Human Exploration and Operations Mission Directorate

NASA Exploration Update
NASA Advisory Council

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Associate Administrator

March 28, 2018

Space Policy Directive-1

"Lead an innovative and sustainable program of exploration with commercial and international partners to enable human expansion across the solar system and to bring back to Earth new knowledge and opportunities.

Beginning with missions beyond low-Earth orbit, the United States will lead the return of humans to the Moon for long-term exploration and utilization, followed by human missions to Mars and other destinations."

Human Exploration and Operations

Exploration Campaign

- Prioritize human exploration and related activities
- Expand Exploration by
  - Providing funding to start transition of low Earth orbit human space flight operations to commercial partners
  - Pursuing a cislunar strategy that establishes U.S. preeminence to, around, and on the Moon, including commercial partnerships and innovative approaches, to achieve human and science exploration goals

	Fiscal Year						
	Enacted	CR	Request	Notional			
Budget Authority ($ in millions)	2017	2018	2019	2020	2021	2022	2023
Deep Space Exploration Systems	$4,184.0	$4,222.6	$4,558.8	$4,859.1	$4,764.5	$4,752.5	$4,769.8
Exploration Research and Technology	$826.5	$820.8	$1,002.7	$912.7	$912.7	$912.7	$912.7
LEO and Spaceflight Operations	$4,942.5	$4,850.1	$4,624.6	$4,273.7	$4,393.3	$4,430.3	$4,438.0
Exploration Campaign CoF	$45.5	$22.4	$44.8	$0.0	$0.0	$0.0	$0.0
Elements of Science	$39.0	$36.0	$268.0	$268.0	$268.0	$268.0	$268.0
EXPLORATION CAMPAIGN TOTAL	$10,037.5	$9,951.9	$10,498.9	$10,313.5	$10,338.5	$10,363.5	$10,388.5

Human Exploration and Operations

Exploration Campaign (continued)

- To support the Nation's new Space Policy, the initiative is funded at $10.5 billion in the FY 2019 President's Budget (a $547 million increase in FY 2019 when compared to the current FY 2018 CR). In total, the Budget proposes $52 billion from 2019-2023 for the exploration strategy, and is centered on
  - Finalizing the development of the Space Launch System rocket and Orion crew capsule for EM-1 flight in FY 2020 and then to send astronauts to the area around the Moon beginning in 2023, and roughly annually thereafter
  - A new initiative for a Lunar Orbital Platform – Gateway to serve as a destination in the lunar vicinity by 2025
  - A new joint SMD and HEOMD initiative to develop small and mid-size lunar robotic lander capabilities through a combination of commercial and in-house efforts, beginning with commercial lunar landings as early as 2019
  - A new Commercial Low Earth Orbit (LEO) program to incentivize new commercial capabilities in LEO
  - A new Exploration Research and Technology account that merges elements of prior technology programs and focuses them on meeting exploration needs
    - Human Research Program (HRP) will continue research on effect of Spaceflight to the human body, will support development of Deep Space Exploration habitat concepts to ensure crew health and performance risks are adequately addressed; NASA is currently working on a reorganization that will take effect later this fiscal year. Until then, HEOMD and STMD will continue to manage their respective programs

Human Exploration and Operations

Exploration Campaign (continued)

