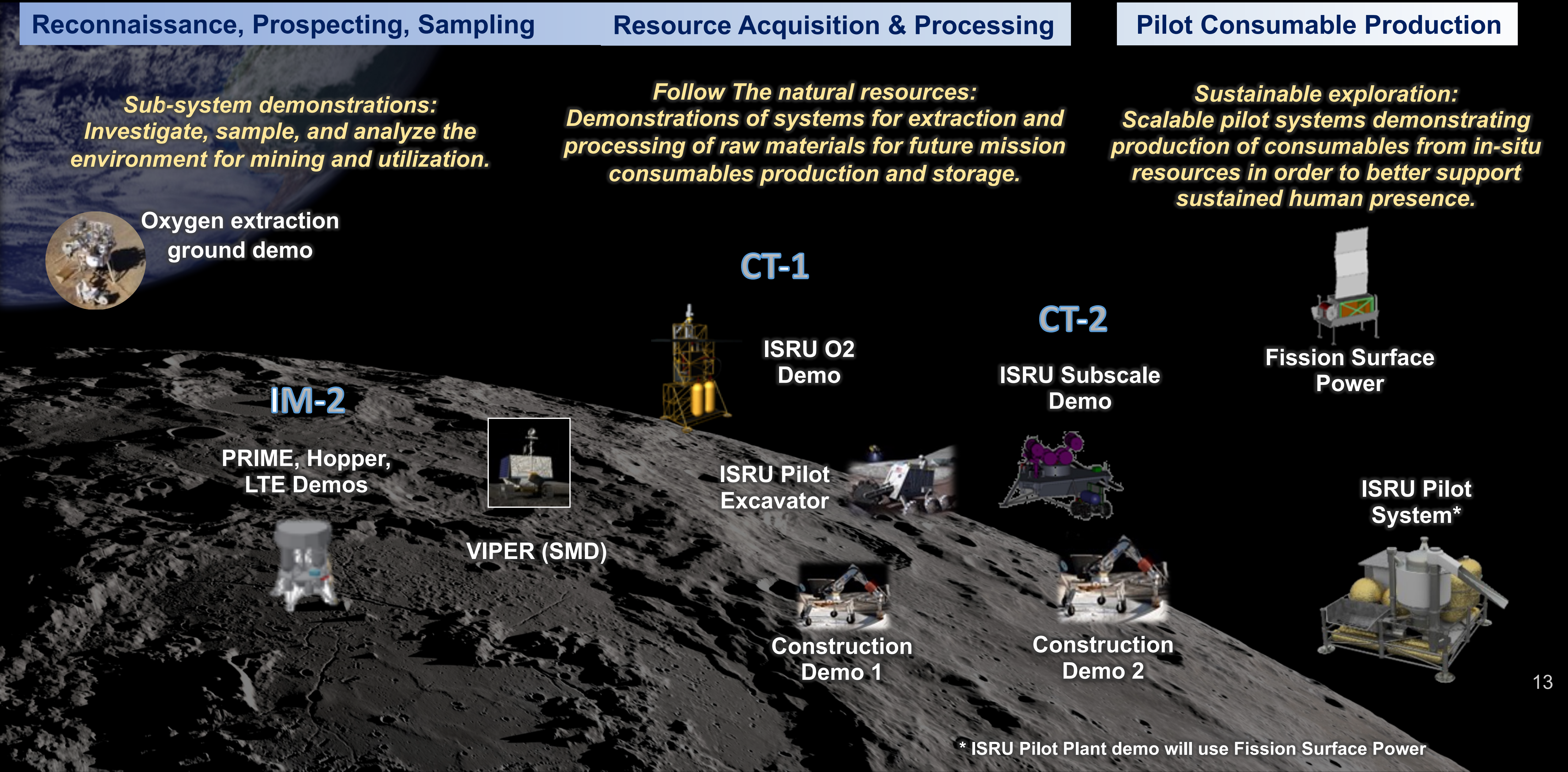
Credit: ULA



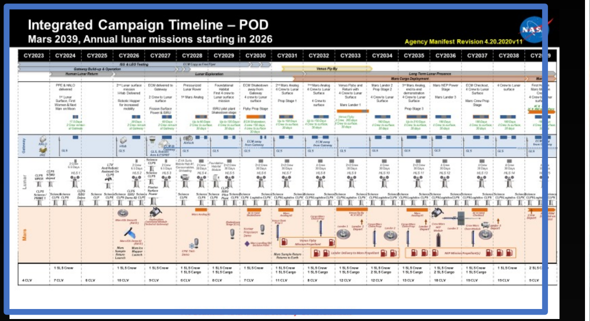
Credit: Lockheed Martin

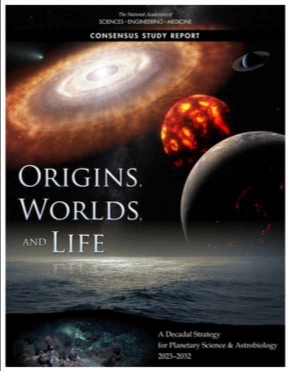
Space Technology Lunar Surface Demonstration Strategy

ISRU, Power, Excavation, and Construction utilizing cross-cutting technologies



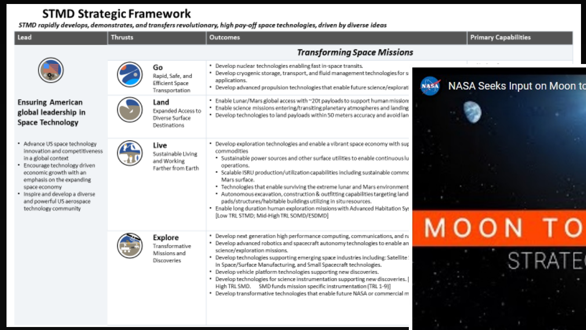
Strategic Technology Architecture Roundtable (STAR) Process

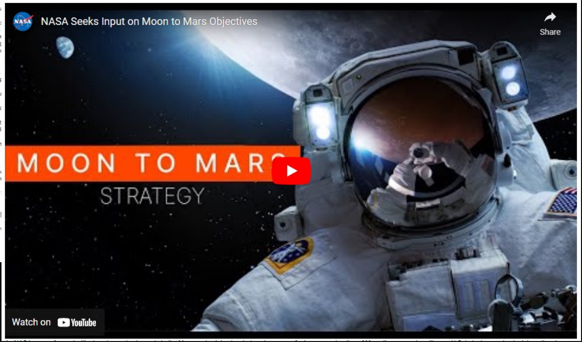




Draws directly on Agency Moon to Mars Manifest and SMD Science Needs to identify technology gaps.

Strategic Technology Framework aligned to Agency Strategic Capability Leadership Teams (SCLT's) and Principal Technologists (PT's) along with the Agency Moon to Mars Strategy. STMD Strategic Framework describes the STMD investment priority strategy.





Industry Partners participation is obtained through Requests for Information (RFIs) to validate envisioned futures, the current state of the art and the gaps between those two.

STAR process inclusive of Center Chief Technologists, ESDMD and SMD Representation.

Maps to Taxonomy.

STARPORT
STMD and ESDMD Gap database

+

Envisioned Future Priorities

PPBE Process

STARport is the database of all Capability Area gaps for both STMD and ESDMD. Envisioned Future Priorities (EFPs) are written by SCLT/PT's to show the future state envisioned and forward planning to inform PPBE Process.