Kennedy Space Center's Chemistry Research

for Human Exploration of the Solar System

National Aeronautics and Space Administration

Luke Roberson, Ph.D

Senior Principal Investigator, Swamp Works/UB-G

NASA Kennedy Space Center, FL

ARTEMIS

Presented to the
University of Wisconsin - Eau Claire
March 5, 2021

Career/Education Background

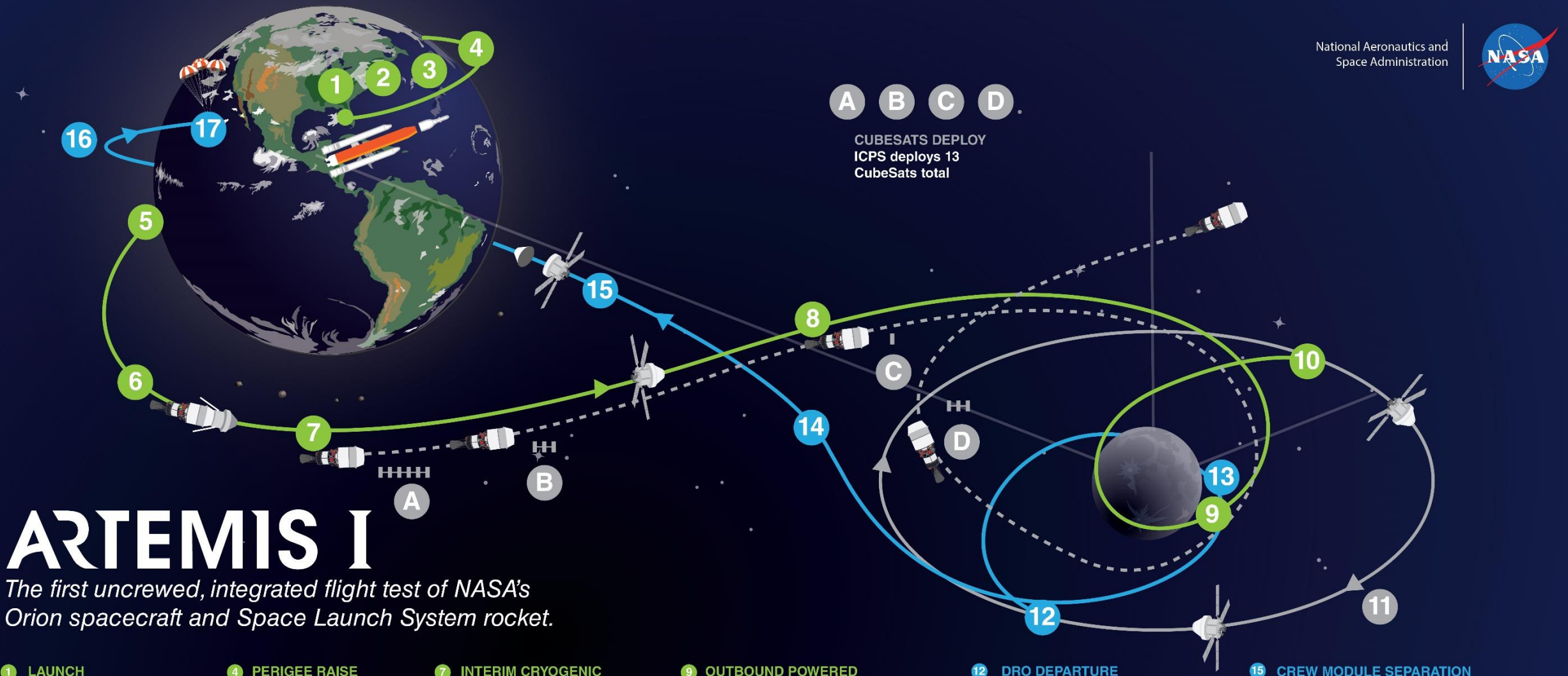
- **Graduate form Georgia Tech**
  - 1999 Bachelors – Polymer Chemistry
  - 2002 Masters – Organic Chemistry
  - 2005 PhD – Materials Chemistry
- **Graduate from the International Space University**
  - 2011 – Space Studies Program
- **15+ years with NASA at Kennedy Space Center in R&D**
- **Currently Senior Principal Investigator for Exploration Research and Technology**
- **Spent 3 years as a payload developer for VEGGIE, APH, and BRIC**

The Artemis Program

Artemis is the twin sister of Apollo and goddess of the Moon in Greek mythology. Now, she personifies our path to the Moon as the name of NASA's program to return astronauts to the lunar surface.

When they land, Artemis astronauts will step foot where no human has ever been before: the Moon's South Pole.

With the horizon goal of sending humans to Mars, Artemis begins the next era of exploration.



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**
The ICPS has committed Orion to 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 for next 6-23 days.

11 **DISTANT RETROGRADE ORBIT**
Perform half or one and a half revolutions in the 12 day orbit period 38,000 nmi from the surface of the Moon.

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

13 **RETURN POWER FLY-BY (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; travel time 5-11 days.

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.

3/1/2021

ARTEMIS 1 (Formerly EM-1)

Artemis-1 will fly beyond the Moon and back to Earth, taking about three weeks in total.

National Aeronautics and Space Administration

NASA

ARTEMIS II

Crewed Hybrid Free Return Trajectory, demonstrating astronaut flight and spacecraft systems performance beyond Low Earth Orbit.

ICPS Earth disposal

Prox Ops Demonstration

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 42 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**
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**
    Astronaut and capsule recovery by U.S. Navy ship.

PROXIMITY OPERATIONS DEMONSTRATION SEQUENCE


ARTEMIS II

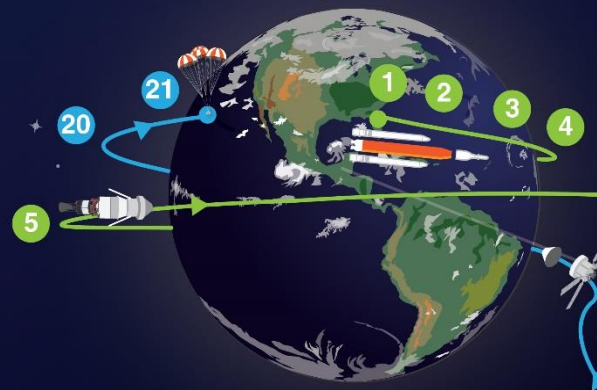

Mode Norm
RHC Pwr: On
Pitch
Yaw
Roll
Switch 1 Auto
Switch 2
Switch 3
Switch 4
THC Pwr: On
X
Y
Z
PB 1
PB 2
Survival Pyros
Pyro Master Arm
CM Prop Act
CM/SM Sep
Drogue Deploy
Main Deploy
Upright Deploy Riser Cut
Survival RCS
Translate
CAUTION
NASA

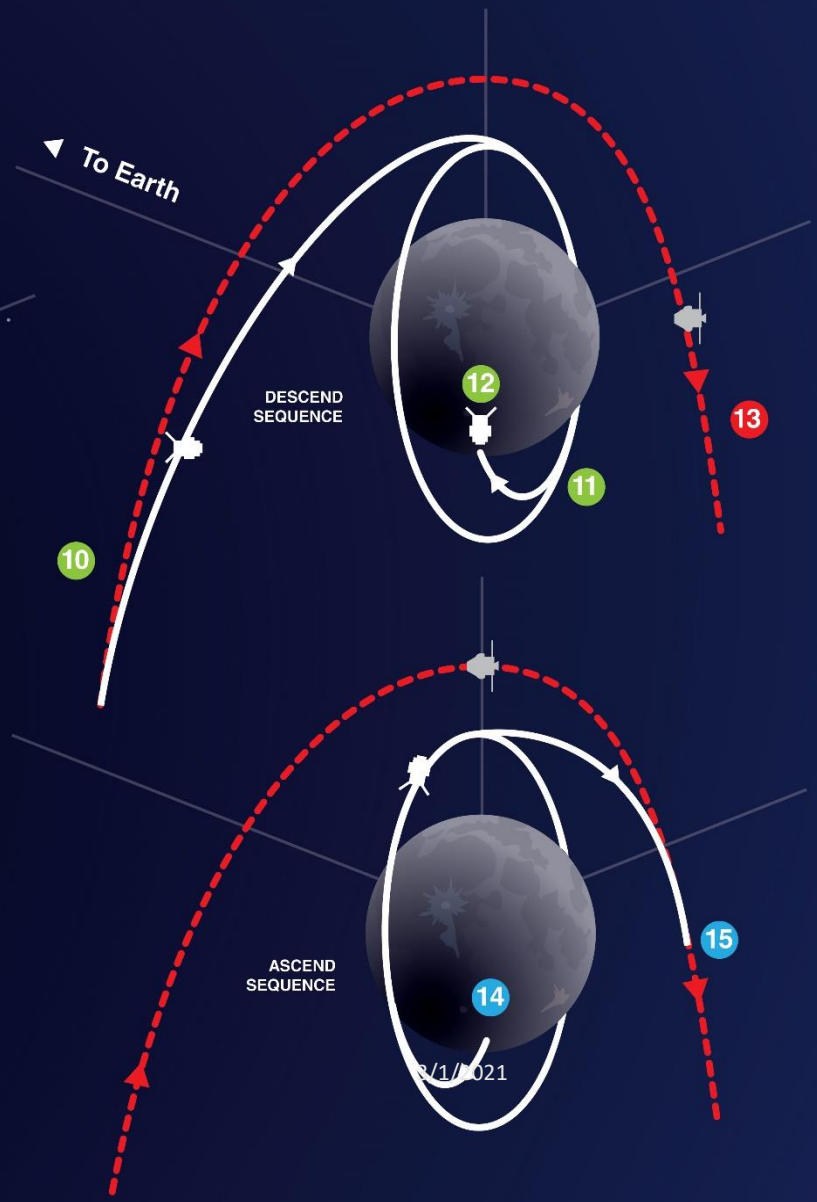
National Aeronautics and Space Administration