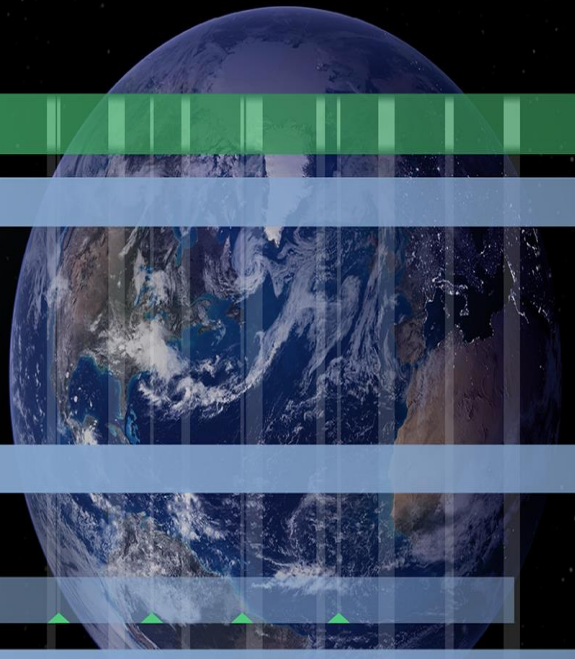
- In addition to these areas, NASA will continue pursuing other human spaceflight programs, most notably the International Space Station and the advancement of commercial crew and cargo transportation services and capabilities
- At the end of the five years proposed in the Budget, NASA plans to have
  - Achieved uncrewed and crewed test launch of the SLS and Orion system,
  - Launched two of the initial elements of the Lunar Orbital Platform - Gateway (to be completed with two additional launches by 2025)
  - Supported numerous commercial lunar robotic landings and developed commercial lunar landing capabilities to support future NASA mission needs
  - Developed key technologies needed to make exploration more capable and cost-effective, and
  - Established a pathway to enable a seamless transition from direct NASA financial support to the ISS in 2025

Human Exploration and Operations

Strategic Principles for Sustainable Exploration

- FISCAL REALISM: Implementable *with the buying power of current budgets*
- COMMERCIAL PARTNERSHIPS: Leveraging the unique capabilities of NASA and the private sector, use partnerships to develop safe, reliable, and cost-effective space systems, while simultaneously developing a commercial LEO space economy
- SCIENTIFIC EXPLORATION*: Exploration enables science and science enables exploration;* leveraging scientific expertise for human exploration of the solar system
- TECHNOLOGY PULL AND PUSH: Application of high TRL technologies for near term missions, while focusing sustained investments on *technologies and capabilities* to address the challenges of future missions
- GRADUAL BUILD UP OF CAPABILITY: *Near-term mission opportunities* with a defined cadence of compelling and integrated human and robotic missions, providing for an incremental buildup of capabilities for more complex missions over time
- ARCHITECTURE OPENNESS AND RESILIENCE : Resilient architecture featuring multi-use, evolvable space infrastructure, minimizing unique developments, with each mission leaving something behind to support subsequent missions
- GLOBAL COLLABORATION AND LEADERSHIP: Substantial *new international and commercial partnerships,* leveraging current International Space Station partnerships and building new cooperative ventures for exploration; and
- CONTINUITY OF HUMAN SPACEFLIGHT*: Uninterrupted expansion of human presence into the solar system* by establishing a regular cadence of crewed missions to cislunar space during ISS lifetime

NASA Exploration Campaign



NOTIONAL LAUNCHES

EARLY SCIENCE & TECHNOLOGY INITIATIVE

- **SMD**–Pristine Apollo Sample, Virtual Institute
- **HEO/SMD**–Lunar CubeSats
- **SMD**/HEO–Science & Technology Payloads

SMALL COMMERCIAL LANDER INITIATIVE

- **HEO**–Lunar Catalyst & Tipping Point
- **SMD**/HEO–Small Commercial Landers/Payloads

MID TO LARGE LANDER INITIATIVE TOWARD HUMAN-RATED LANDER

- **HEO**/SMD–Mid-sized Landers (~500kg–1000kg)
- **HEO**/SMD–Human Descent Module Lander (5-6000kg)
- **SMD**/HEO–Payloads & Technology/Mobility & Sample Return
- **SMD**–Mars Robotics

