



Returning to the Moon: NASA's Artemis Missions

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PERSONAL INFORMATION

- Project Manager for Orion (Multi-Purpose Crew Vehicle) operations at NASA Ames Research Center since 2018
 - Orion is one of the elements of NASA's Artemis program with objective to land the first woman and next man on Moon by 2024
- Project Manager for Science mission proposals
- Prior to current role, I spent 11 years in Entry Systems division designing, developing and testing heatshield materials and systems. I had the opportunity to work on many different projects at NASA.
 - Mission concept studies to send probes to Ice giants
 - Thermal analysis of Entry vehicles
 - Asteroid entry on Earth and their break-up

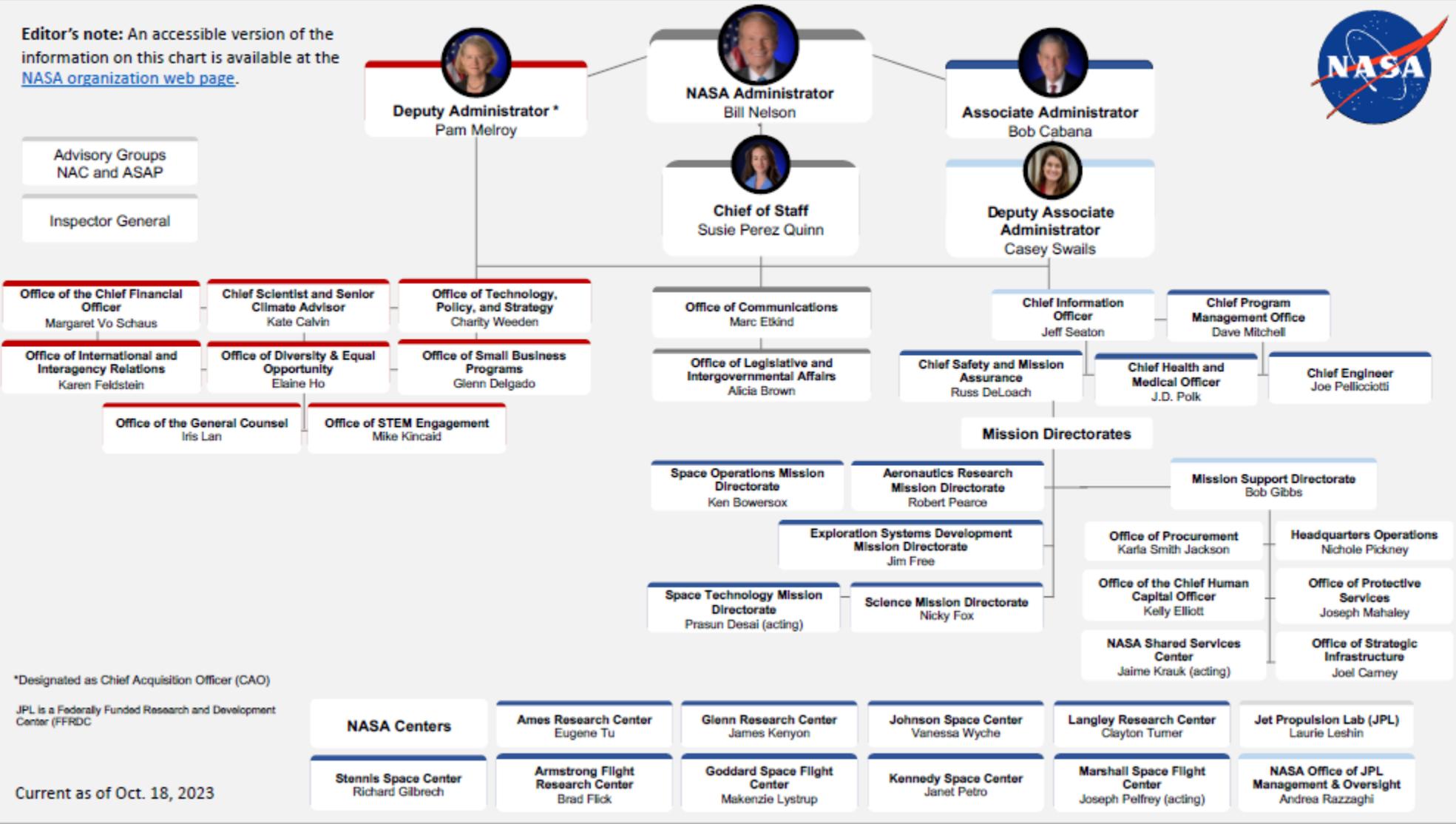


**Returning to Earth at
25,000 MPH**

NASA Organization Structure



Editor's note: An accessible version of the information on this chart is available at the [NASA organization web page](#).



*Designated as Chief Acquisition Officer (CAO)

JPL is a Federally Funded Research and Development Center (FFRDC)

Current as of Oct. 18, 2023



“At NASA, we make Air and Space available for everyone.”

NASA's existing Core Values of Safety, Integrity, Inclusion, Teamwork, and Excellence mandate individual and organizational behavior across the Agency at all levels:

Safety

NASA's constant attention to safety is the cornerstone upon which we build mission success.

Integrity

NASA is committed to maintaining an environment of trust, built upon honesty, ethical behavior, respect, and candor.

Inclusion

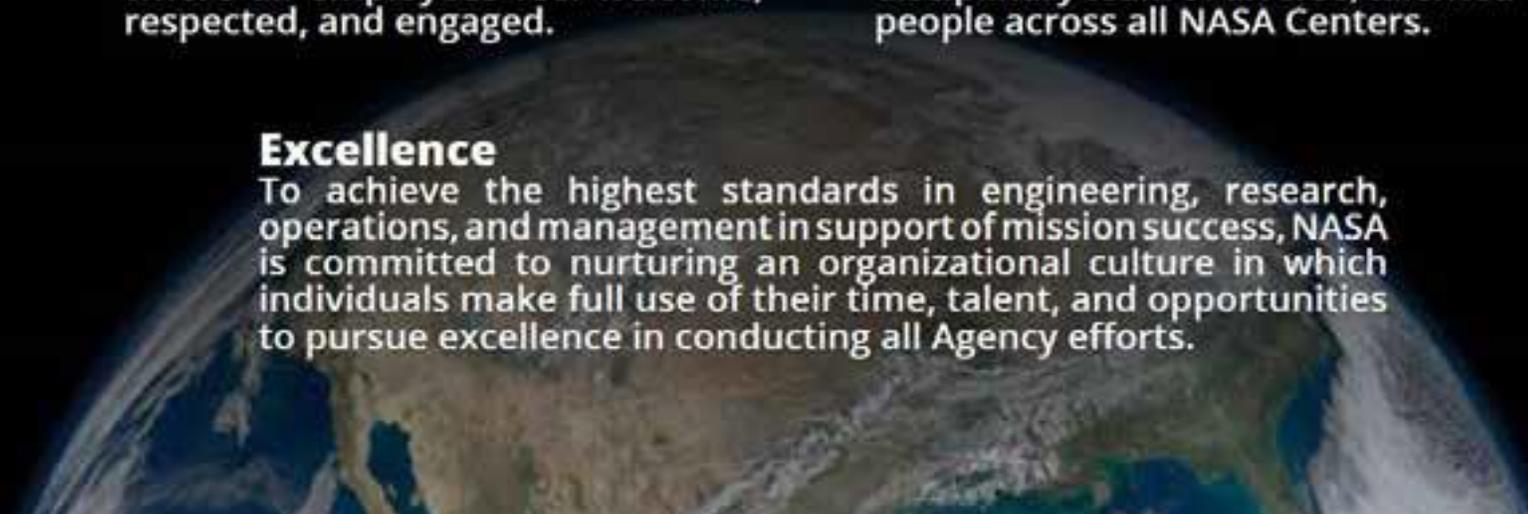
NASA is committed to a culture of diversity, inclusion, and equity, where all employees feel welcome, respected, and engaged.

