



Returning to the Moon: NASA's Artemis Missions

Tracy Gill

Lander Ground Operations – Human Lander
Systems Program

Kennedy Space Center



My background

- Tracy holds a BS in Electrical Engineering (1989) and an MS in Aerospace and Mechanical Systems (2000) from the University of Florida, an MS in Space Systems from Florida Tech (1994), and is a graduate of the International Space University Space Studies Program in 2006.
- Tracy is a big sports fan following football and basketball and any team that represents the University of Florida. Tracy enjoys speaking to local schools on various topics in the space field and has been an adjunct professor for the International Space University.

Galileo School connection

- Charter School Founder
- Michele G. Gill, PhD
- Gill was recognized for her dedication, advocacy and actions to transform public education through the application of psychological learning principles. In 2010, Gill designed and founded a free K-8 charter school in the high-poverty area of Midway in Sanford, Fla. based on cutting edge educational research. Currently Galileo School is one of the top performing schools in Seminole County and is known for its educational innovations, such as differentiation for all students, and student-selected “creative productivity” learning blocks. Gill continues to serve the school as chairperson of the Galileo School Board and chair of the Curriculum Committee.



And as expected of someone in the space field, he is a fan of popular science fiction including Star Wars and Star Trek and participates in the occasional comic book or sci-fi convention.



Star Wars Celebration 2017



San Diego Comic Con 2016



D23 Expo 2017



Megacon Orlando 2018

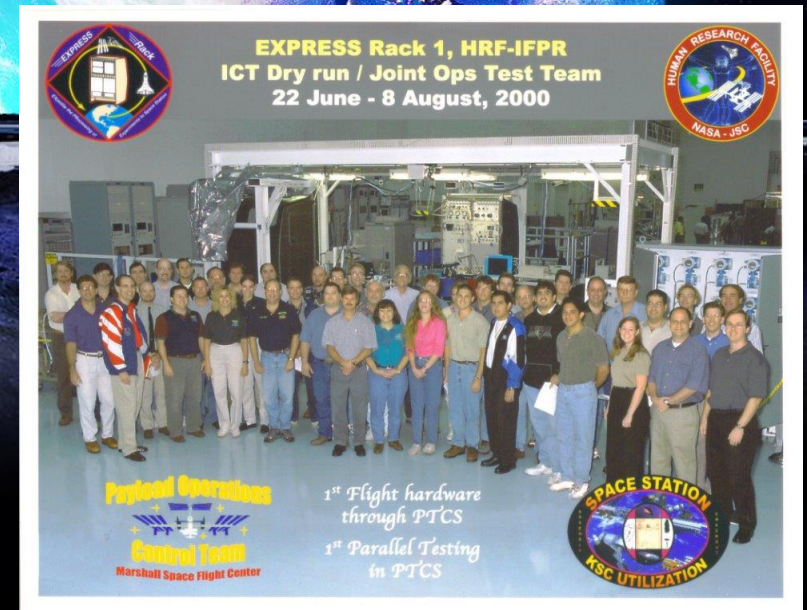
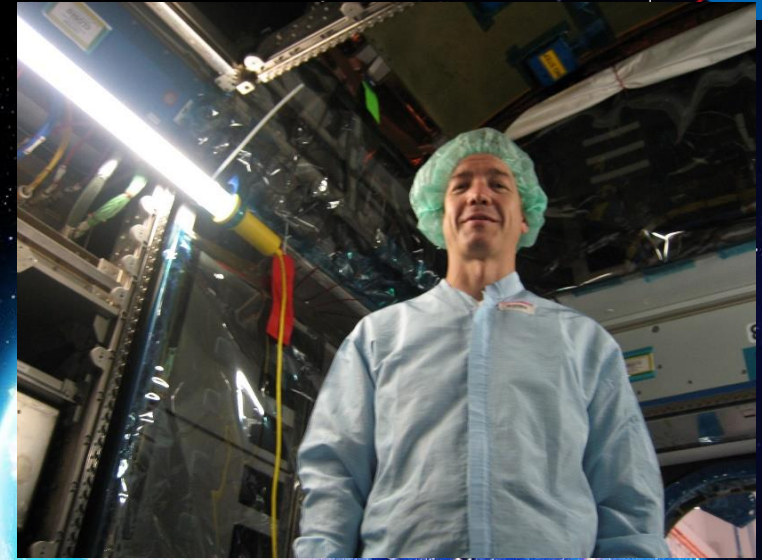
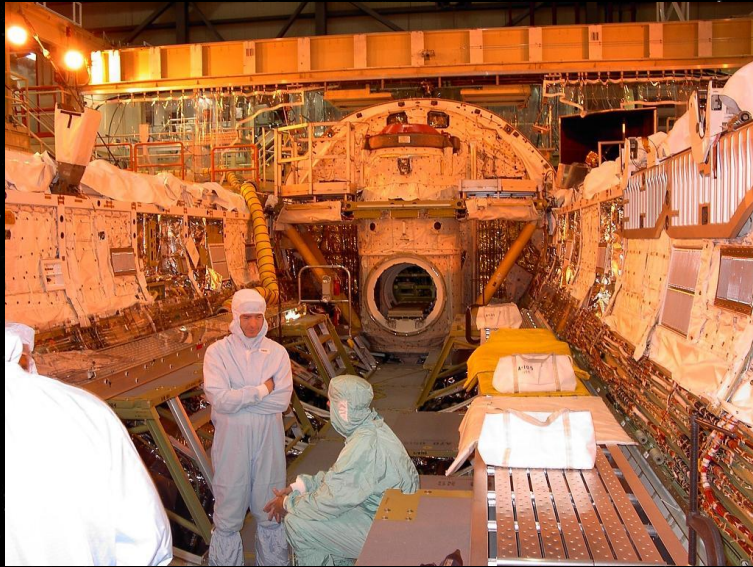