LUNAR ORBITAL PLATFORM—GATEWAY

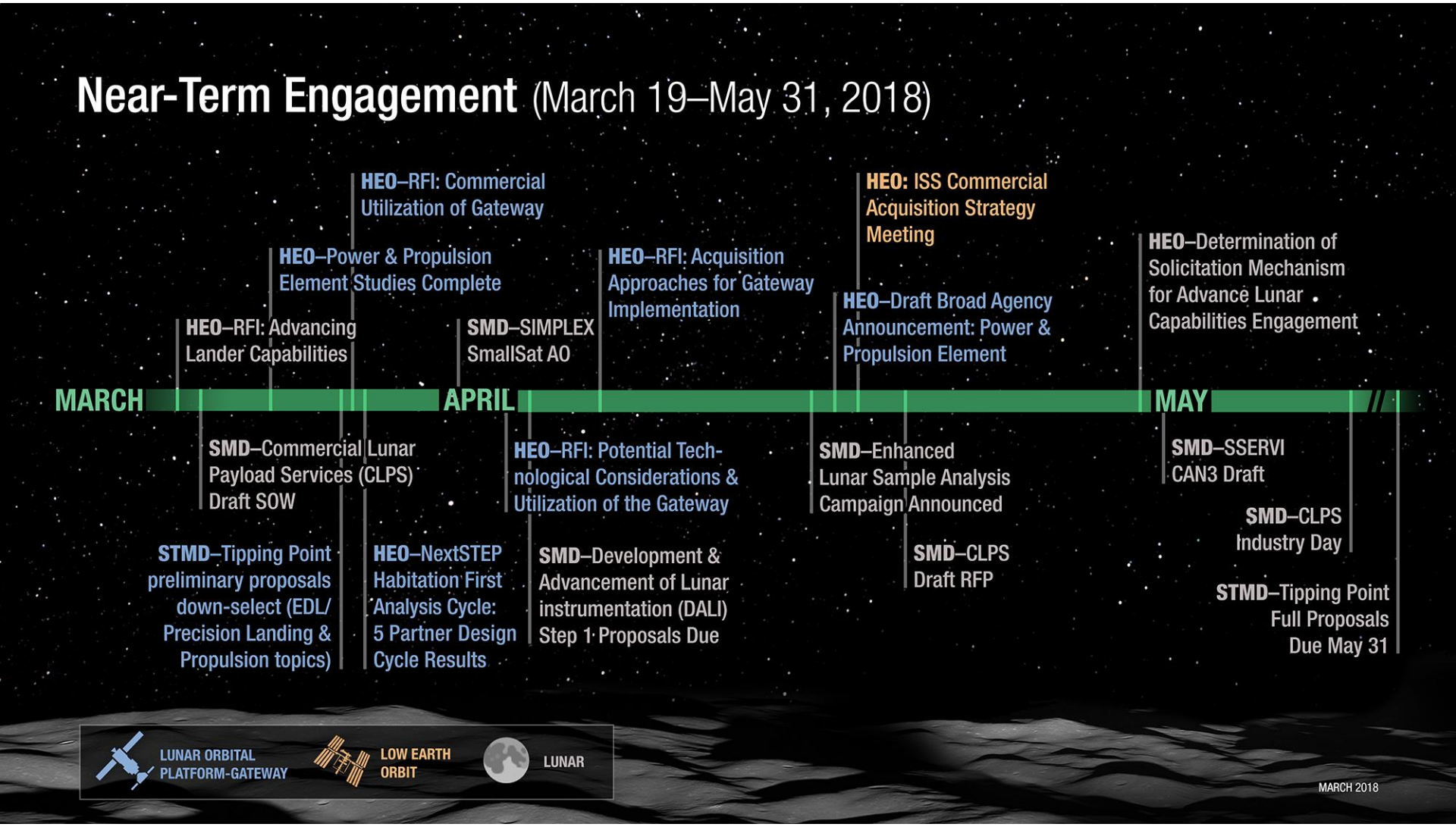
- **HEO**–Orion/SLS (Habitation Elements/Systems)
- **HEO**/SMD–Gateway Elements (PPE, Commercial Logistics)/Crew Support of Lunar Missions
- **HEO**/SMD–Lunar Sample Return Support