Teamwork

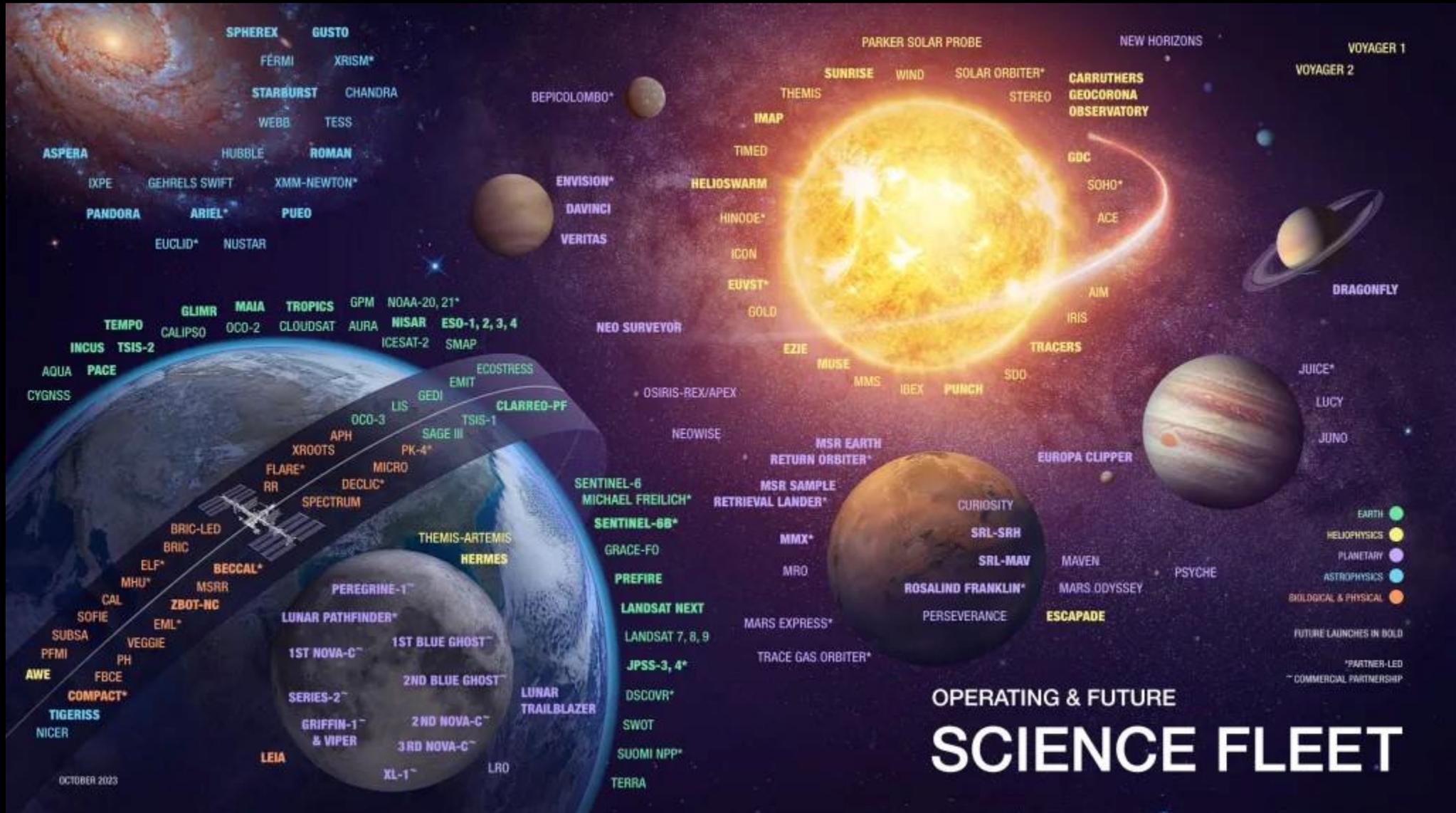
NASA's most powerful asset for achieving mission success is a multi-disciplinary team of diverse, talented people across all NASA Centers.

Excellence

To achieve the highest standards in engineering, research, operations, and management in support of mission success, NASA is committed to nurturing an organizational culture in which individuals make full use of their time, talent, and opportunities to pursue excellence in conducting all Agency efforts.



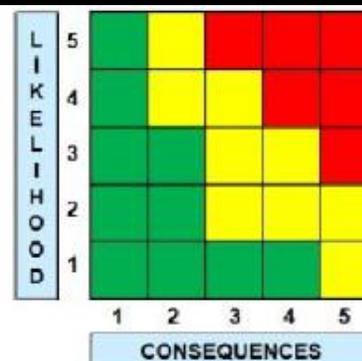
NASA Science Missions



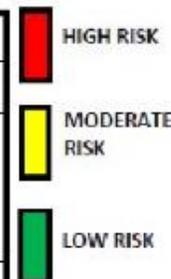
OCTOBER 2023



Likelihood	Safety Estimated likelihood of Safety event occurrence	Technical Estimated likelihood of not meeting performance requirements	Cost Schedule Estimated likelihood of not meeting cost or schedule commitment
5 Very High	$(P_{SE} > 10^{-1})$	$(P_T > 50\%)$	$(P_{CS} > 75\%)$
4 High	$(10^{-2} < P_{SE} \leq 10^{-1})$	$(25\% < P_T \leq 50\%)$	$(50\% < P_{CS} \leq 75\%)$
3 Moderate	$(10^{-3} < P_{SE} \leq 10^{-2})$	$(15\% < P_T \leq 25\%)$	$(25\% < P_{CS} \leq 50\%)$
2 Low	$(10^{-5} < P_{SE} \leq 10^{-3})$	$(2\% < P_T \leq 15\%)$	$(10\% < P_{CS} \leq 25\%)$
1 Very Low	$(10^{-6} < P_{SE} \leq 10^{-5})$	$(0.1\% < P_T \leq 2\%)$	$(2\% < P_{CS} \leq 10\%)$



Consequence Categories					
Risk	1 Very Low	2 Low	3 Moderate	4 High	5 Very High
Safety	Negligible or not impact	Could cause the need for only minor first aid treatment	May cause minor injury or occupational illness or minor property damage	May cause severe injury or occupational illness or major property damage.	May cause death or permanently disabling injury or destruction of property.
Technical	No impact to full mission success criteria	Minor impact to full mission success criteria	Moderate impact to full mission success criteria. Minimum mission success criteria is achievable with margin	Major impact to full mission success criteria. Minimum mission success criteria is achievable	Minimum mission success criteria is not achievable
Schedule	Negligible or no schedule impact	Minor impact to schedule milestones; accommodates within reserves; no impact to critical path	Impact to schedule milestones; accommodates within reserves; moderate impact to critical path	Major impact to schedule milestones; major impact to critical path	Cannot meet schedule and program milestones
Cost	<2% increase over allocated and negligible impact on reserve	Between 2% and 5% increase over allocated and can handle with reserve	Between 5% and 7% increase over allocated and cannot handle with reserve	Between 7% and 10% increase over allocated, and/or exceeds proper reserves	>10% increase over allocated, and/or can't handle with reserves



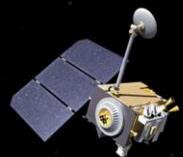


ARTEMIS

Twin sister of Apollo and goddess of the Moon in Greek mythology, Artemis is the torch-bringer personifying our path to the Moon. During the next era of human exploration, we will discover life-saving, Earth-changing science and technology along the way.

NASA's goal is to land the first woman and first person of color on the Moon and return them safely to Earth. When the Artemis astronauts land on the lunar surface, they will step into the future, bringing all of humanity with them.

Artemis: Landing Humans On the Moon



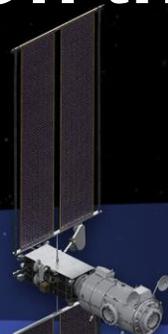
Lunar Reconnaissance Orbiter: Continued surface and landing site investigation



Artemis I: First human spacecraft to the Moon in the 21st century



Artemis II: First humans to orbit the Moon and rendezvous in deep space in the 21st century



Gateway begins science operations with launch of Power and Propulsion Element and Habitation and Logistics Outpost



Artemis III-V: Deep space crew missions; cislunar buildup and initial crew demonstration landing with Human Landing System



Early South Pole Robotic Landings
Science and technology payloads delivered by Commercial Lunar Payload Services providers



Volatiles Investigating Polar Exploration Rover
First mobility-enhanced lunar volatiles survey



Uncrewed HLS Demonstration



Humans on the Moon - 21st Century
First crew expedition to the lunar surface

LUNAR SOUTH POLE TARGET SITE

Artemis: Foundation for Deep Space Exploration



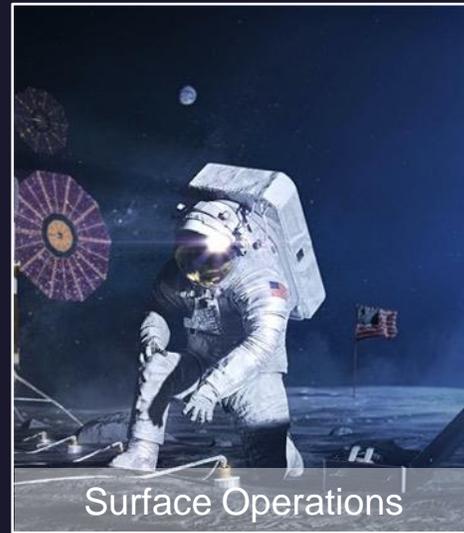
Space Launch System



Orion spacecraft



Human Landing System



Surface Operations



Gateway



Exploration Ground Systems



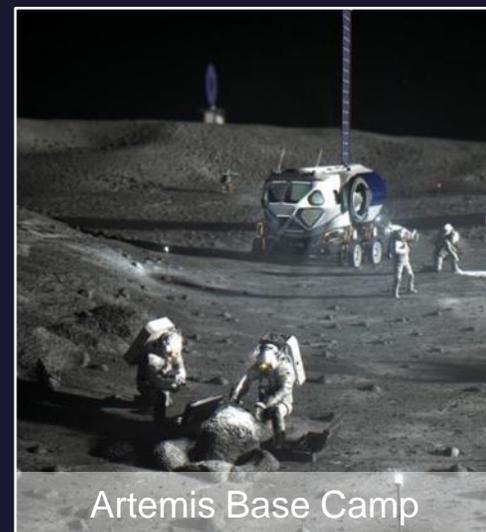
Space Communications & Navigation



Surface Mobility



Space Suits



Artemis Base Camp

Artemis I: 2022

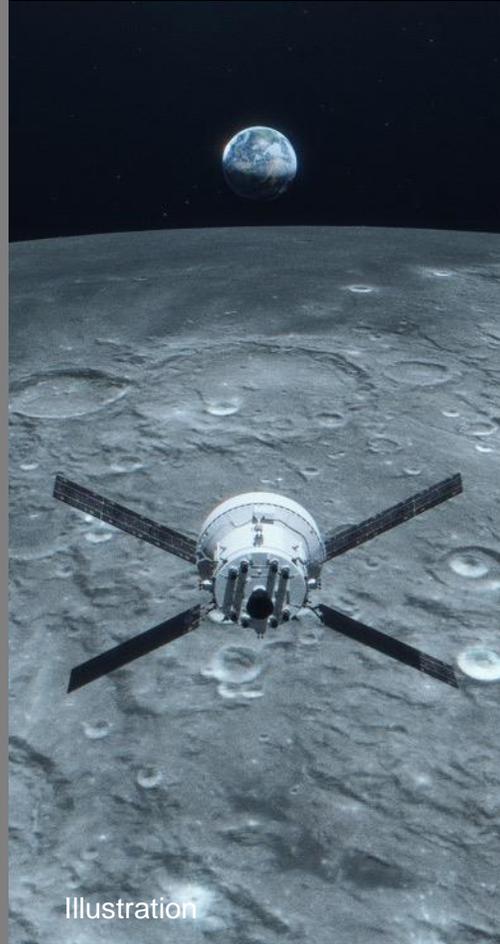
Uncrewed flight test

COMPLETE



Artemis II

Crewed flight test



Illustration

Artemis III

Crewed surface expedition



Illustration

Artemis IV

*Gateway assembly,
crewed sustaining
lander expedition*



Illustration

Artemis V

*Crewed mobile
surface exploration,
Gateway expansion*



Illustration

SLS, Orion, EGS

SLS, Orion, EGS

SLS, Orion, EGS, HLS

SLS, Orion, EGS,
HLS, Gateway
(PPE/HALO, I-HAB)

SLS, Orion, EGS,
HLS, LTV, Gateway
(ESPRIT, Canadarm3)

Why Artemis?