NASA

ARTEMIS III

Landing on the Moon



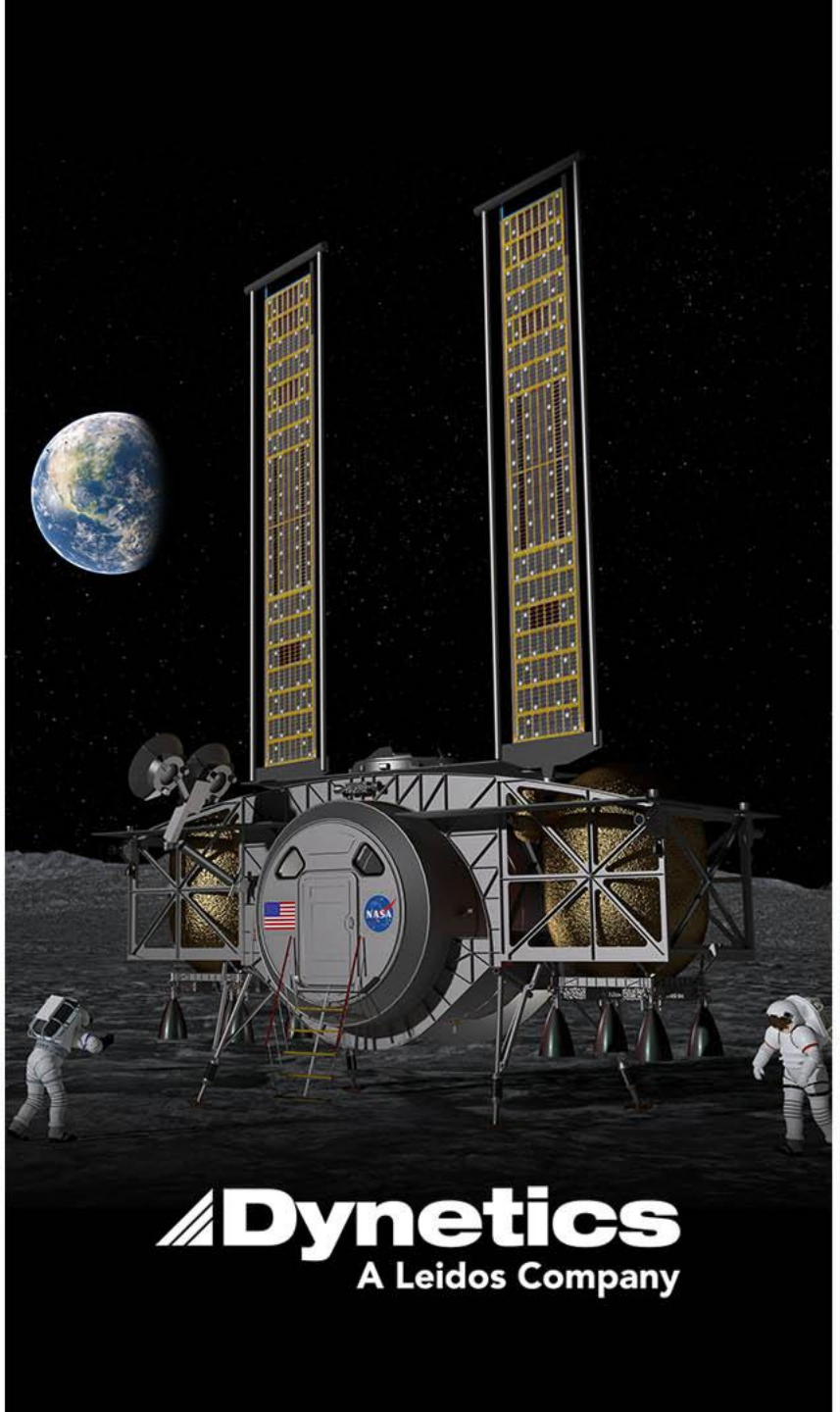


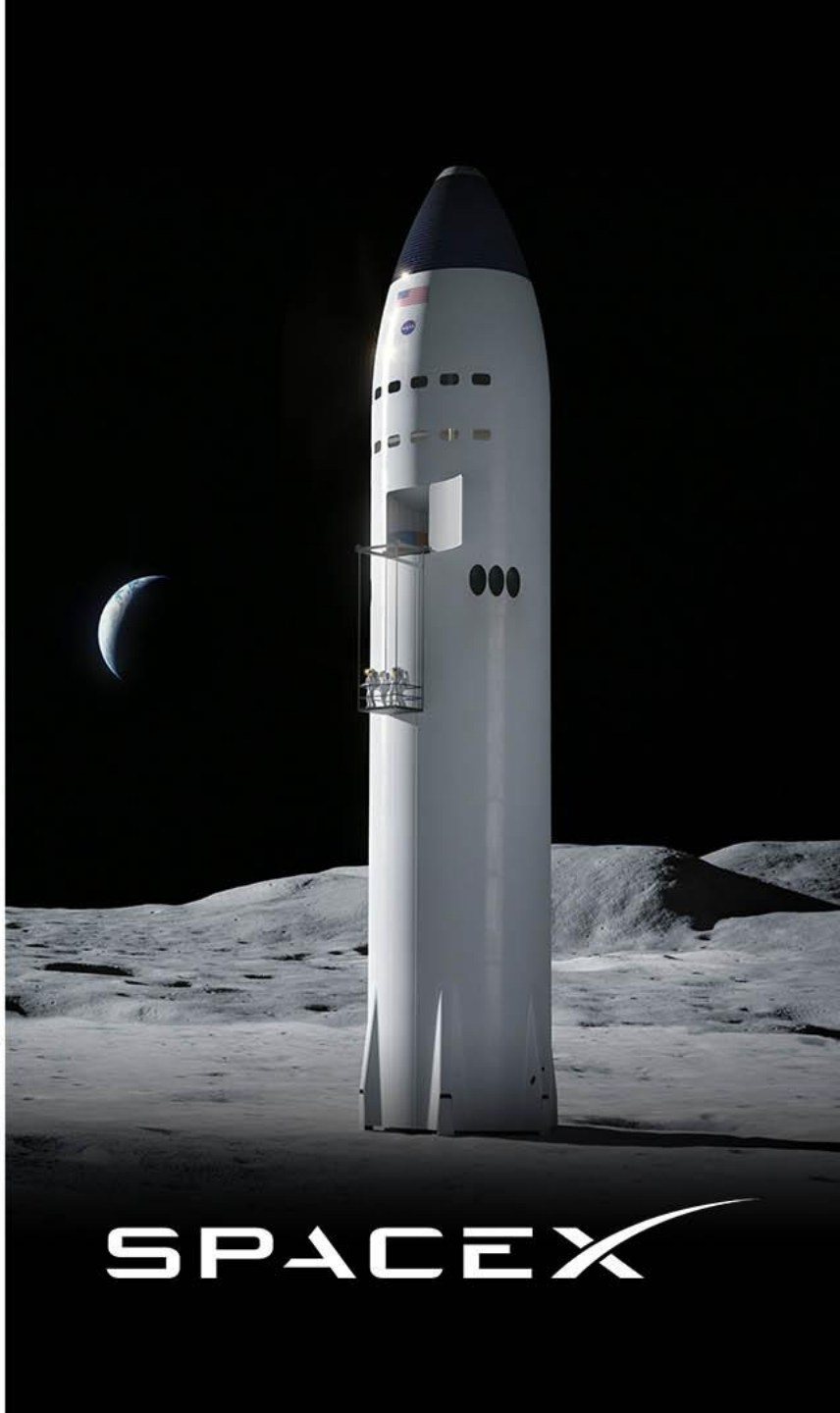
1. **LAUNCH**
   SLS and Orion lift off from Kennedy Space Center.
2. **JETTISON ROCKET BOOSTERS, FAIRINGS, AND LAUNCH ABORT SYSTEM**
3. **CORE STAGE MAIN ENGINE CUT OFF**
   With separation.
4. **ENTER EARTH ORBIT**
   Perform the perigee raise maneuver. Systems check and solar panel adjustments.
5. **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 burns.
7. **ORION OUTBOUND POWERED FLYBY**
   60 nmi from the Moon.
8. **NHRO ORBIT INSERTION BURN**
   Orion performs burn to establish rendezvous point and executes rendezvous and docking.
9. **LUNAR LANDING PREPARATION**
   Crew activates lander and prepares for departure.
10. **LANDER UNDOCKING AND SEPARATION**
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. **ORION REMAINS IN NHRO ORBIT**
    During lunar surface mission.
14. **LANDER ASCENDS LOW LUNAR ORBIT**
15. **LANDER PERFORMS RENDEZVOUS AND DOCKING**
16. **CREW RETURNS IN ORION**
    Orion undocks, performs orbit departure burn.
17. **ORION PERFORMS RETURN POWERED FLYBY**
    60 nmi from the Moon.
18. **FINAL RETURN TRAJECTORY CORRECTION (RTC) BURN**
    Precision targeting for Earth entry.
19. **CREW MODULE SEPARATION FROM SERVICE MODULE**
20. **ENTRY INTERFACE (EI)**
    Enter Earth's atmosphere.
21. **SPLASHDOWN**
    Astronaut and capsule recovery by U.S. Navy ship.