2018 2019 2020 2021 2022 2023 2024 2025 2026 2027 2028 2029 2030

Timelines are tentative and will be developed further in FY 2019

MARCH 2018

HEOMD/SMD/STMD
Near-Term Engagement Schedule



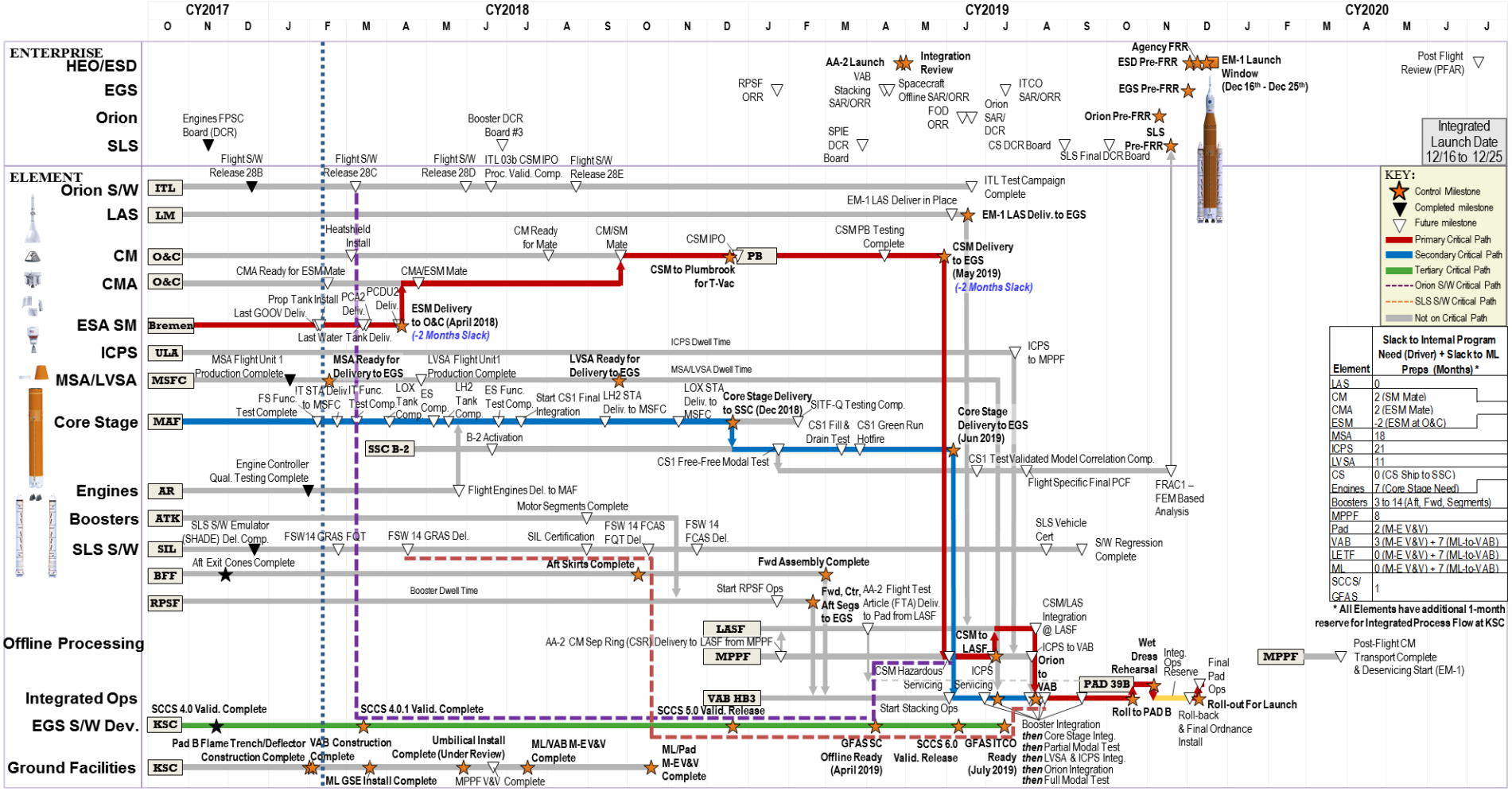
Human Exploration and Operations

Exploration Systems Development:
EM-1 Integrated Mission Milestone Summary

Last update: 02/07/18

December Month End Data

EM-1 INTEGRATED MISSION MILESTONE SUMMARY



Element	Slack to Internal Program Need (Driver) + Slack to ML Preps (Months) *
LAS	0
CM	2 (SM Mate)
CMA	2 (ESM Mate)
ESM	-2 (ESM at O&C)
MSA	18
ICPS	21
LVSA	11
CS	0 (CS Ship to SSC)
Engines	7 (Core Stage Need)
Boosters	3 to 14 (Aft, Fwd, Segments)
MPPF	8
Pad	2 (M-E V&V)
VAB	3 (M-E V&V) + 7 (ML-to-VAB)
LETF	0 (M-E V&V) + 7 (ML-to-VAB)
ML	0 (M-E V&V) + 7 (ML-to-VAB)
SCCS/ GFAS	1

* All Elements have additional 1-month reserve for Integrated Process Flow at KSC