VALUABLE LUNAR SCIENCE



Study of Planetary Processes



Understanding Volatile Cycles



Impact History of Earth-Moon System



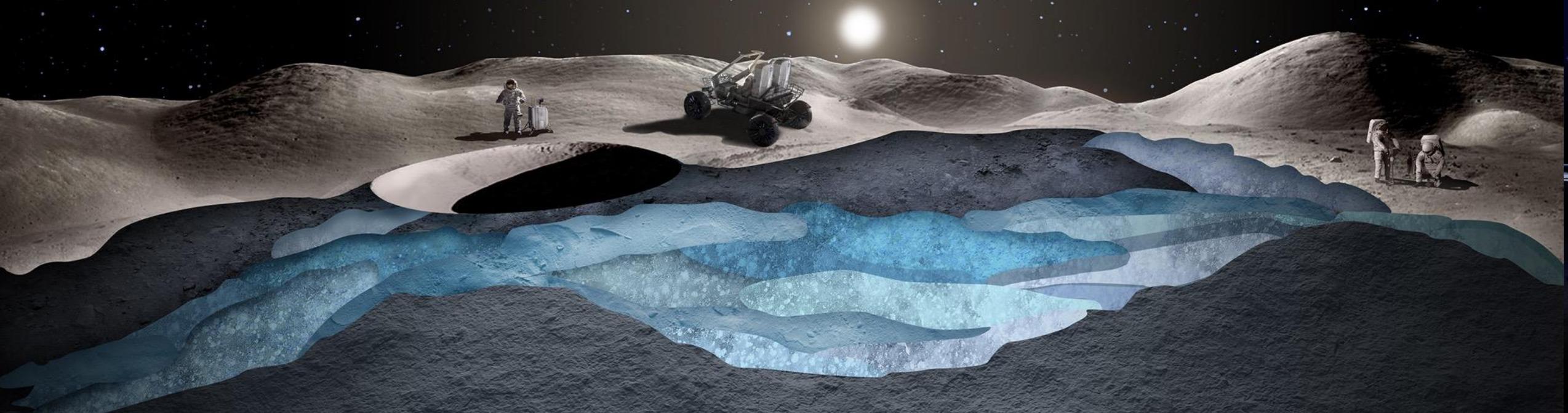
Record of the Ancient Sun



Fundamental Lunar Science

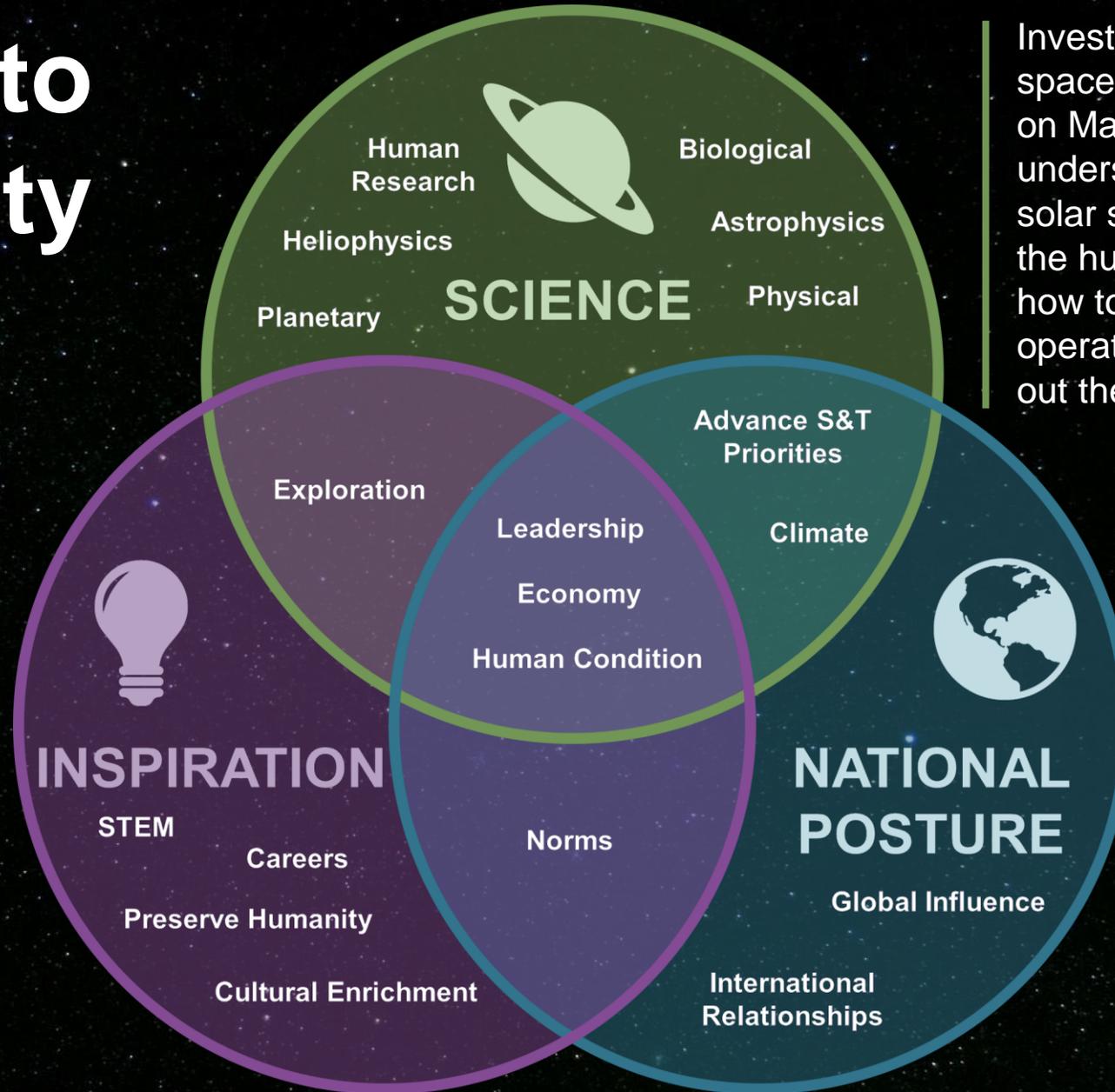


Platform to Study the Universe



LUNAR SURFACE SCIENCE OBJECTIVES

Benefits to Humanity



Investigations in deep space, on the Moon, and on Mars will enhance our understanding of the solar system, the Earth, the human body, and how to perform new operations while we are out there exploring.

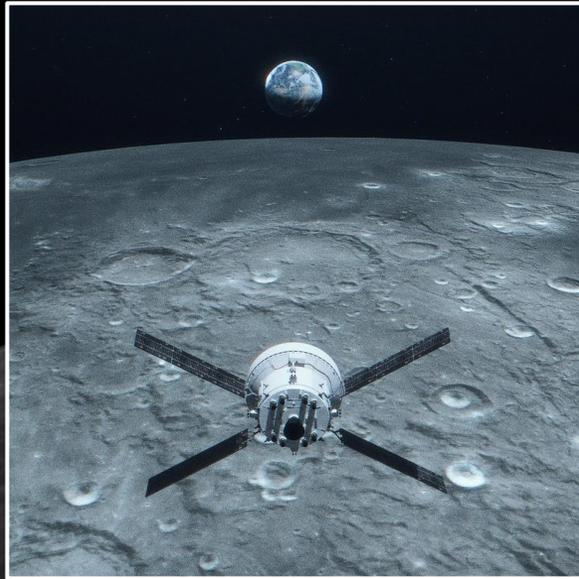
Accepting audacious challenges and succeeding through perseverance and tenacity in the face of adversity motivates current and future generations to dare mighty things.

What we choose to do, how we do those things, and who we do them with greatly impacts our place in the world today, our quality of life, and our possibilities for the future.