ARTEMIS III

THE HUMAN LANDING SYSTEM

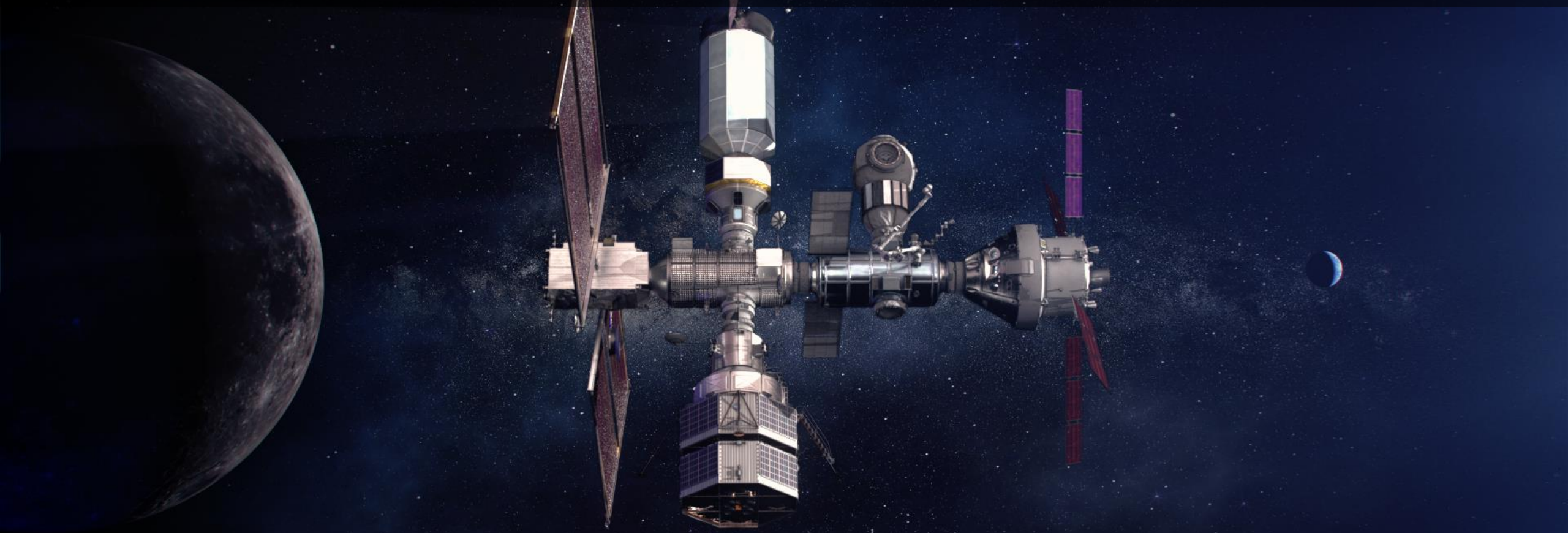

BLUE ORIGIN
LOCKHEED MARTIN
NORTHROP GRUMMAN
DRAPER


Dynetics
A Leidos Company


SPACEX

Gateway International Partners

Building on ISS partnerships to expand deep space capabilities



NASA

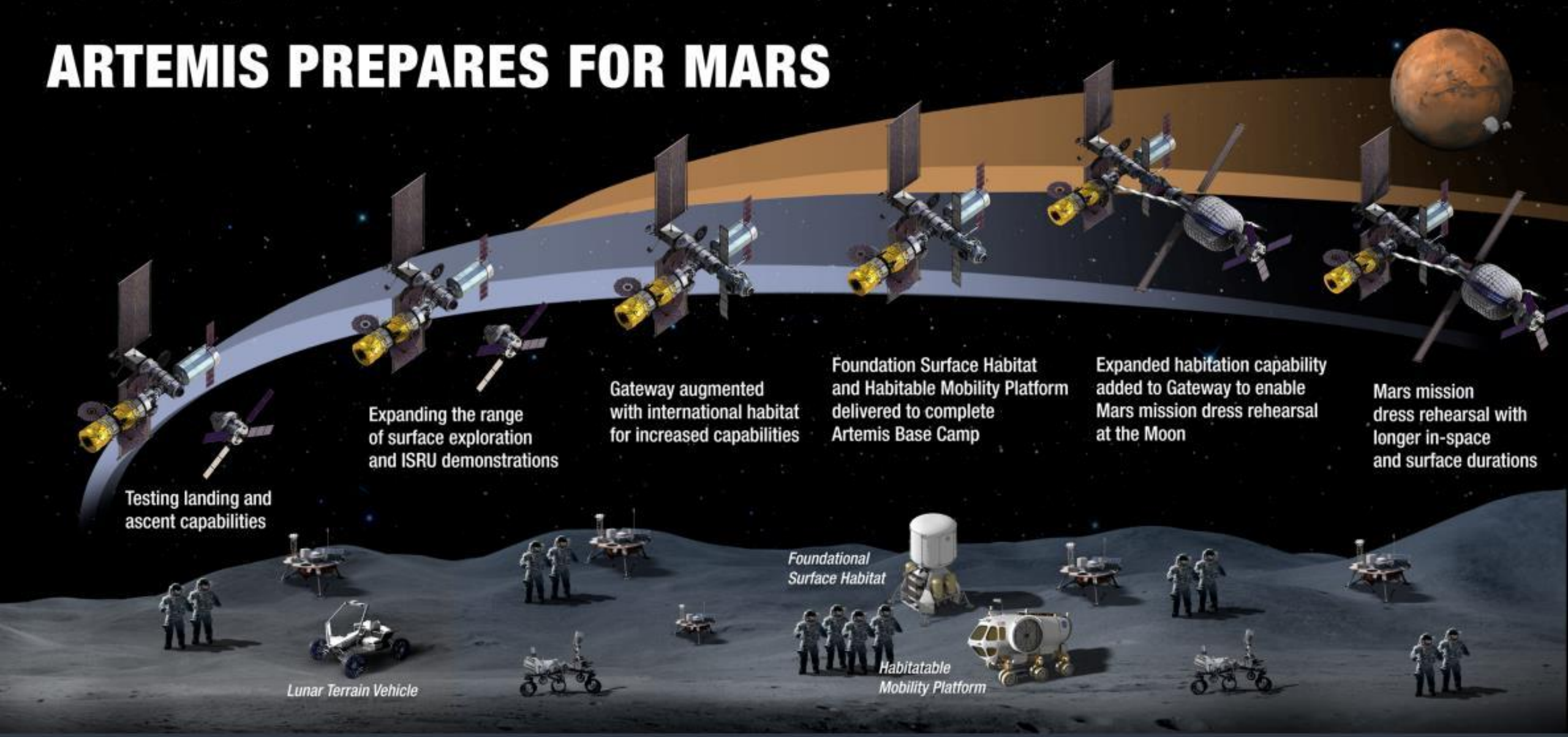
CSA ASC

esa European Space Agency

JAXA

ROSCOSMOS

ARTEMIS PREPARES FOR MARS



SUSTAINABLE LUNAR ORBIT STAGING CAPABILITY AND SURFACE EXPLORATION

MULTIPLE SCIENCE AND CARGO PAYLOADS | INTERNATIONAL PARTNERSHIP OPPORTUNITIES | TECHNOLOGY AND OPERATIONS DEMONSTRATIONS FOR MARS

PREPARING KSC FOR THE FUTURE

Transforming the Kennedy Space Center
for new rockets and spacecraft.

EGS PATH TO ARTEMIS I

LVSA Arrival to KSC

Boosters Arrival to KSC

ICPS Arrival to SSPF

Orion Handover

RPSF Processing

Booster Stacking on the ML

Booster Integration

Core Stage Handover

LVSA/ICPS Integration

Core Stage Integration

SLS/Orion Integration with Launch Vehicle

Vehicle ITCO

Vehicle Modal Testing

Wet Dress Rehearsal

Roll Out for Launch

OUR HEAVY ROCKET: SLS

The Space Launch System will be the most powerful rocket ever built, designed for flights to the Moon, Mars, and beyond.

Launch Services Program - LSP

Launch broker

Acquisition and program management

Flight design and trajectory

CubeSat Launch Initiative


Stay Connected with LSP
Visit us on the web at http://go.nasa.gov/lsprockets
Like us on Facebook at https://www.facebook.com/NASALSP
Follow us on Twitter @NASA_LSP
LSP
LAUNCH SERVICES PROGRAM
www.nasa.gov
SP-2016-02-076-KSC