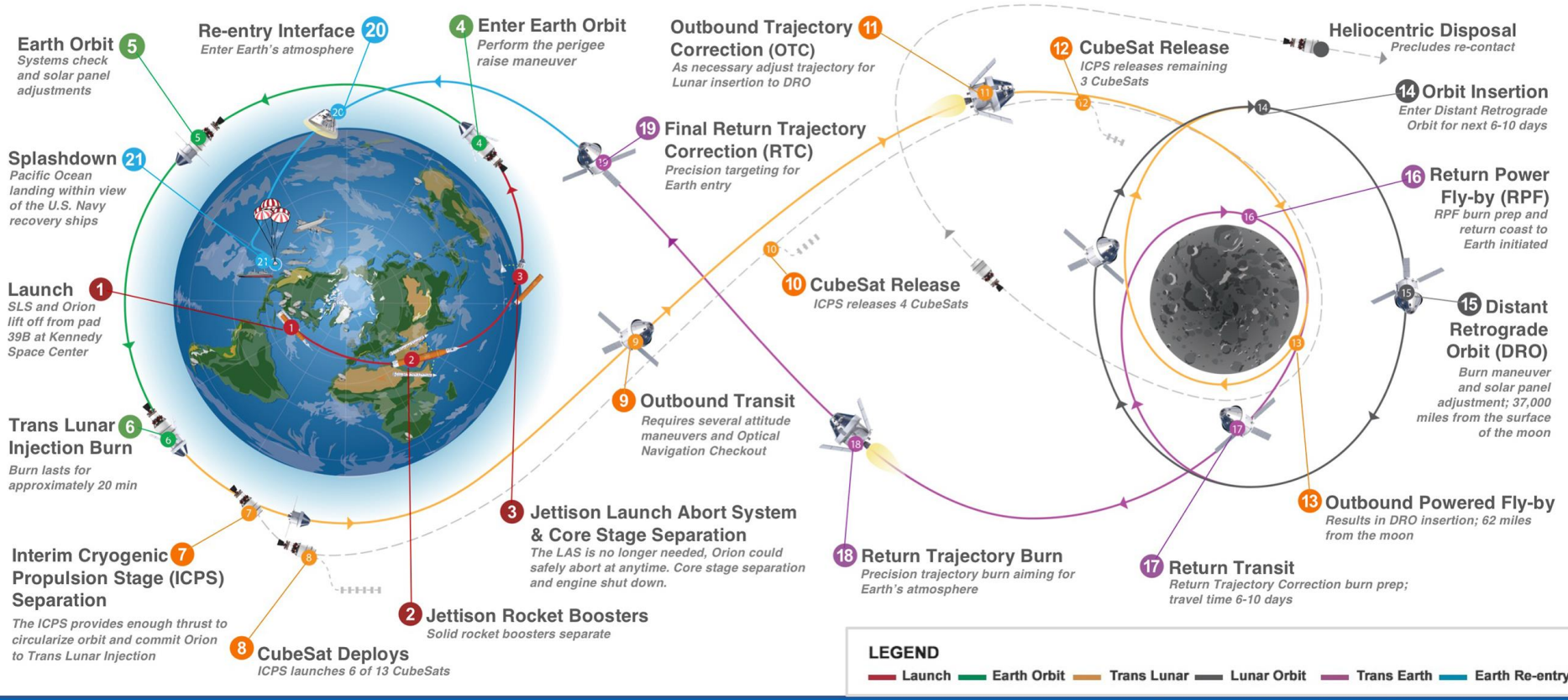
Human Exploration and Operations

Exploration Systems Development: EM-1 Mission Summary

EXPLORATION MISSION-1

National Aeronautics and Space Administration

The first uncrewed, integrated flight test of NASA's Deep Space Exploration Systems. The Orion spacecraft and Space Launch System rocket will launch from a modernized Kennedy spaceport



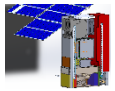
Total distance traveled: 1.3 million miles – Mission duration: 25.5 days – Re-entry speed: 24,500 mph (Mach 32) – 13 CubeSats deployed

Human Exploration and Operations

Exploration System Development:

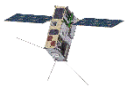
EM-1 Secondary Payloads - First Cubesats Delivered to Deep Space

LUNAR FOCUS

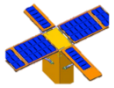


- **LUNAr polar Hydrogen Mapper (LunaH-Map)**
  - Payload Developer: Arizona State University (ASU)
  - Objective: Perform neutron spectroscopy of lunar surface to determine H abundance
  - Mission Destination: Lunar Orbit

- **Lunar Flashlight**
  - Payload Developer: Jet Propulsion Laboratory
  - Objective: Search for lunar surface ice deposits using near-IR band lasers
  - Mission Destination: Lunar Orbit

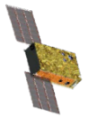


- **Lunar IceCube**
  - Payload Developer: Moorehead State University
  - Objective: Prospect for water (ice, liquid & vapor) & other lunar volatiles using IR spectrometer
  - Mission Destination: Lunar Orbit