Lunar Exploration Architecture



TRANSPORTATION



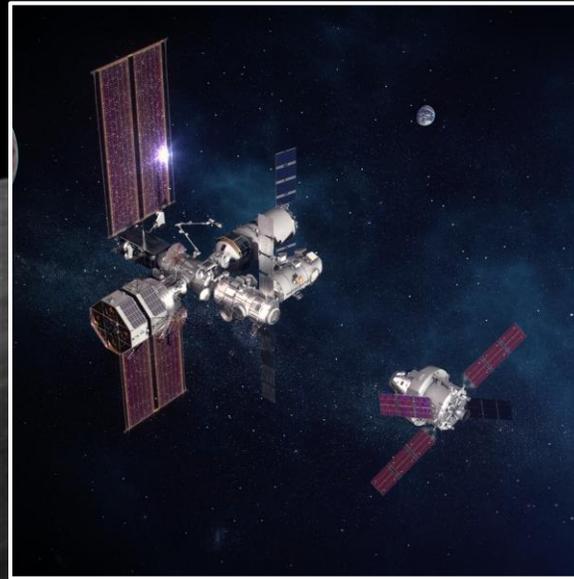
IN
SPACE

SLS
Orion
Commercial Launch Providers

ON
SURFACE

Human Landing System
Lunar Terrain Vehicle
Pressurized Rover

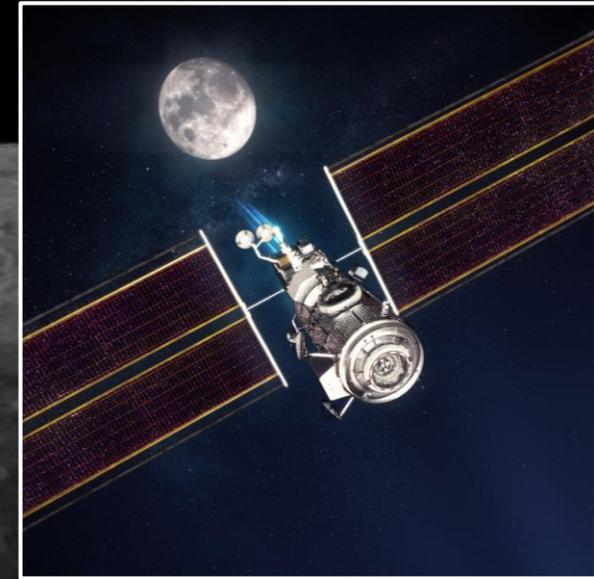
HABITATION & LIFE SUPPORT



Orion
Gateway HALO
Gateway I-Hab

Human Landing System
Spacesuits
Surface Habitat
Pressurized Rover

INFRASTRUCTURE



PPE: Comm and Power
Deep Space Logistics Deliveries
LunaNet

Fission Surface Power
Logistics and Science Deliveries

NASA's Exploration Campaign & Segments

HUMAN PRESENCE IN LEO

PARTNER ENABLED

HUMAN LUNAR RETURN

SUSTAINED LUNAR PRESENCE PARTNER ENABLED

HUMANS TO MARS



GATEWAY

Increased Crew Size & Longer Durations in Micro-gravity

TRANSIT HABITAT AND MARS TRANSIT

COMMUNICATIONS RELAYS



HUMAN LANDING SYSTEM

SURFACE UTILITIES

SURFACE HABITAT

LOGISTICS LANDER

Fission Surface Power

Habitation Systems

Mobile Expedition Duration / Mobile Exploration Range

Partial Gravity Operations

In-Situ Resource Utilization

Autonomous Robotics Systems & Contingency Crew Transportation

MARS ASCENT VEHICLE

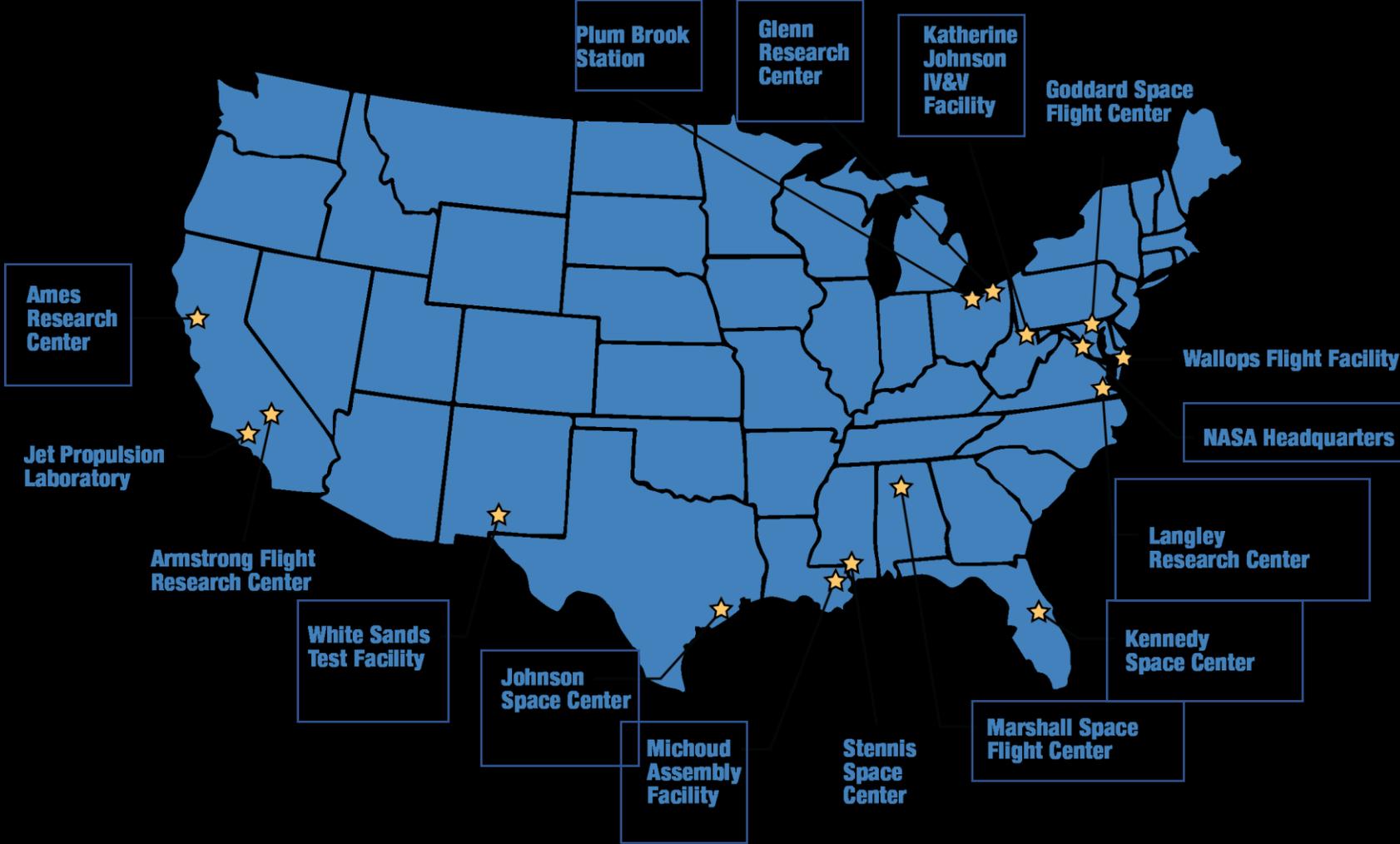
PRESSURIZED ROVER

LUNAR TERRAIN VEHICLE

PRESSURIZED ROVER

MARS TERRAIN VEHICLE

Key Artemis Contributions by NASA Centers



EGS





ORION

GATEWAY



ARTEMIS BASE CAMP

Comm, Nav, Power >>

Surface Habitat >>

>> In-Situ Resource Utilization (ISRU)

Pressurized Rover >>

Spacesuits >>

Lunar Terrain Vehicle >>



Artist's illustration of Artemis Base Camp

Orion on the Pad

June 14, 2022 / KSC



Mission Needs Drive Design



LOW EARTH RETURN

3 HOURS

3,000°F

17,500 MPH

250 MILES



LUNAR RETURN

3 DAYS

5,200°F

24,700 MPH

240,000 MILES



MARS RETURN

9 MONTHS

6,200°F

26,800 MPH

39,000,000 MILES



Orion Quick Facts

Performance

Number of crew 4

Mission Duration up to 21 days

Trans-Lunar Insertion Mass

Artemis I 53,000 lbs.

Artemis II 58,000 lbs.

Gross Liftoff Weight

Artemis I 72,000 lbs.

Artemis II 78,000 lbs.

Height

Crew module + service module 26 ft.

Orion stack (launch abort system + crew module + service module) 67 ft.

SLS Block 1 Configuration (Orion + SLS stack) 322 ft.

Post-Trans Lunar Insertion Mass

Artemis I 51,500 lbs.

Artemis II 57,000 lbs.

Usable Propellant 19,000 lbs.

Total Change in Velocity (ΔV) with Fully Loaded Propellant Tank

Artemis I 53,000 lbs.

Artemis II 58,000 lbs.

ORION'S PATH TO HUMAN SPACE EXPLORATION

Pad Abort
LAS performance

Orion Crew Module test
4.5 hours
3,600 mi altitude
20,000 mph reentry

Ascent Abort
LAS performance

Uncrewed Integrated Vehicle test
25.5 days
1.4M miles
Lunar DRO orbit
25,000 mph reentry