NASA
COMMERCIAL CREW PROGRAM

National Aeronautics and Space Administration

NASA

Commercial Crew Program

www.nasa.gov


Collaborations & Partnerships
help us explore

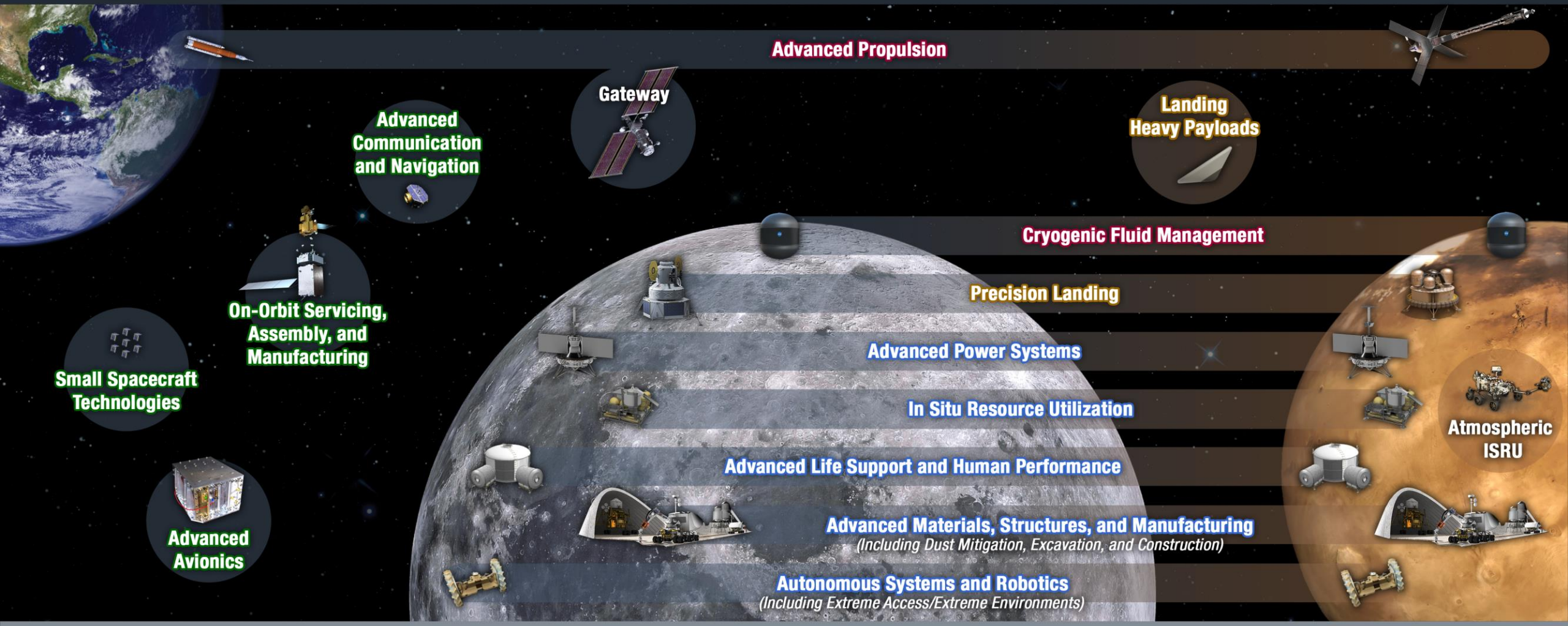
TECHNOLOGY DRIVES EXPLORATION

Rapid, Safe, and Efficient Space Transportation

Expanded Access to Diverse Surface Destinations

Sustainable Living and Working Farther from Earth

Transformative Missions and Discoveries

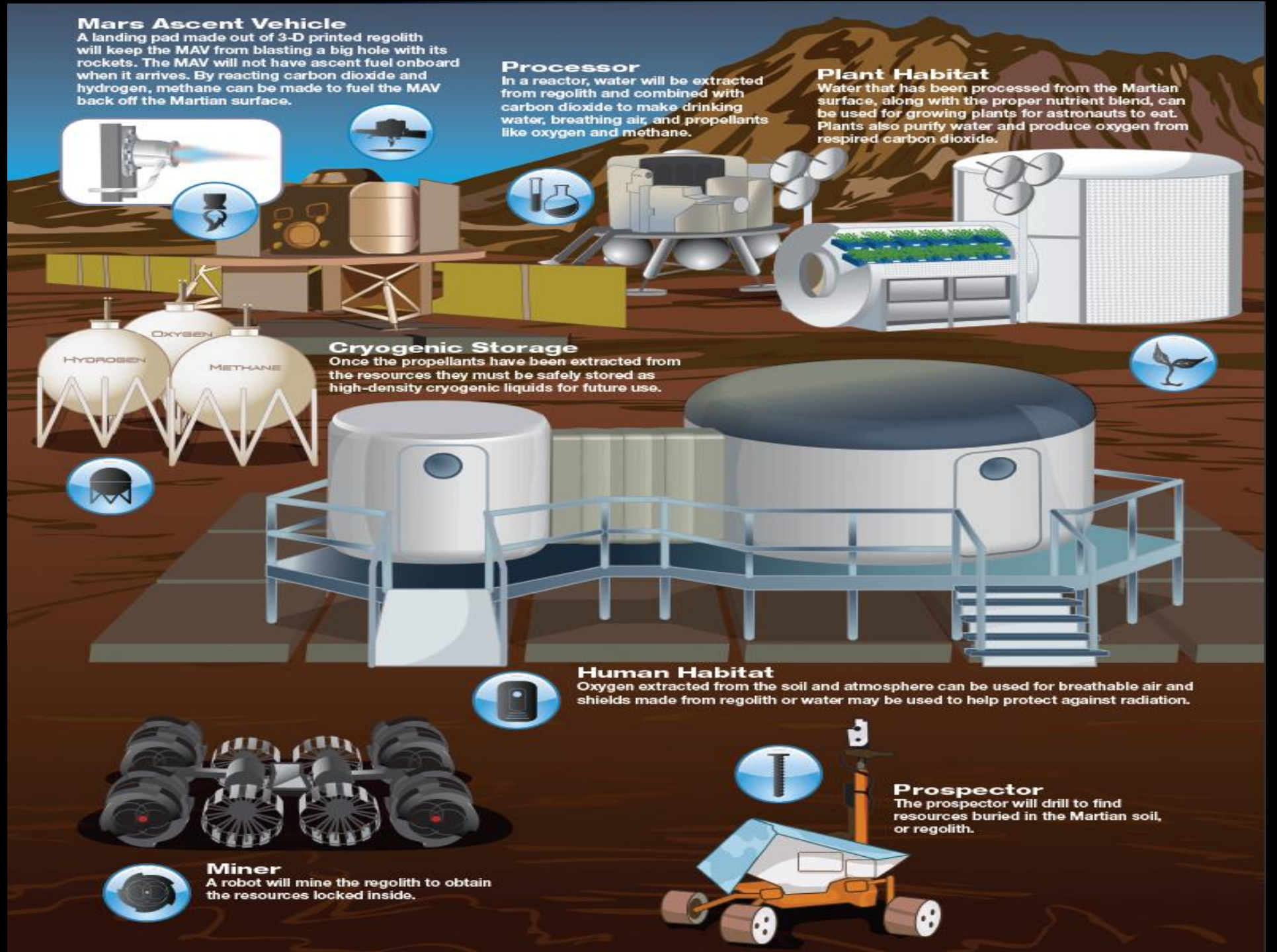


2020 **GO | LAND | LIVE | EXPLORE** 203X

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


Mars Ascent Vehicle
A landing pad made out of 3-D printed regolith will keep the MAV from blasting a big hole with its rockets. The MAV will not have ascent fuel onboard when it arrives. By reacting carbon dioxide and hydrogen, methane can be made to fuel the MAV back off the Martian surface.
Processor
In a reactor, water will be extracted from regolith and combined with carbon dioxide to make drinking water, breathing air, and propellants like oxygen and methane.
Plant Habitat
Water that has been processed from the Martian surface, along with the proper nutrient blend, can be used for growing plants for astronauts to eat. Plants also purify water and produce oxygen from respired carbon dioxide.
OXYGEN
HYDROGEN
METHANE
Cryogenic Storage
Once the propellants have been extracted from the resources they must be safely stored as high-density cryogenic liquids for future use.
Human Habitat
Oxygen extracted from the soil and atmosphere can be used for breathable air and shields made from regolith or water may be used to help protect against radiation.
Miner
A robot will mine the regolith to obtain the resources locked inside.
Prospector
The prospector will drill to find resources buried in the Martian soil, or regolith.

Robotic Mining of Moon's Surface Chemistry:
Resource Prospector Mission

Regolith Operations

Regolith Advanced Surface Systems Operations Robot (RASSOR)

Printing Martian Habitats

Moon and Mars Simulations: MDRS and Hi-SEAS

International Space Station - ISS

Ground Processing support

Research Project Office

Payload Development and Processing

ISS Enables Long Duration Exploration for Mars

Health and Human Performance

Crew Habitability and Logistics

System and Technology Testbed

- Docking System
- High Reliability Closed Loop Life Support
- Long Term System Performance
- Extravehicular Activity

ISS Activities

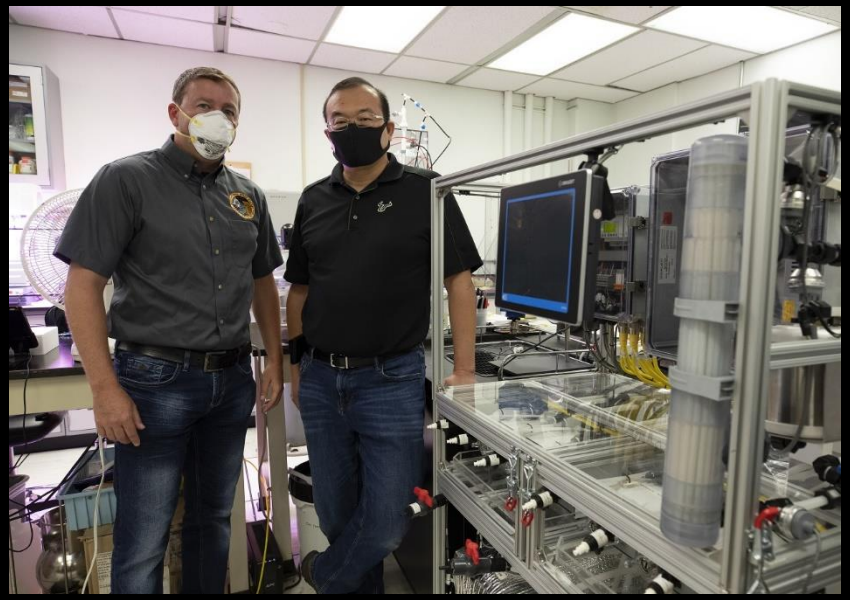
Lack of Gravity Has a Huge Impact

Plant Growth Chambers Aboard ISS

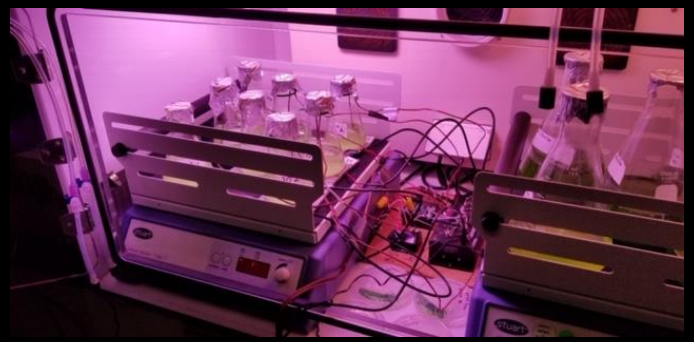
VEGGIE (April 2014)

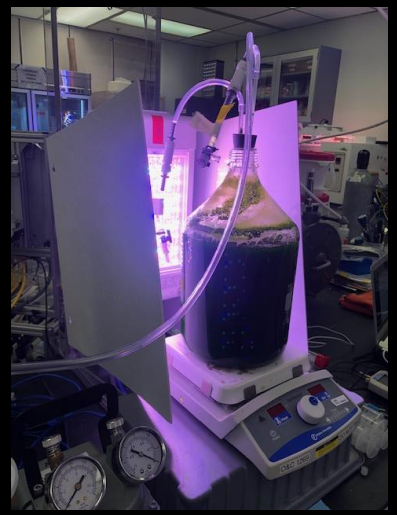
Advanced Plant Habitat (2017)