D23 Expo 2019



San Diego Comic Con 2018

NASA "ACTION" SHOTS



Deep Space Habitats

Habitat Demonstration Unit (2011-2013)



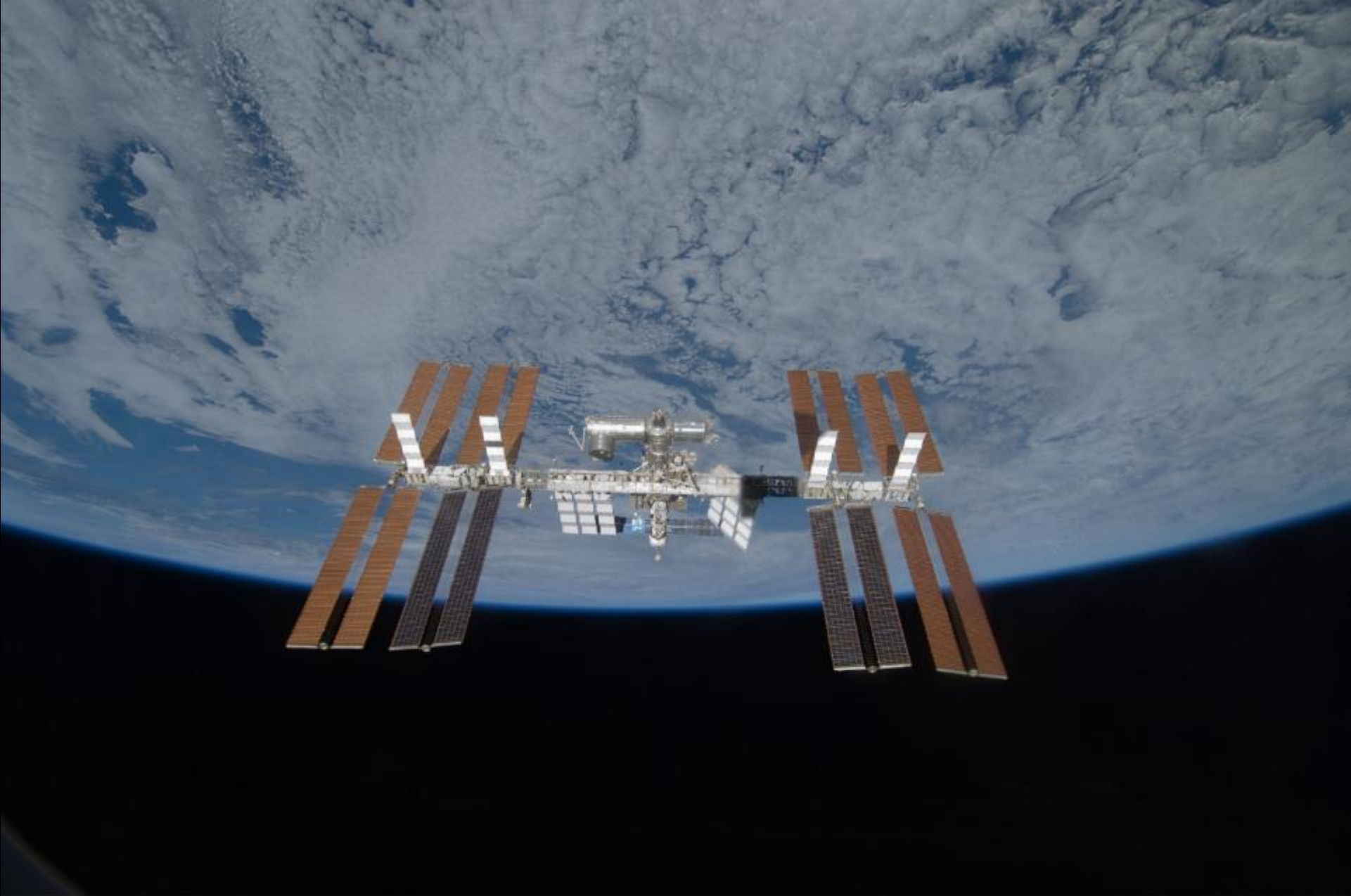
Multi-Purpose Logistics Module: Donatello – to be used in NextSTEP Habitat project



INTERNATIONAL SPACE STATION (ISS)



- **Spacecraft Mass: +800,000 lb (+362,874 kg)**
- **Velocity: 17,500 mph (28,200 kph)**
- **Orbits: 16 times around the Earth/day (~every 90 minutes)**
- **Altitude: 220 miles above Earth**
- **Power: 80 kW continuous**



S119E008357

See the ISS pass overhead your area! - <https://spotthestation.nasa.gov/>



S126E008372





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. When the Artemis astronauts land on the lunar surface, they will step into the future, bringing all of humanity with them.



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



**Numbers are averages*



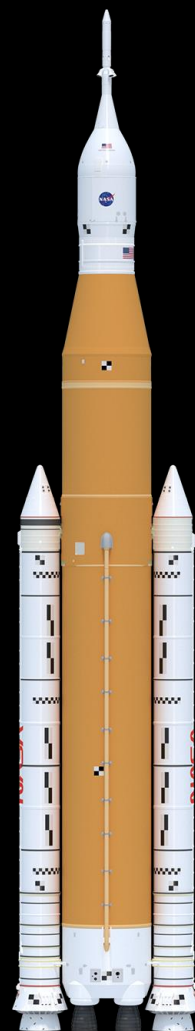
SLS



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.