Crewed Integrated Vehicle test
10 days
RPO
Lunar fly-by

Crewed
Lunar lander docking
Lunar landing and return

Crewed
Gateway docking
Comanifest payload
Lunar landing and return

2010

2014

2019

2022

COMPLETE

COMPLETE

COMPLETE

COMPLETE



PA-1

EFT-1

AA-2

Artemis I

Artemis II

Artemis III

Artemis IV

Artemis V

Artemis VI

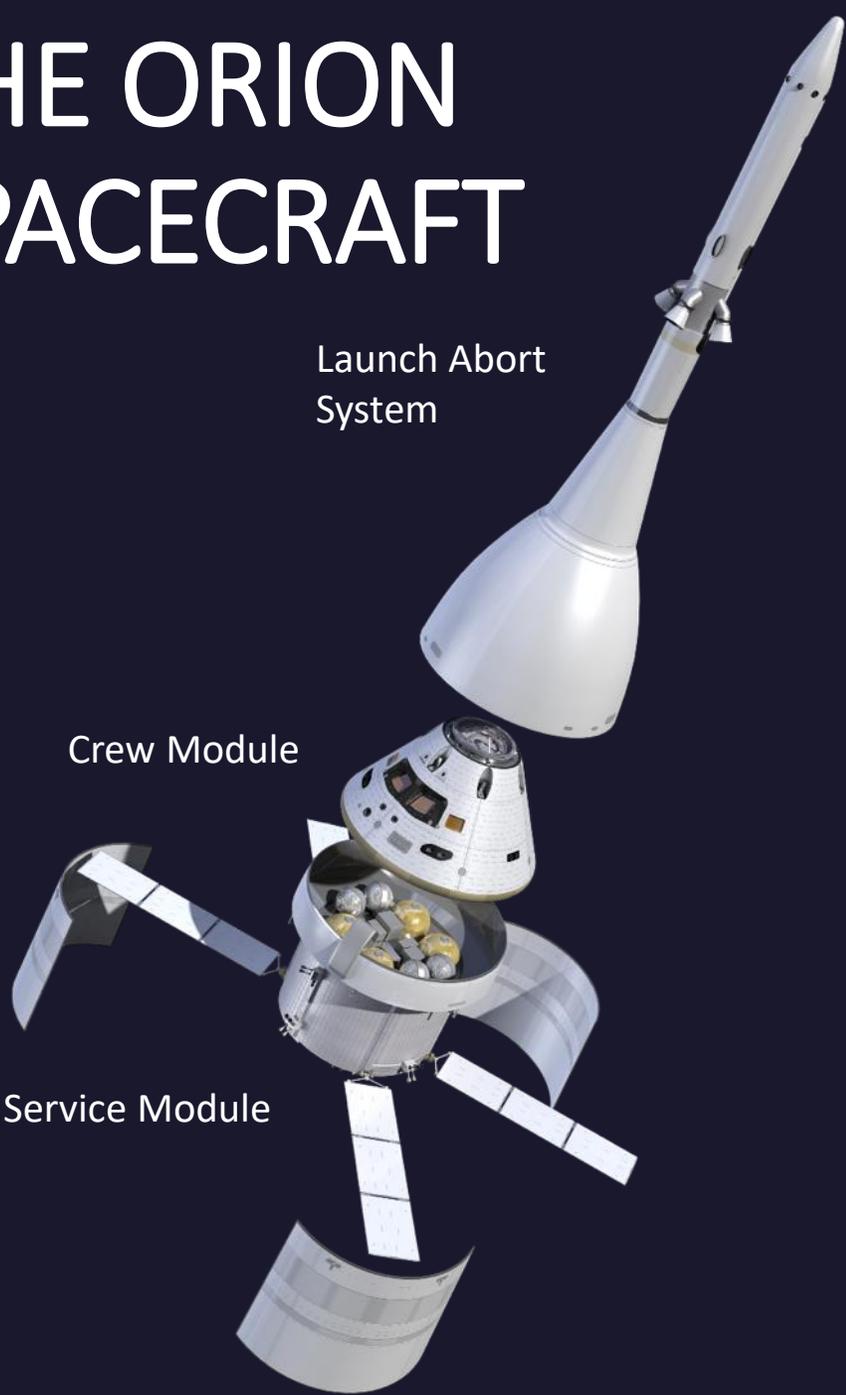
THE ORION SPACECRAFT



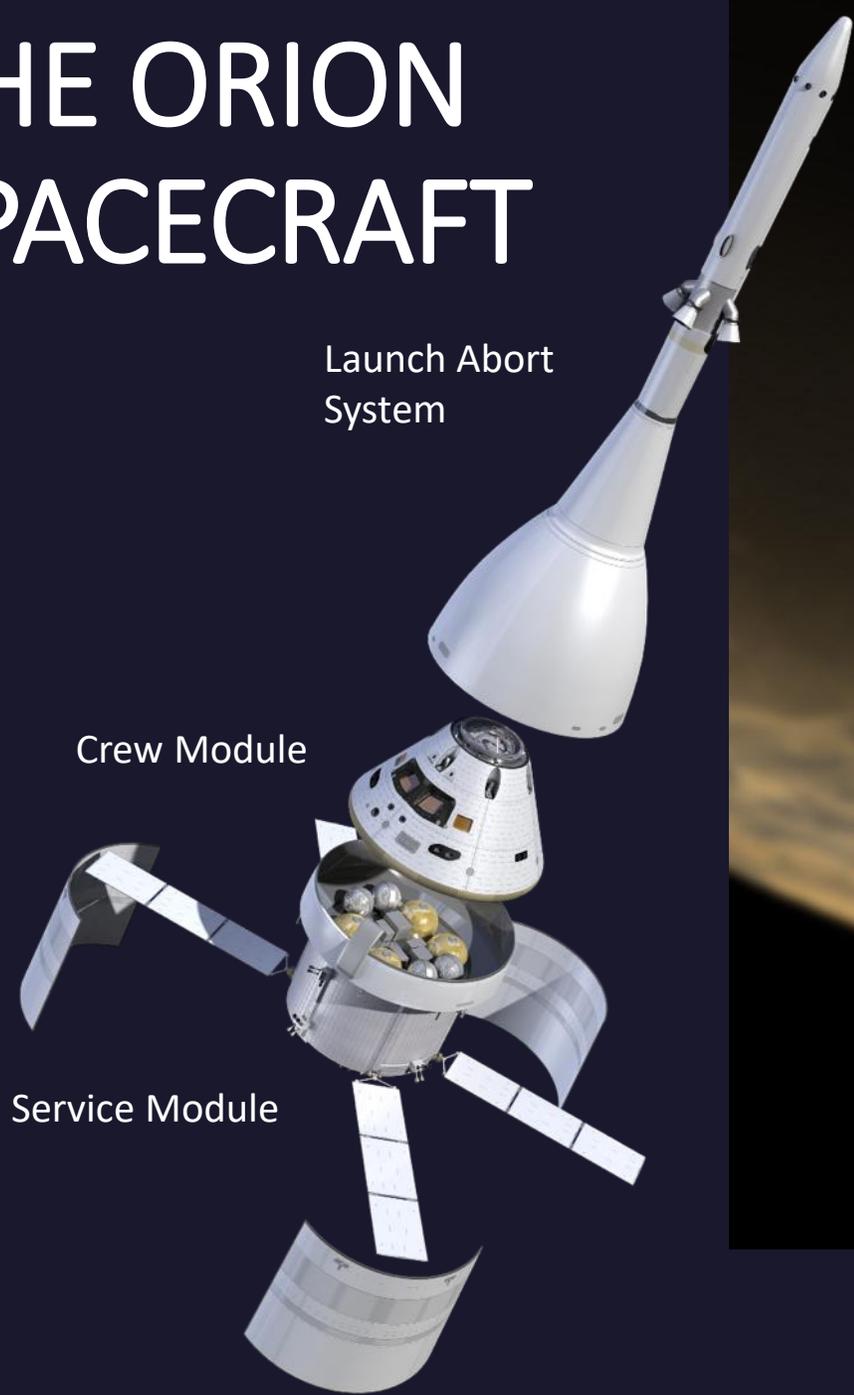
Launch Abort
System

Crew Module

Service Module

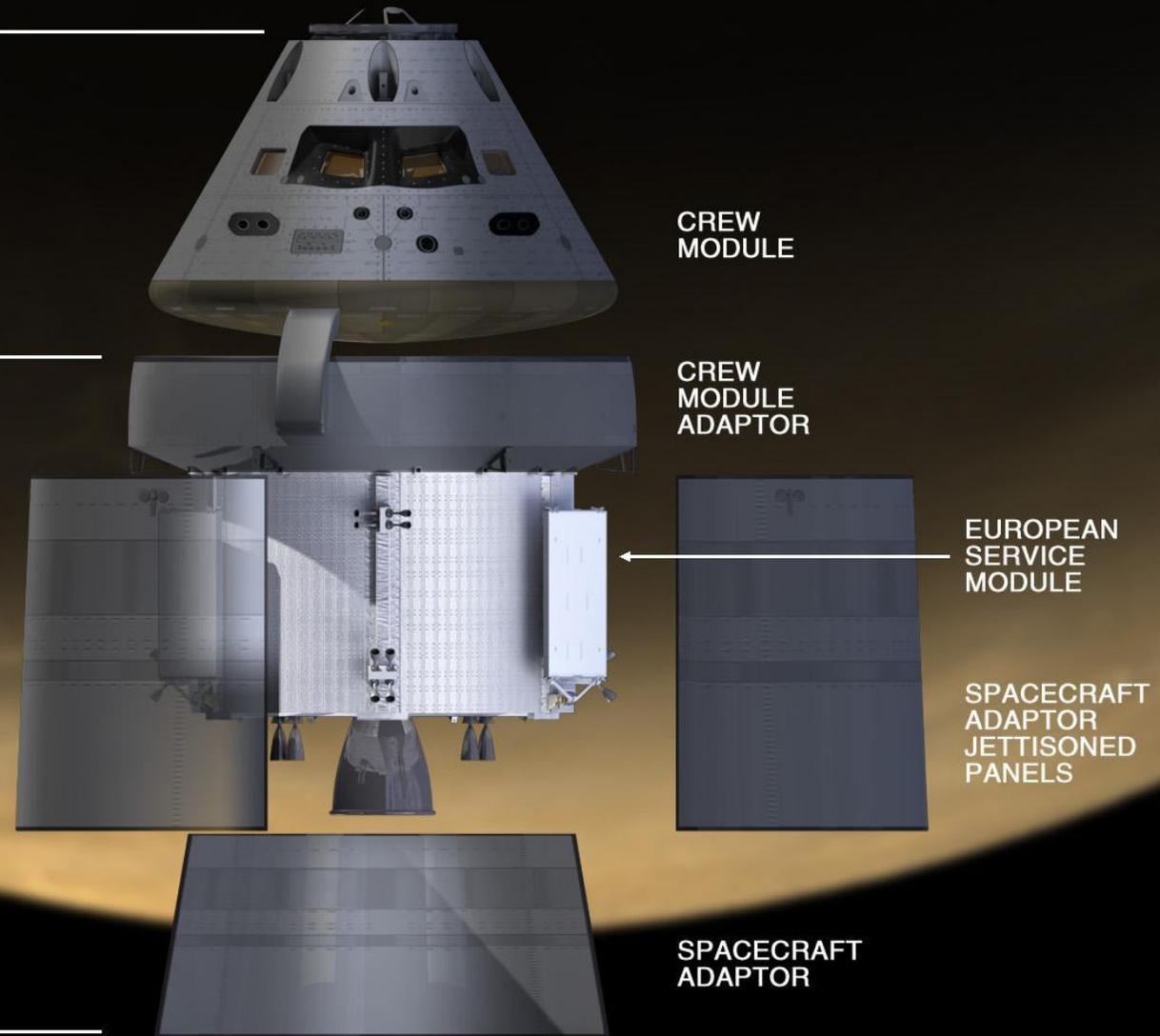


THE ORION SPACECRAFT



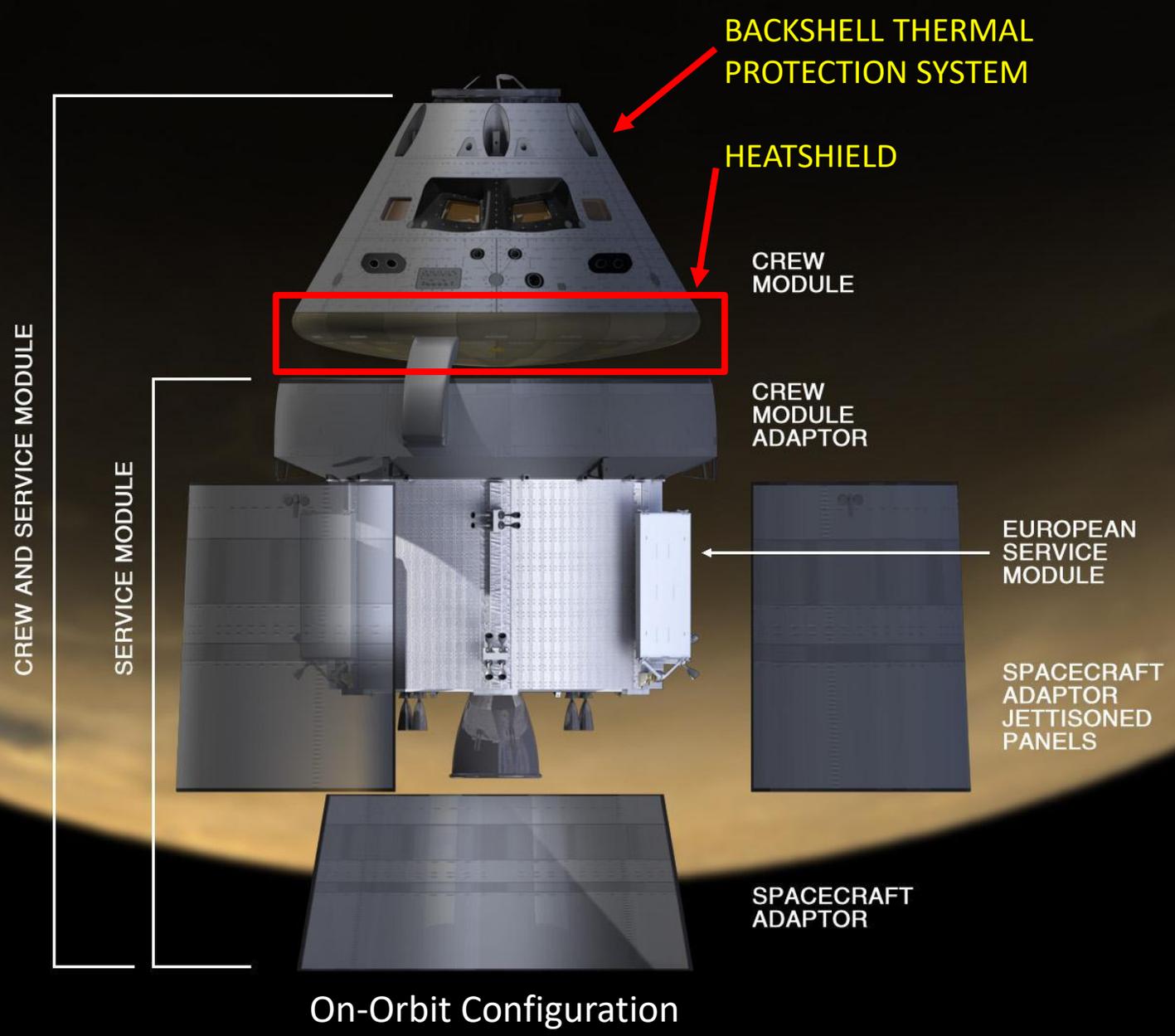
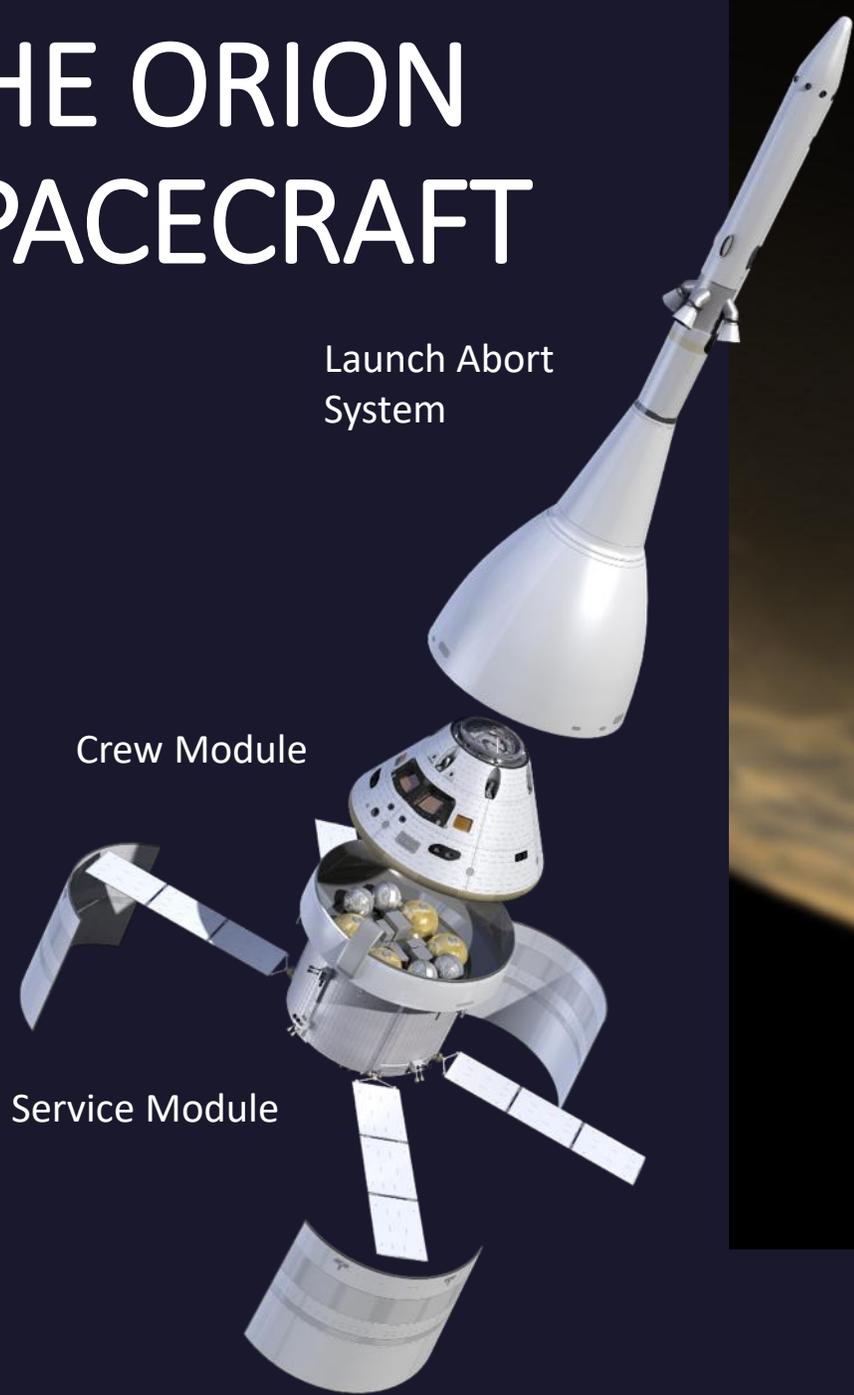
CREW AND SERVICE MODULE