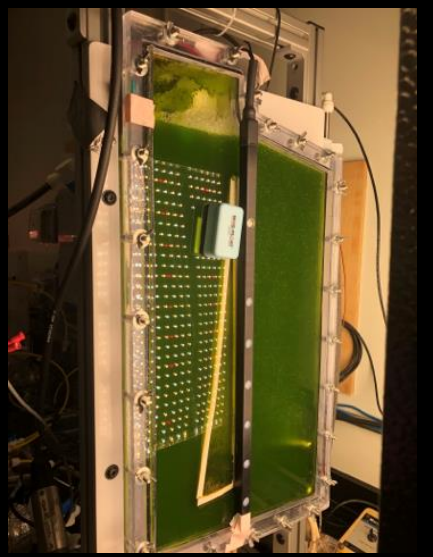
AES ECLSS: Wastewater Processing & Water Management
Bioregen Water Systems



https://images.nasa.gov/details-KSC-20200819-PH-CSH01_00136







Sustainability on ISS

For a crew of 4 over one year, the waste can be used to:
Produce up 1500 kg of methane
Produce up 300 kg of water


Food waste “football”

Oxygen
Water
Methane

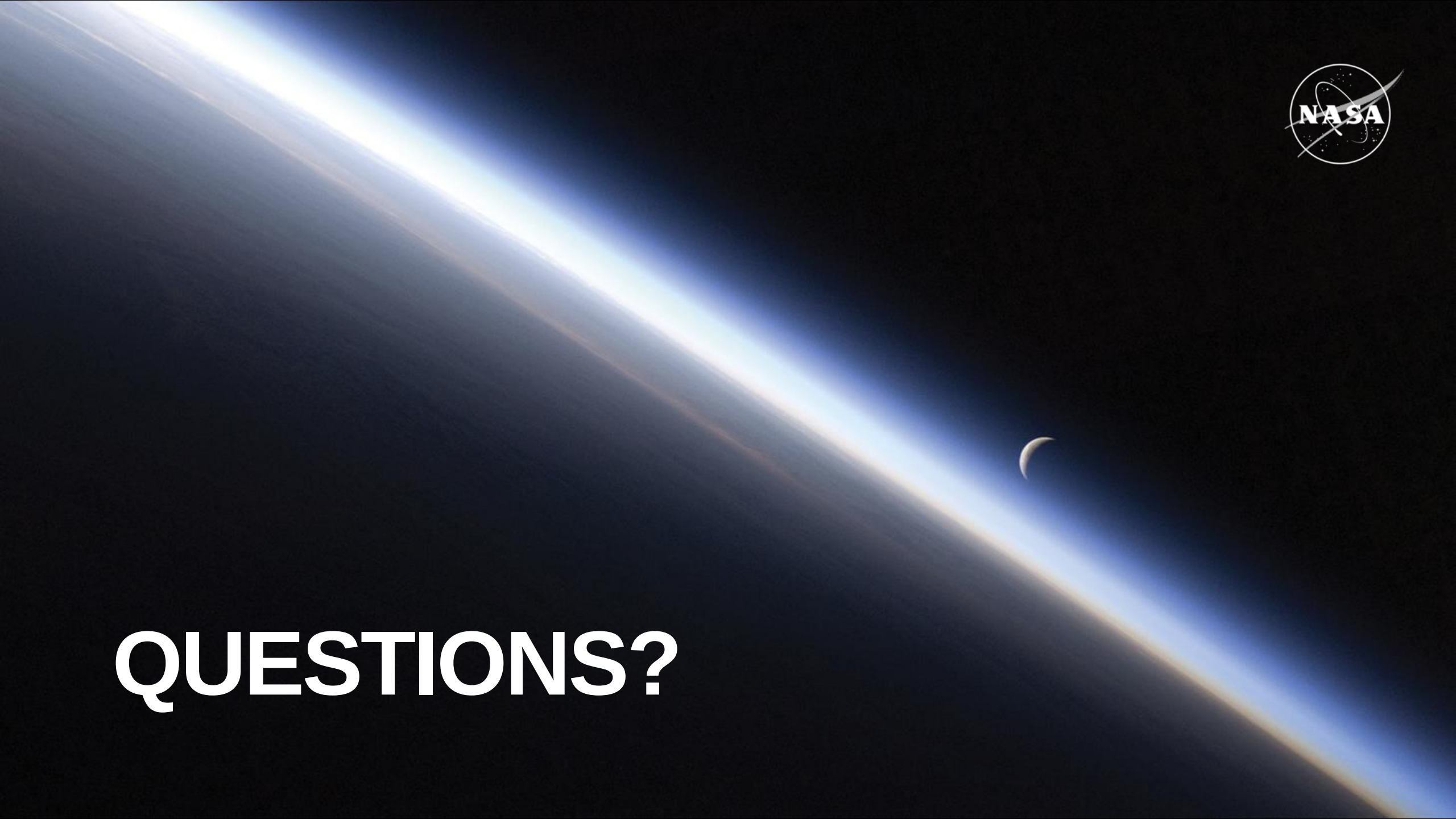
www.nasa.gov

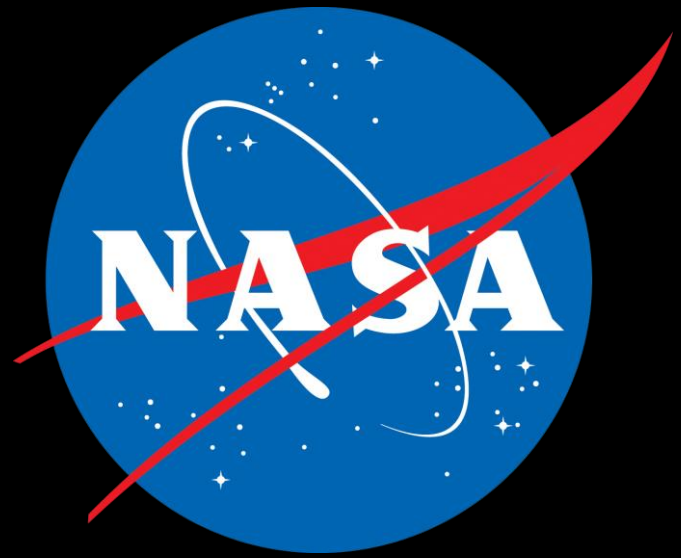
www.intern.nasa.gov

www.nspires.nasa.gov

www.KSCpartnerships.ksc.nasa.gov

Let's go. *The time is now.*


QUESTIONS?



Back Up Slides

Mission Needs Drive Design

LOW EARTH RETURN

3 HOURS
3,000°F
17,500 MPH
250 MILES

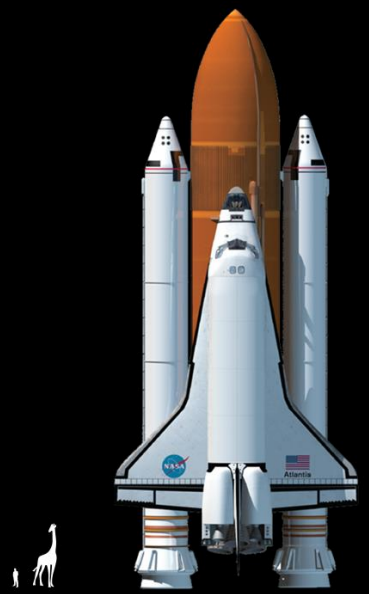
LUNAR RETURN

3 DAYS
5,200°F
24,700 MPH
240,000 MILES

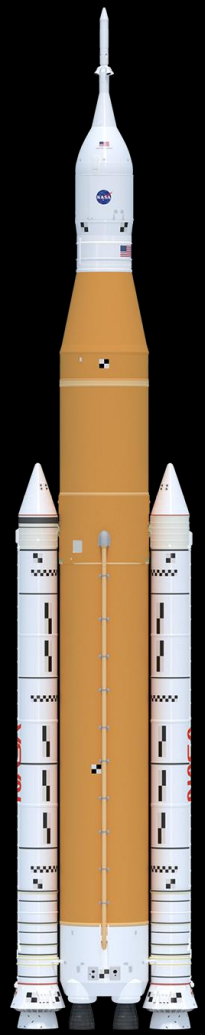
MARS RETURN

9 MONTHS
6,200°F
26,800 MPH
39,000,000 MILES

STATUE OF LIBERTY
305 ft.



SPACE SHUTTLE
184 ft.