- **LunIR**
  - Payload Developer: Lockheed Martin Space Systems
  - Objective: Collect IR imaging of Lunar Surface
  - Mission Destination: Heliocentric via Lunar Flyby

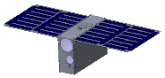
- **Outstanding Moon exploration TEchnologies demonstrated by NAno Semi-Hard Impactor (OMOTENASHI)**
  - Payload Developer: JAXA
  - Objective: Develop world's smallest lunar lander and observe lunar radiation environment
  - Mission Destination: Lunar Surface



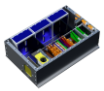
- **EQUULEUS**
  - Payload Developer: JAXA
  - Objective: Characterize radiation environment in geospace by imaging the Earth's plasmasphere
  - Mission Destination: Earth-Moon L2

- **Cislunar Explorers**
  - Payload Developer: Cornell University
  - Objective: Compete in the **Lunar Derby** for Achieving Lunar Orbit and Spacecraft Longevity prizes
  - Mission Destination: Lunar Orbit

OTHER DEEP SPACE ENABLING

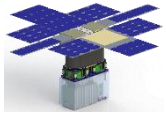


- **ArgoMoon**
  - Payload Developer: ASI
  - Objective: Provide photography of EM-1 Mission, detailed imagery of ICPS as well as demonstrate image system operability
  - Mission Destination: Elliptical Earth Orbit (ICPS proximity)



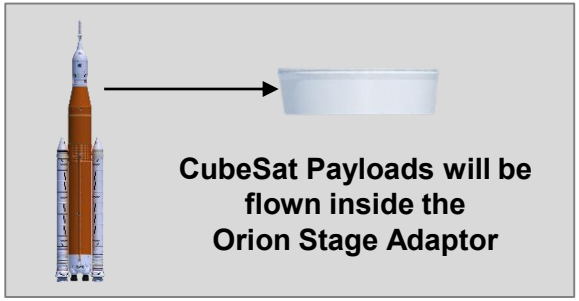
- **Team Miles**
  - Payload Developer: Fluid & Reason, LLC
  - Objective: Compete in the **Deep Space Derby** for Furthest Communication Distance from Earth prize
  - Mission Destination: Deep Space