Spacecraft
Adapter
Jettison
Panels

ORION

Crew Module (CM)

Launch Abort System

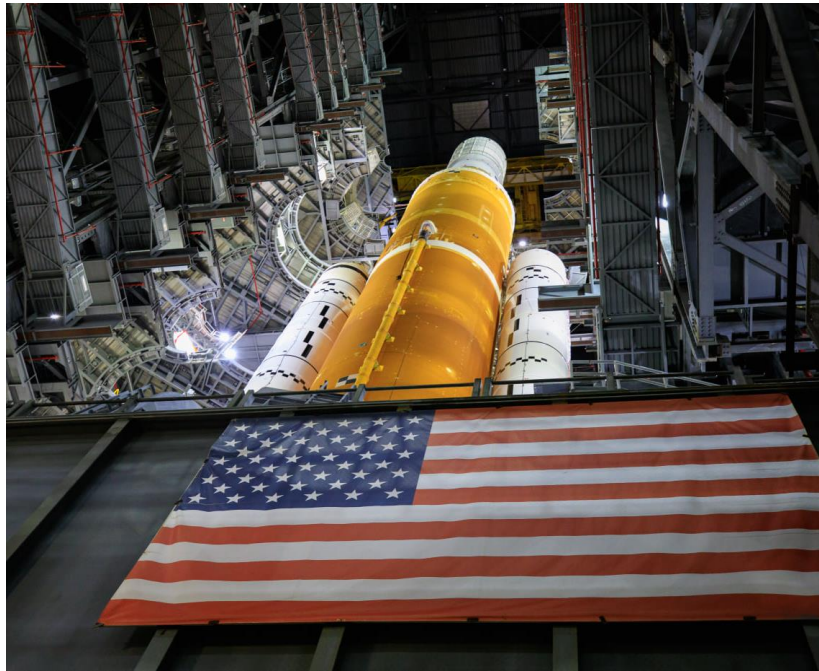
Abort
Motor

Jettison
Motor

Attitude
Control
Motor

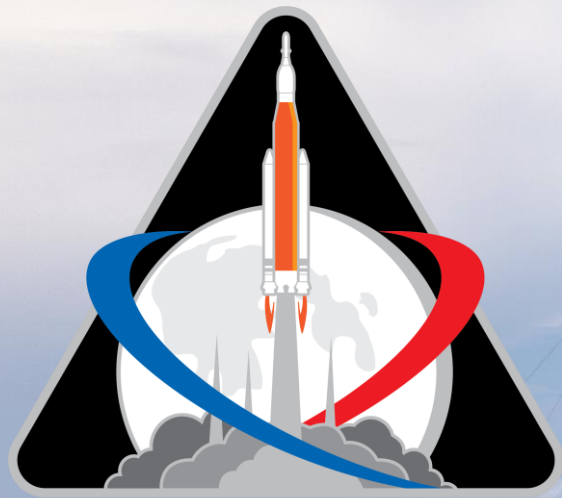
Spacecraft Adapter

Service Module (SM)
*Includes the European Service Module
and the NASA Crew Module Adapter*