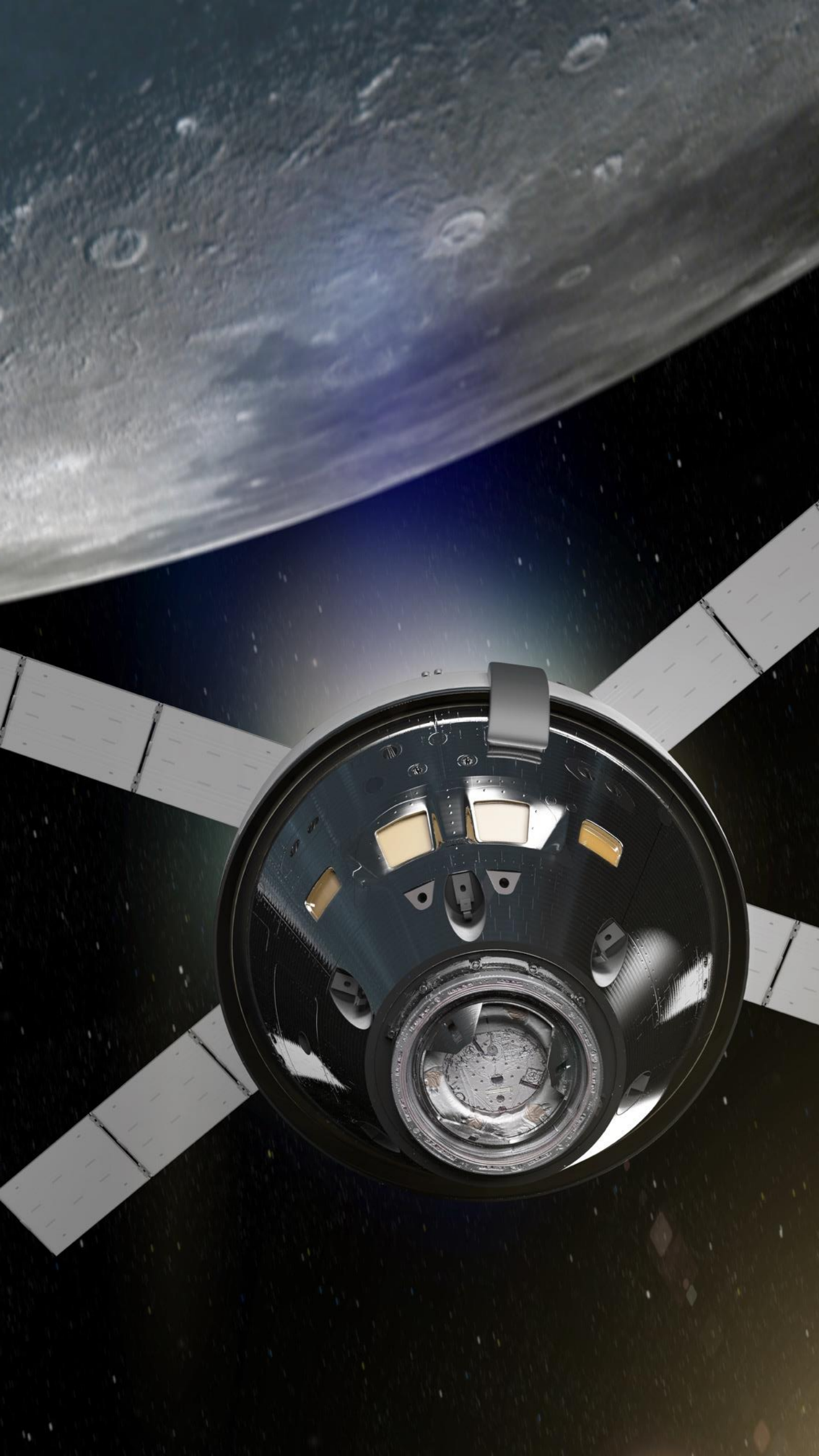


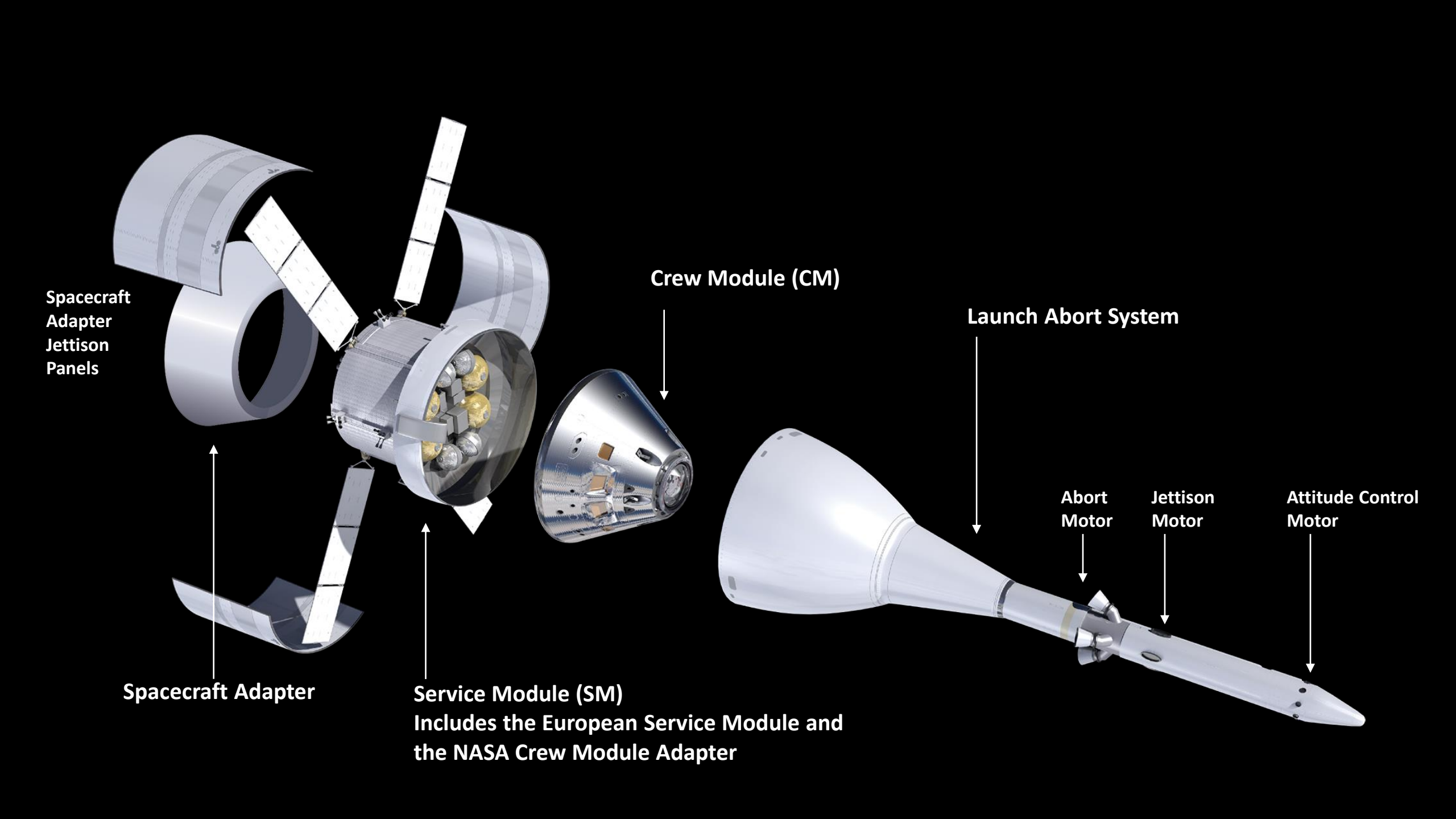
SLS / ORION Block I
322 ft.

SLS / ORION Block II
364 ft.

SATURN 5
363 ft.

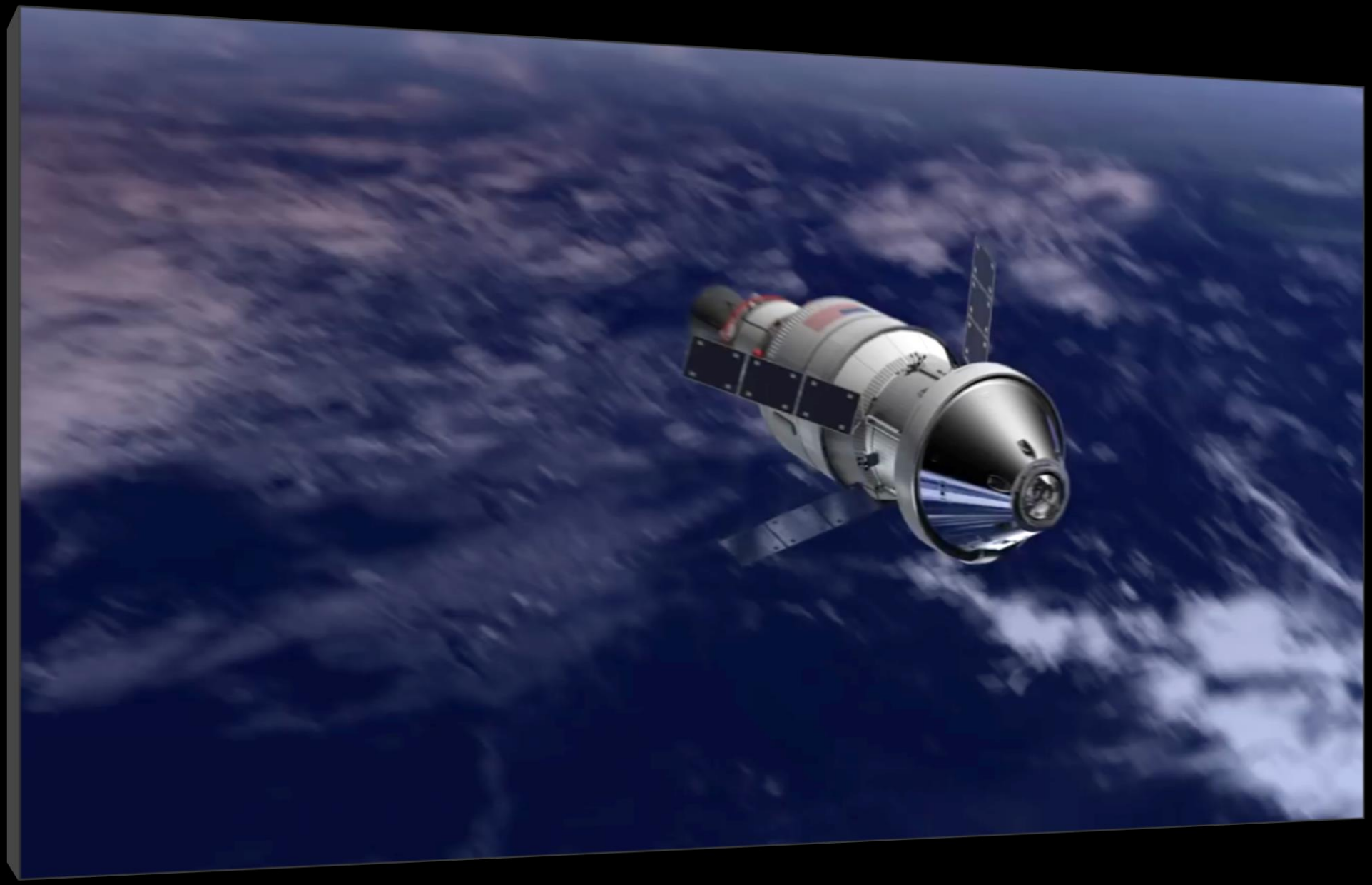

NASA




Spacecraft Adapter Jettison Panels
Crew Module (CM)
Launch Abort System
Abort Motor
Jettison Motor
Attitude Control Motor
Spacecraft Adapter
Service Module (SM)
Includes the European Service Module and the NASA Crew Module Adapter