SERVICE MODULE



On-Orbit Configuration

THE ORION SPACECRAFT



ARTEMIS I HIGHLIGHTS

22% more power generated than predicted

~25% less power consumption than predicted

1.4M total miles traveled

~155 GB of data downlinked

~38,000 commands uplinked

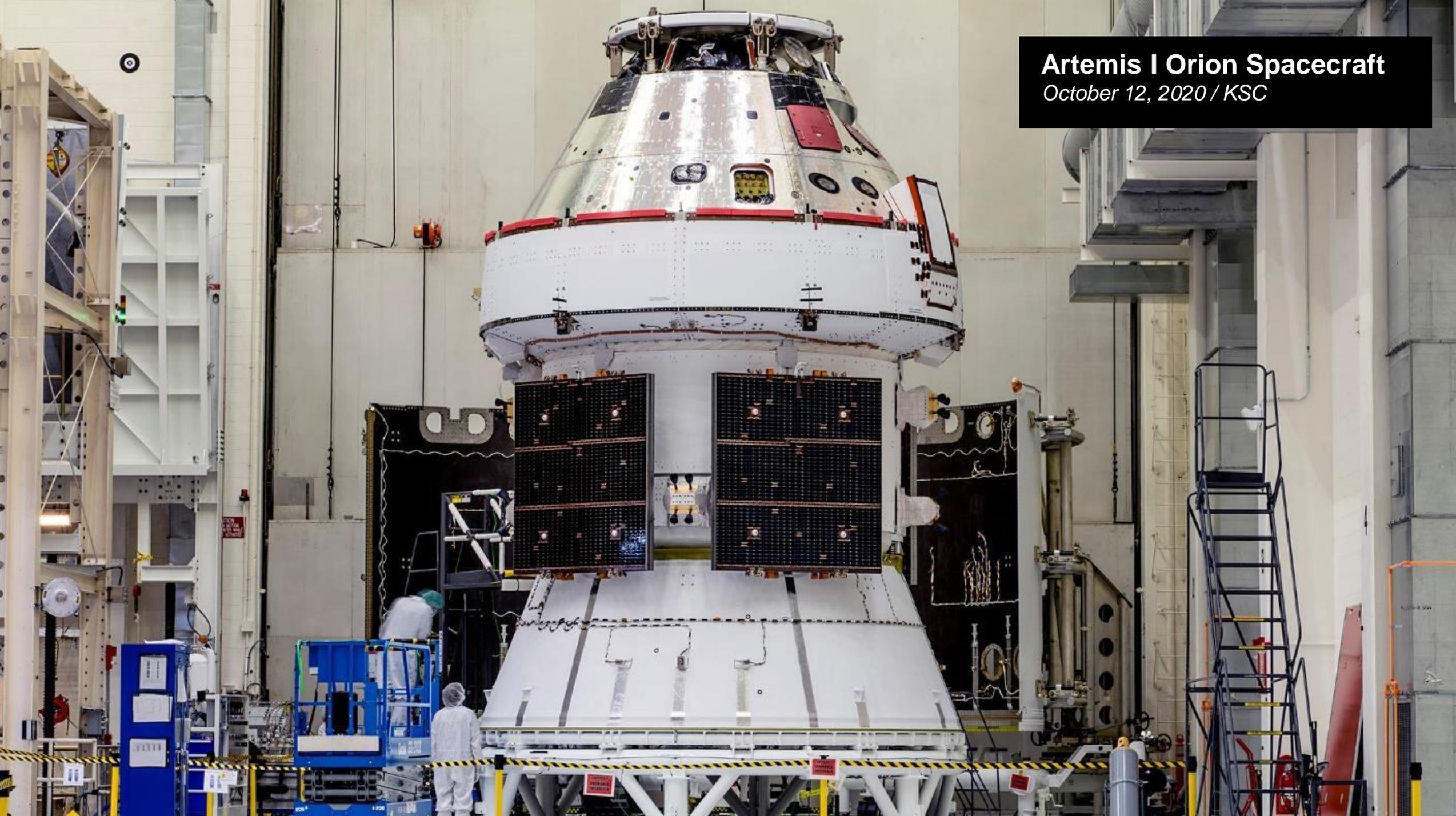
161 total FTOs/DFTOs with 21 new test objectives added mid flight

Splashdown 2.4 miles from target



Artemis I Orion Spacecraft

October 12, 2020 / KSC





Flight Day 1

<u>Velocity</u>	
0 mph	0 km/h
<u>Distance from the Moon</u>	
240,122 mi	386,440 km

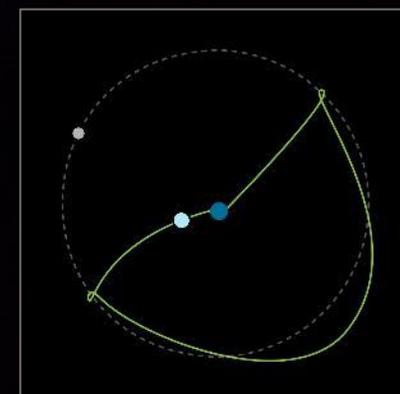


Flight Day 1 / Nov 16

Earth: 58,000 mi / 93,340 km

Moon: 203,524 mi / 330,760 km

Velocity: 5,448 mph / 8,770 kmh





Flight Day 13 / Nov 28

Earth: 268,565 mi / 432,213 km

Moon: 43,471 mi / 69,960 km

Velocity: 1,674 mph / 2,694 kmh



REENTRY



CALLISTO TECH-DEMO

LOCKHEED MARTIN alexa webbox



NASA

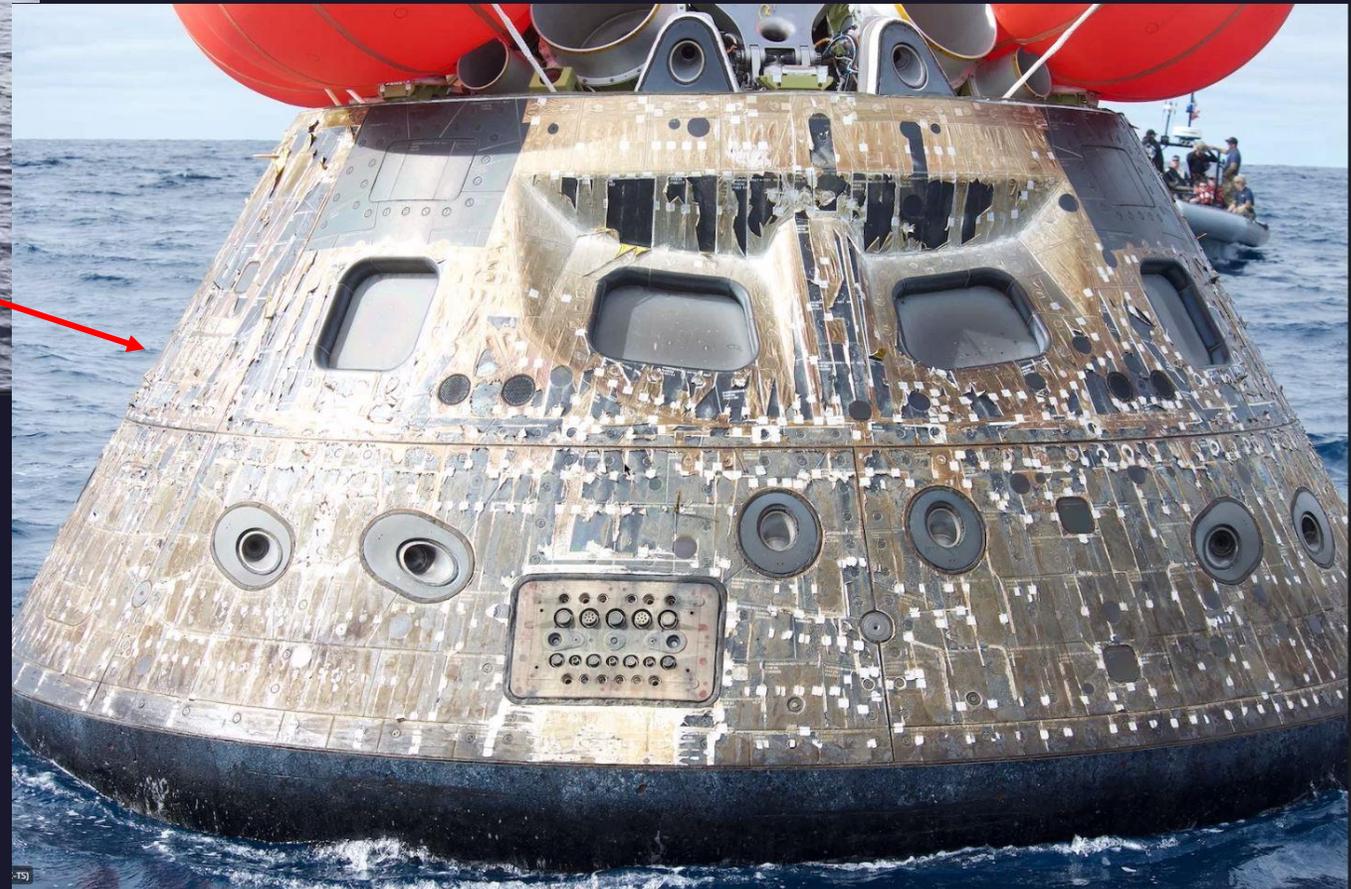
NASA

10 X SPEED



ARTEMIS-1 Successes!

SUCCESSFUL RECOVERY IN THE PACIFIC OCEAN



<https://youtu.be/gofbEjjN8gg>

NEW *for* **ARTEMIS II**

10-day mission

Free return trajectory

24 hour high-Earth orbit to ensure Orion's systems are working as expected

Proximity operations demonstration of spacecraft and manual handling qualities

Closest lunar flyby of 4,000 nmi (7,400 km) from the surface

Crew displays and controls

Environmental control and life support systems

Orion Crew Survival System (OCSS) Suits

Universal Waste Management System

New FTOs/DFTOS including first-time operations of unique crew subsystems, evaluation of emergency procedures/protocols, manual control capabilities, etc.