- **CU-E3**
  - Payload Developer: University of Colorado
  - Objective: Compete in the **Deep Space Derby** for Best Burst Data Rate, Largest Aggregate Data Volume Sustained over time, Spacecraft Longevity and Furthest Communication Distance from Earth prizes
  - Mission Destination: Deep Space



- **Near Earth Asteroid Scout (NEA Scout)**
  - Payload Developer: Marshall Space Flight Center
  - Objective: Perform target detection, reconnaissance and close proximity imaging of a NEA
  - Mission Destination: a Near Earth Asteroid (within ~1.0 AU distance from Earth)

- **BioSentinel**
  - Payload Developer: Ames Research Center
  - Objective: Quantify DNA damage from space radiation environment
  - Destination: Heliocentric Trajectory

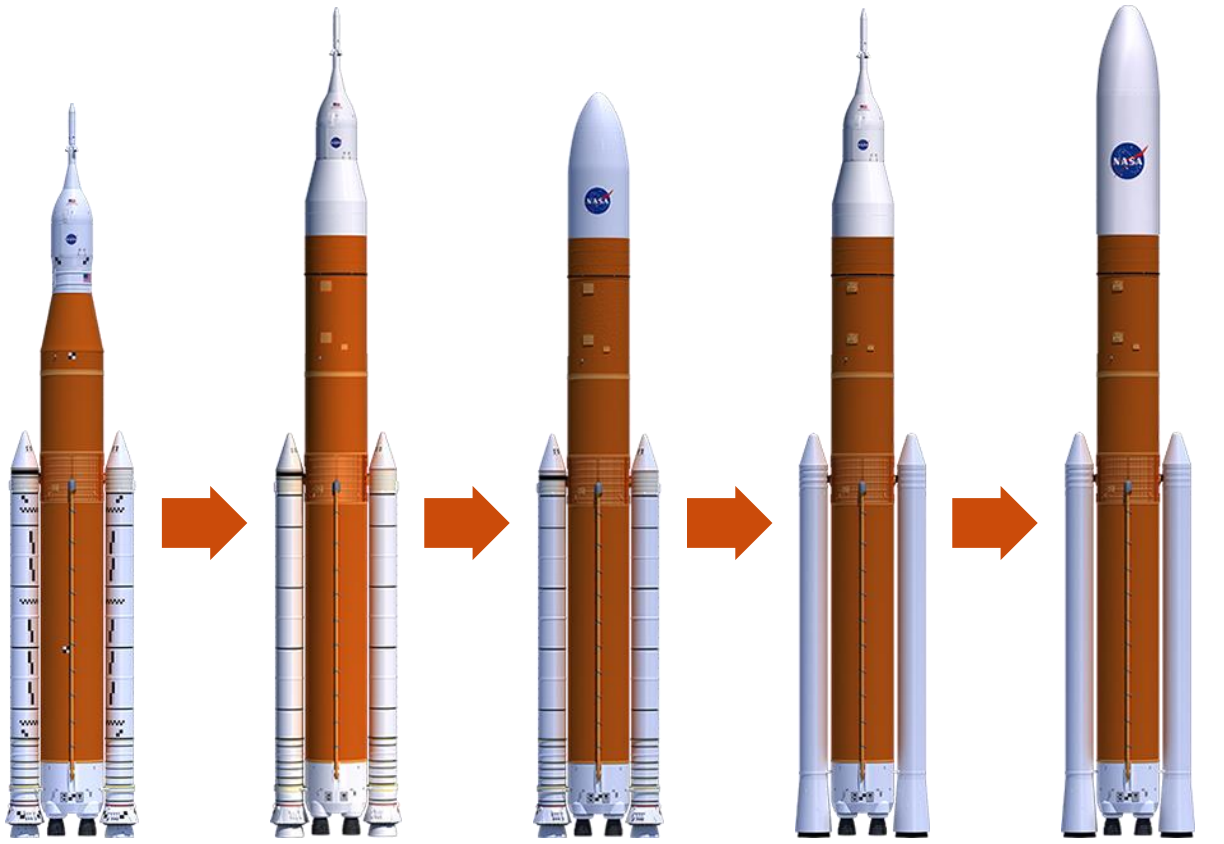


Space Launch System Lift Capabilities

	SLS Block 1	SLS Block 1B Crew	SLS Block 1B Cargo	SLS Block 2 Crew	SLS Block 2 Cargo
Payload to TLI/Moon	> 26 t (57k lbs)	34 37 t (74k 81k lbs)	37 40 t (81k 88k lbs)	> 45 t (99k lbs)	> 45 t (99k lbs)