AVM
FORKLIFT
HE 001-683

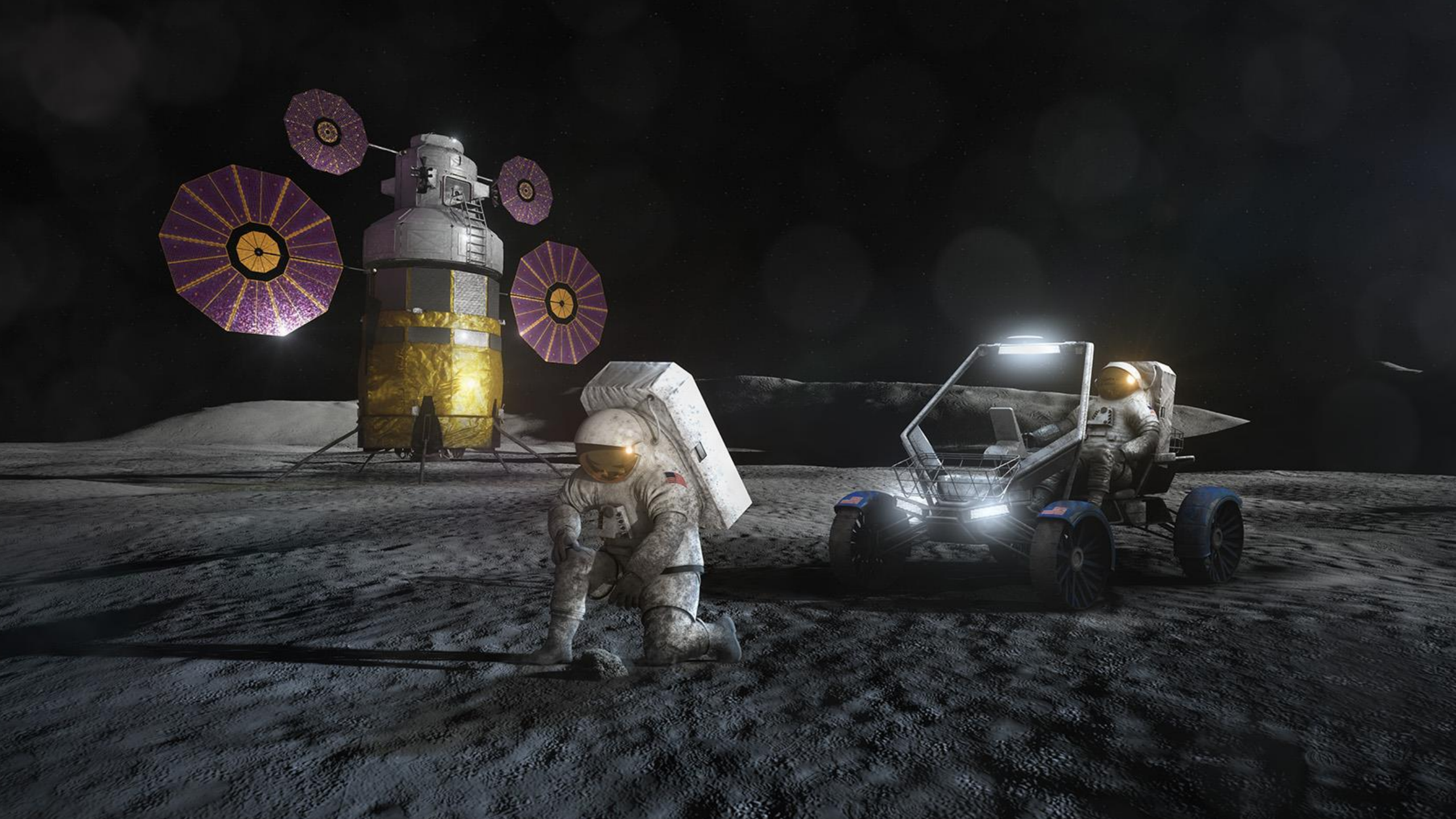

NASA

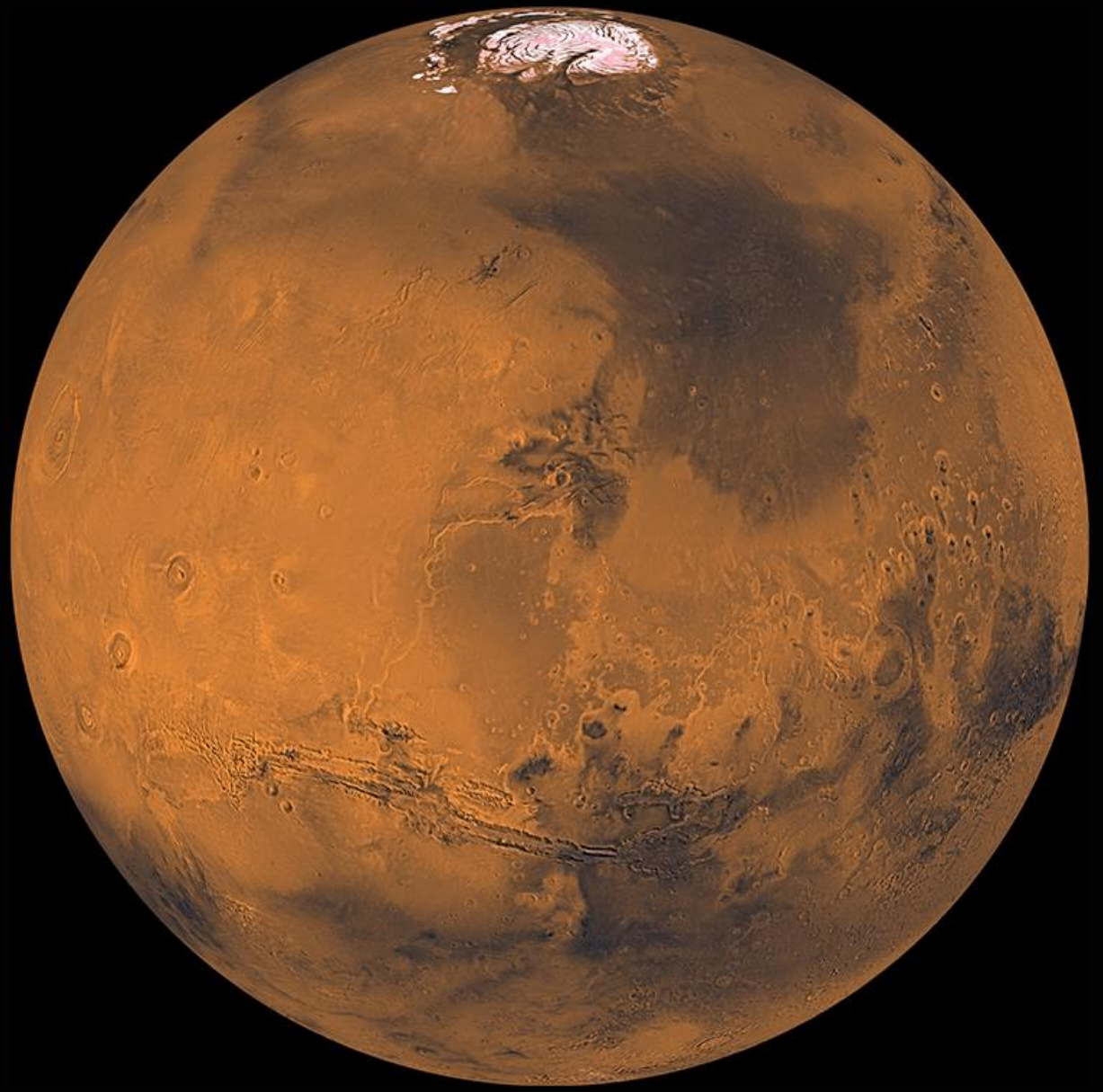


ARTEMIS

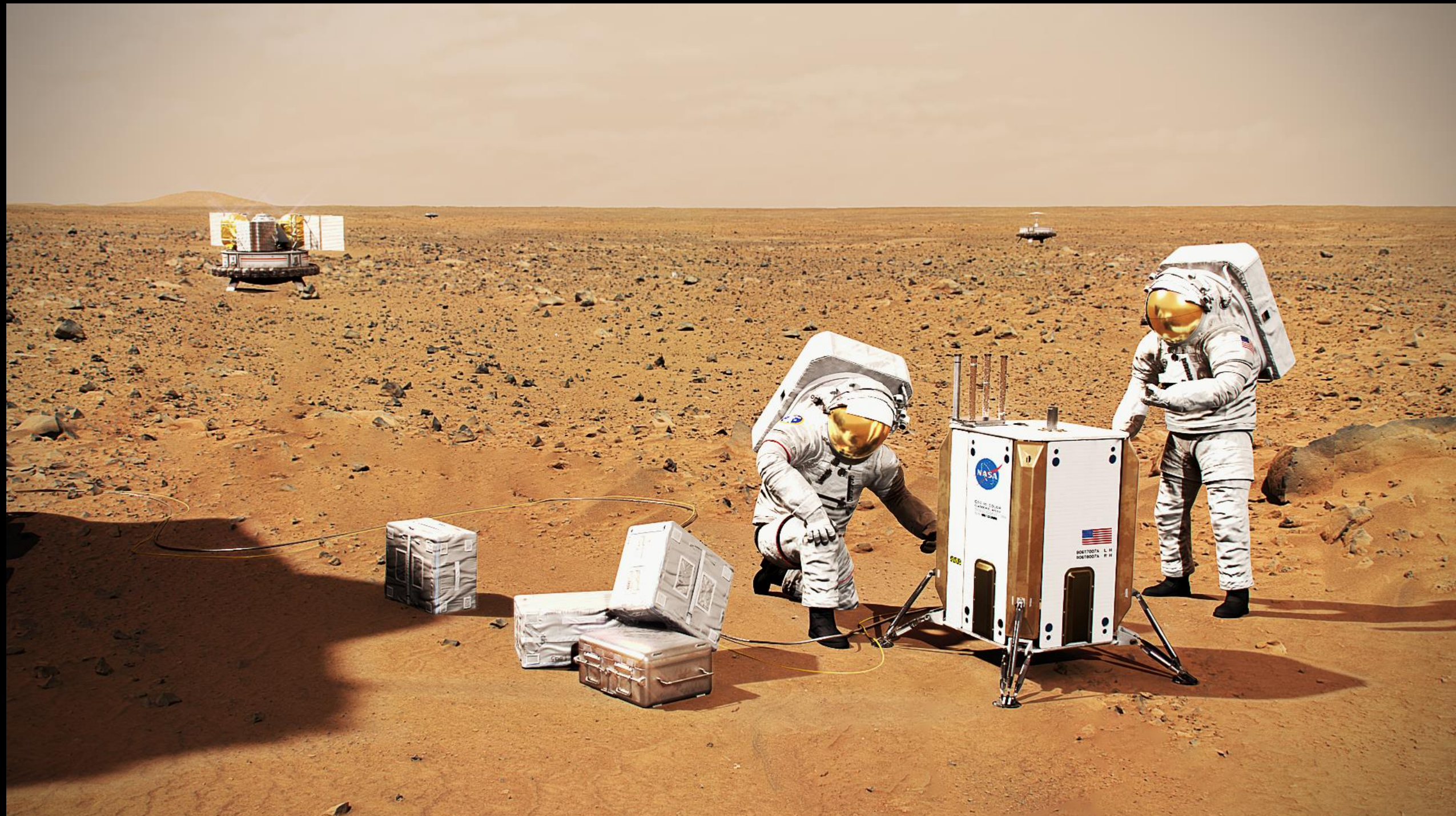
Expanding Partnerships to the Moon

The recently released Artemis Accords demonstrate the commitment of both NASA and international partners to peaceful exploration, transparency, interoperability, and the sharing of scientific data as we move to a new frontier – sustainable deep space exploration.