ARC Technical Support Areas

Crew Service Module (CSM) : TS, Analysis, and Support



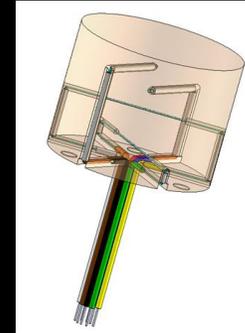
Heatshield testing, system analysis, recovery and post flight support



Backshell testing, analysis recovery and post flight support

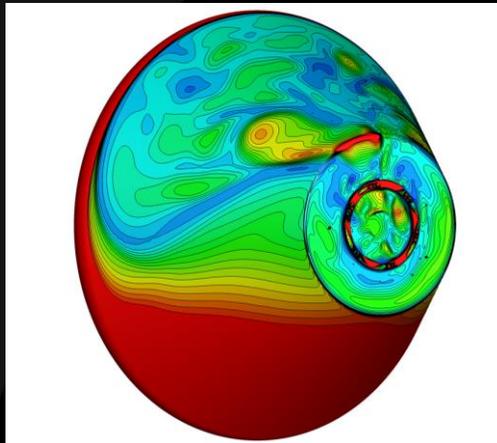


Arcjet testing

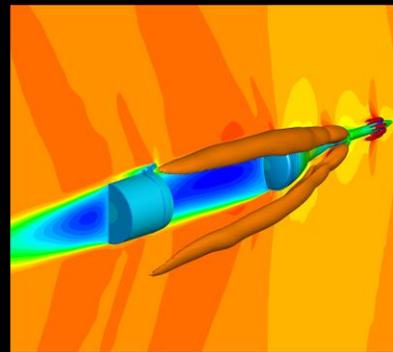


TPS Development Flight Instrumentation (DFI)

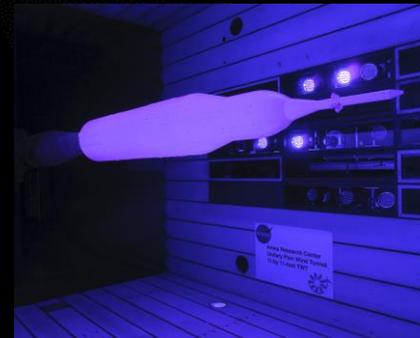
Vehicle



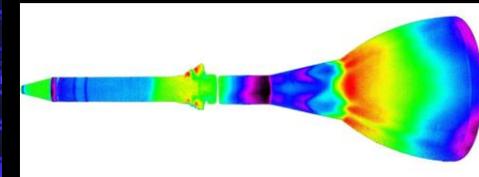
Aerothermal environment and Aerothermal database generation



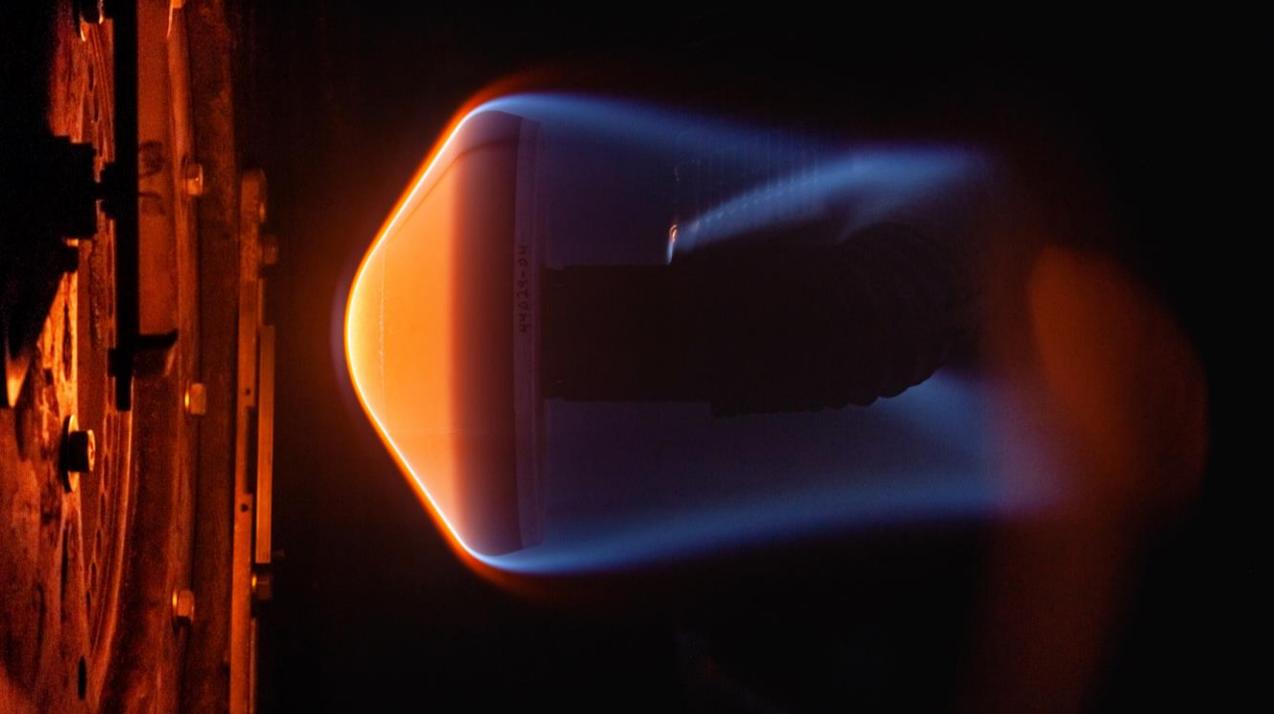
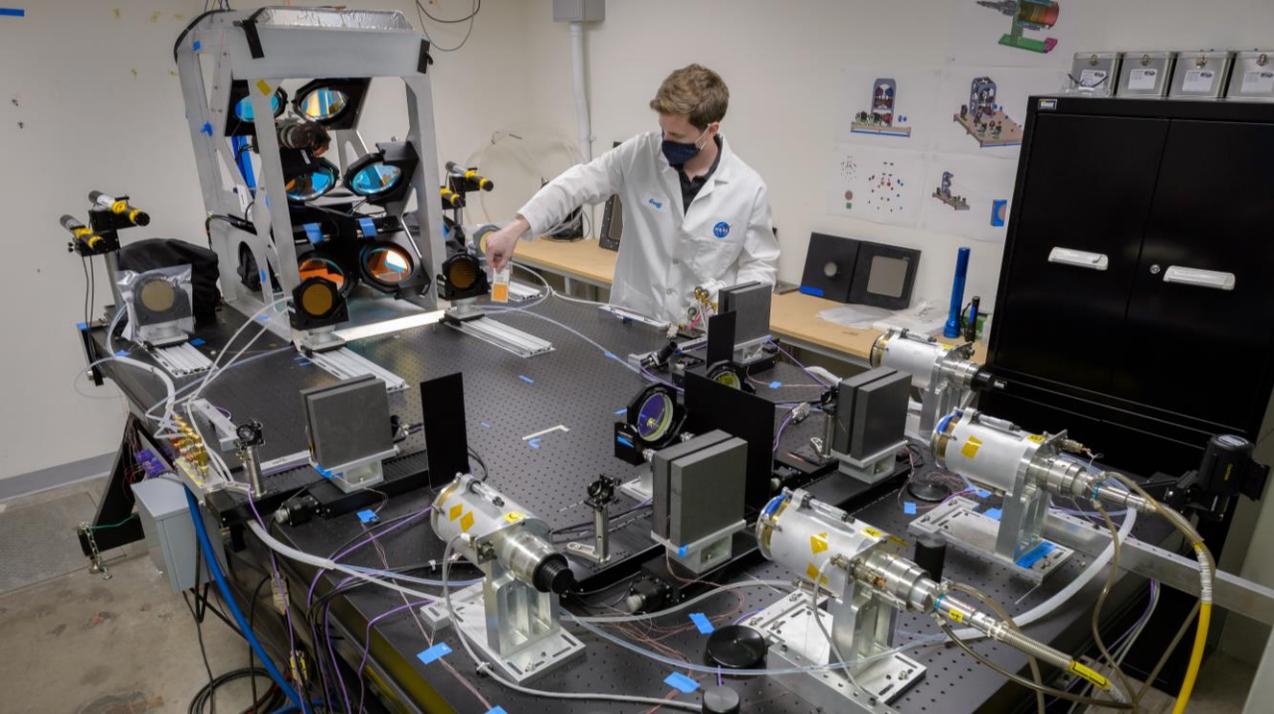
Vehicle Aerodynamics, wind tunnel test support and aero database



wind tunnel testing



Launch abort environments, acoustics and vibrations



ARTEMIS



QUESTIONS?

BACKUP

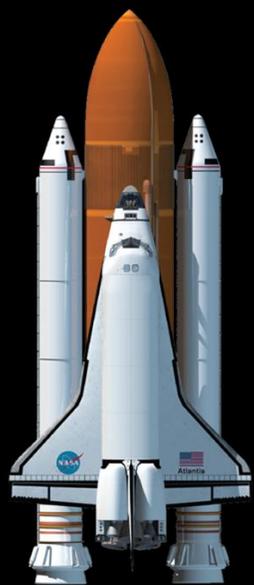
OPPORTUNITY

Artemis missions **enable a growing lunar economy** by fueling new industries, supporting job growth, and furthering the demand for a skilled workforce.

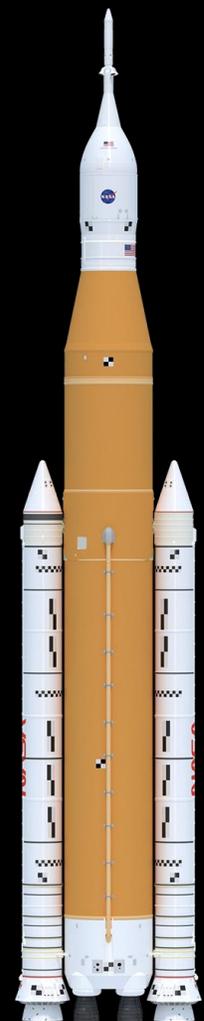




STATUE OF LIBERTY
305 ft.



SPACE SHUTTLE
184 ft.



SLS / ORION Block I
322 ft.



SLS / ORION Block II
364 ft.



SATURN 5
363 ft.

SOLAR ARRAY WING DEPLOYMENT