Payload Volume	N/A**	10,100 ft^3 (286m^3)**	18,970 ft^3 (537 m^3)	10,100 ft^3 (286m^3)**	31,950 ft^3 (905 m^3)

Trans-Lunar Injection (TLI) is a propulsive maneuver used to set a spacecraft on a trajectory that will cause it to arrive at the Moon. A spacecraft performs **TLI** to begin a lunar transfer from a low circular parking orbit around Earth.

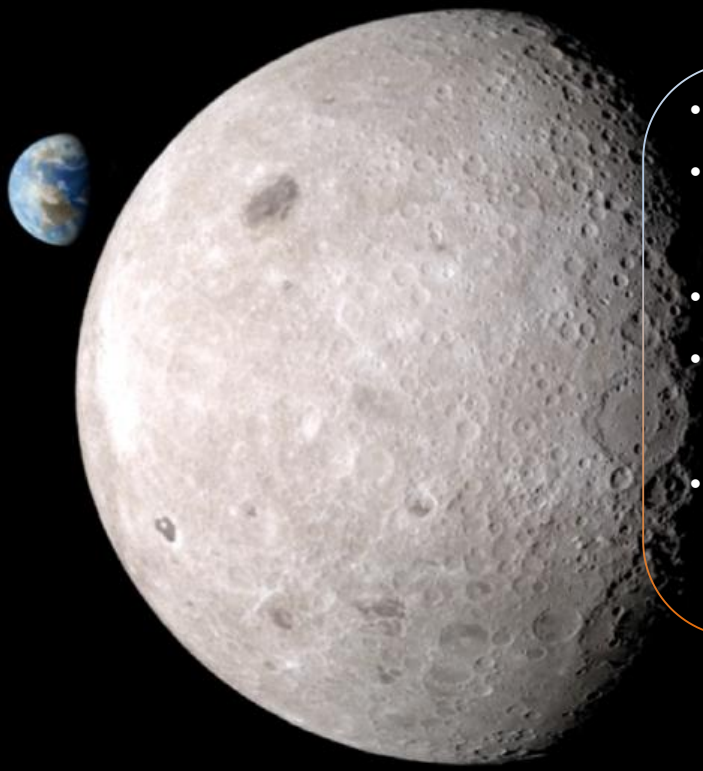
The numbers depicted here indicate the mass capability at the Trans-Lunar Injection point.



** Not including Orion/Service Module volume

	SLS Block 1	SLS Block 1B Crew	SLS Block 1B Cargo	SLS Block 2 Crew	SLS Block 2 Cargo
Maximum Thrust	8.8M lbs	8.8M lbs	8.8M lbs	11.9M lbs	11.9M lbs

HOW ARE WE LEADING FUTURE EXPLORATION



- Building a platform that will orbit the Moon
- Sending landers to the lunar surface in preparation for a human return
- Stimulating the low-Earth orbit commercial space economy
- Developing technologies needed for exploration and resolving human health and performance challenges
- Expanding US leadership through partnerships with commercial industry and other nations