THE EVOLUTION OF A MARTIAN



Taking the Next Giant Leap

Humans on Mars

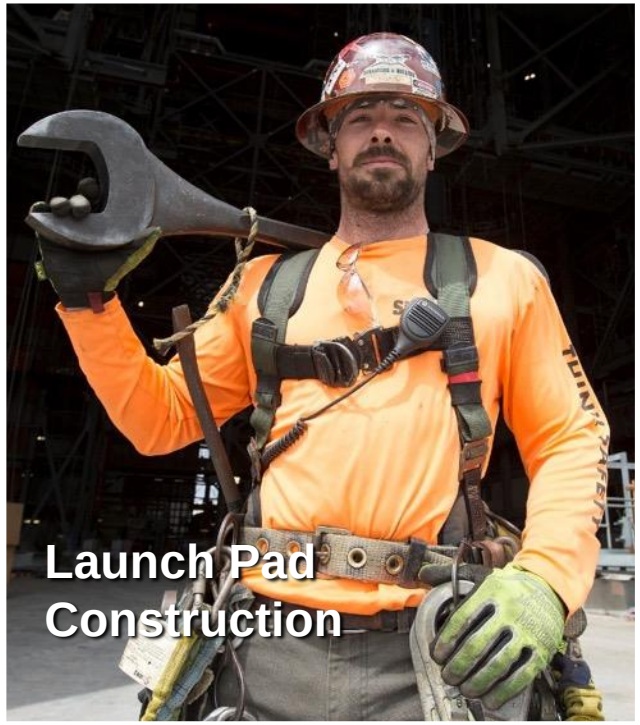

#NASAINTERNS


Welding
Technician

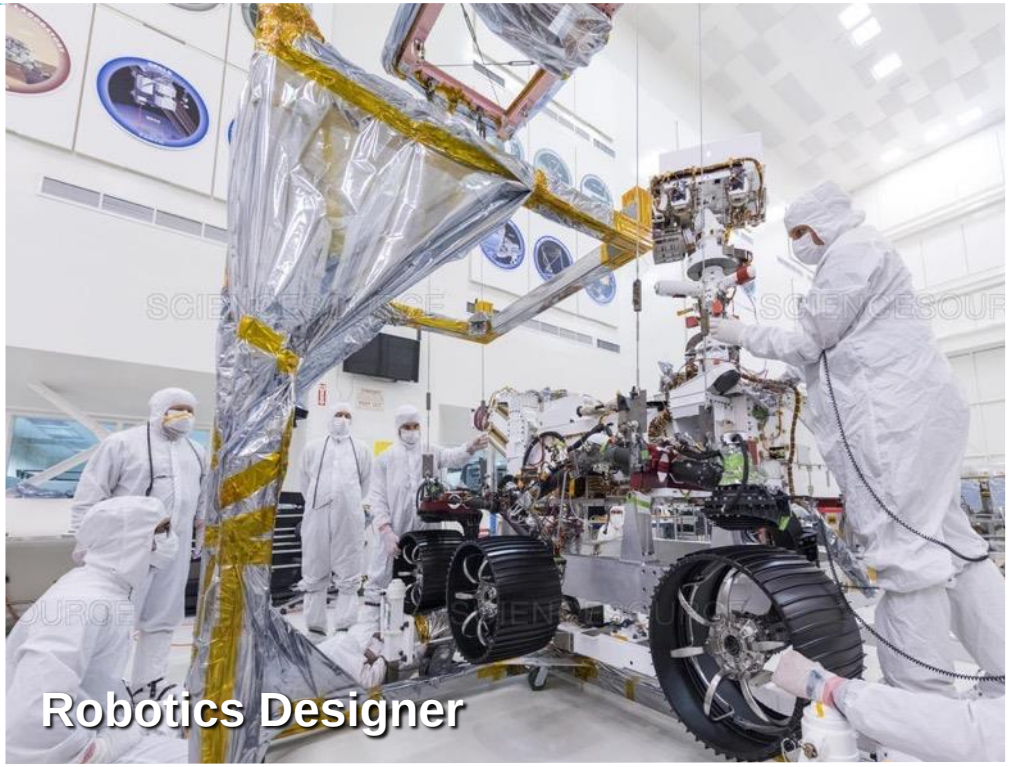

Avionics
Technician

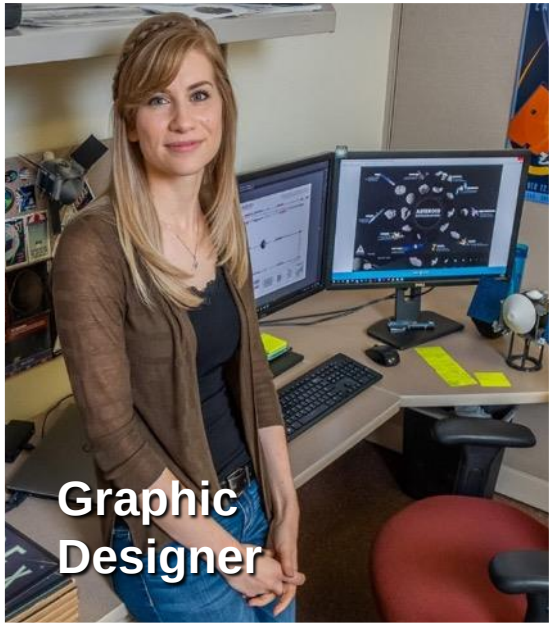

NASA
Food
Scientist


MISSION CONTROL CENTER
FLIGHT OPERATIONS
FLIGHT DIRECTOR
Flight Controller


Launch Pad
Construction


Social Media


Robotics Designer


Graphic
Designer


Spacesuit
Designer


Geologist

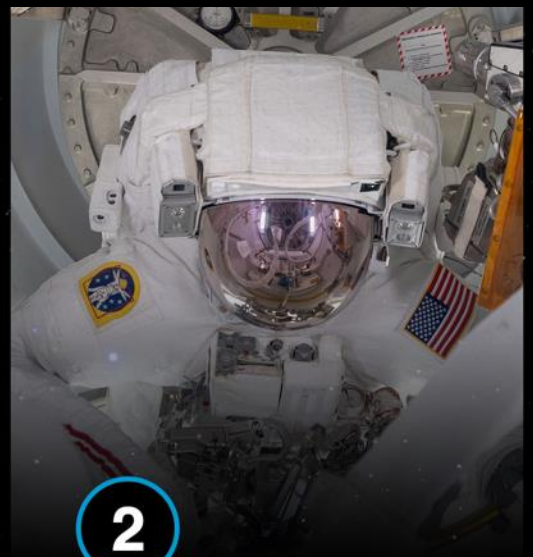

Astronaut
Trainer

The ARTEMIS Team

Hazards of Human Spaceflight

1 Space Radiation

Invisible to the human eye, radiation increases cancer risk, damages the central nervous system, and can alter cognitive function, reduce motor function and prompt behavioral changes.



2 Isolation and Confinement

Sleep loss, circadian desynchronization, and work overload may lead to performance reductions, adverse health outcomes, and compromised mission objectives.

3 Distance from Earth

Planning and self-sufficiency are essential keys to a successful mission. Communication delays, the possibility of equipment failures and medical emergencies are some situations the astronauts must be capable of confronting.

4 Gravity (or lack thereof)

Astronauts encounter a variance of gravity during missions. On Mars, astronauts would need to live and work in three-eighths of Earth's gravitational pull for up to two years.

5 Hostile/Closed Environments

The ecosystem inside a vehicle plays a big role in everyday astronaut life. Important habitability factors include temperature, pressure, lighting, noise, and quantity of space. It's essential that astronauts stay healthy and happy in such an environment.

Unpressurized Rover

Lunar Terrain Vehicle

Pressurized Rover

NASA has featured 2,000+ spinoff technologies improving life on Earth

Everyone benefits:

Students

Construction Workers

Conservationists

Farmers

Doctors and Patients

Airplane Passengers

First Responders

NASA spinoff technologies:

- Save lives
- Make the planet cleaner
- Create jobs
- Educate and entertain
- Help small businesses
- And more

Commercial Lunar Payload Services

14 CLPS providers are currently on contract and eligible to bid on payload deliveries to the Moon

ORION CREW SURVIVAL SYSTEM

Protects astronauts during launch, reentry and emergency situations during Artemis missions • Custom-fit for each crew member • Lighter, more comfortable helmet with noise reduction and easier connection to the communications system

MOONWALKING IN THE MODERNIZED SPACE SUITS

NASA is preparing to build the modernized spacesuits for 2024, called *Exploration Extravehicular Mobility Unit*, or xEMU

Spacesuit improvements include advanced safety additions, more flexibility, better communications, and custom fitting.

Humans on Mars

Pushing the Boundaries of Current Possibilities

Go	***Land***	***Live***	***Explore***
Rapid, safe, & efficient space transportation	*Expanded access to diverse surface destinations*	*Sustainable living and working farther from Earth*	*Transformative missions and discoveries*