Artist Concept

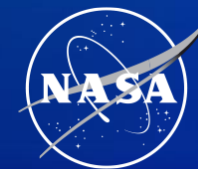


ARTEMIS I



ARTEMIS II





Joseph
ACABA

Kayla
BARRON

Raja
CHARI

Matthew
DOMINICK

Victor
GLOVER

Warren
HOBURG

Jonny
KIM

Christina H.
KOCH

Kjell
LINDGREN



Nicole A.
MANN

Anne
McCLAIN

Jessica
MEIR

Jasmin
MOGHBELI

Kate
RUBINS

Frank
RUBIO

Scott
TINGLE

Jessica
WATKINS

Stephanie D.
WILSON

ARTEMIS III



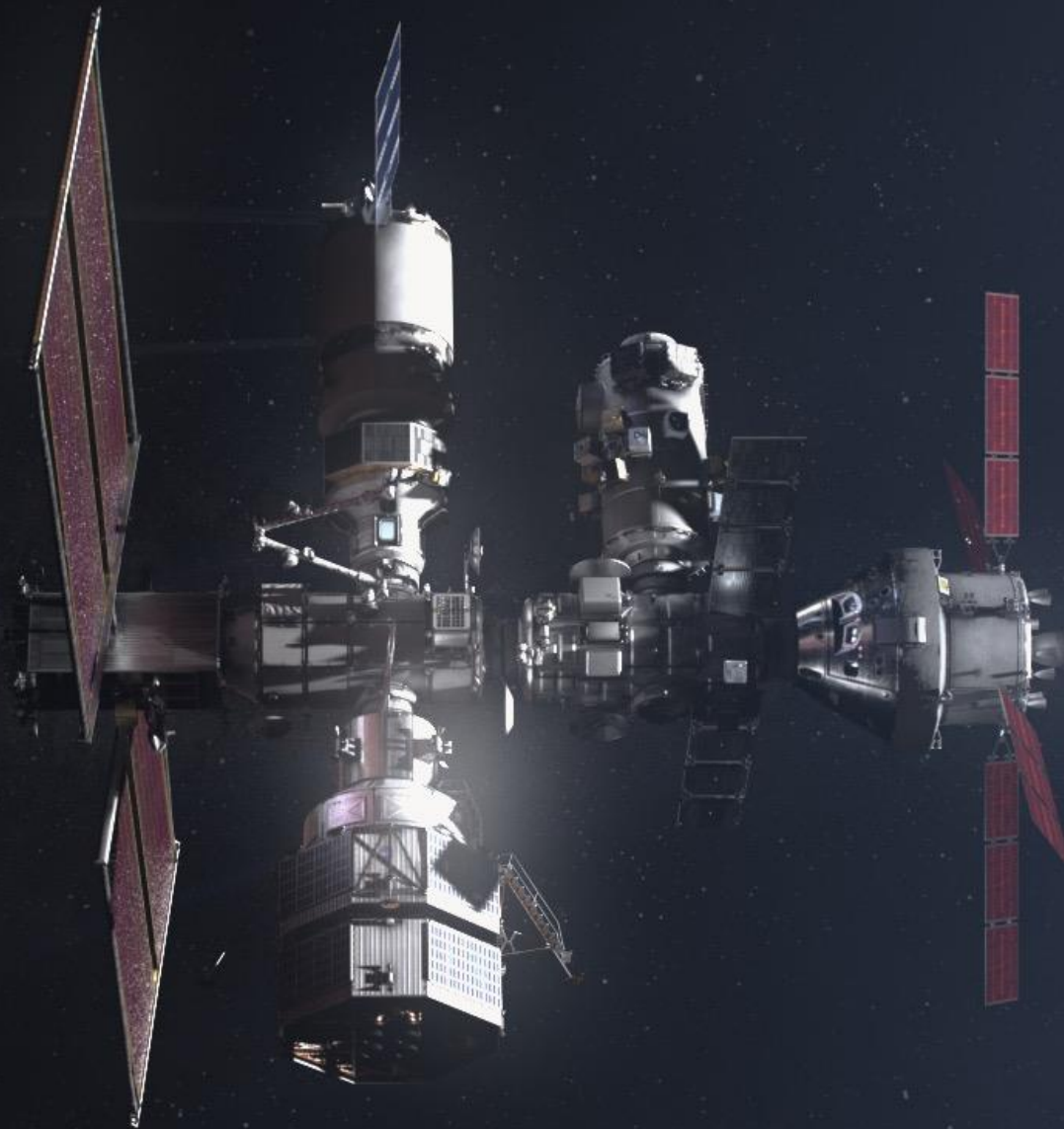
HLS

Initial Human Landing System



Image Credit: SpaceX

G A T E W A Y



ARTEMIS BASE CAMP

Comm, Nav, Power >>

Surface Habitat >>

>> In-Situ Resource Utilization (ISRU)

Pressurized Rover >>

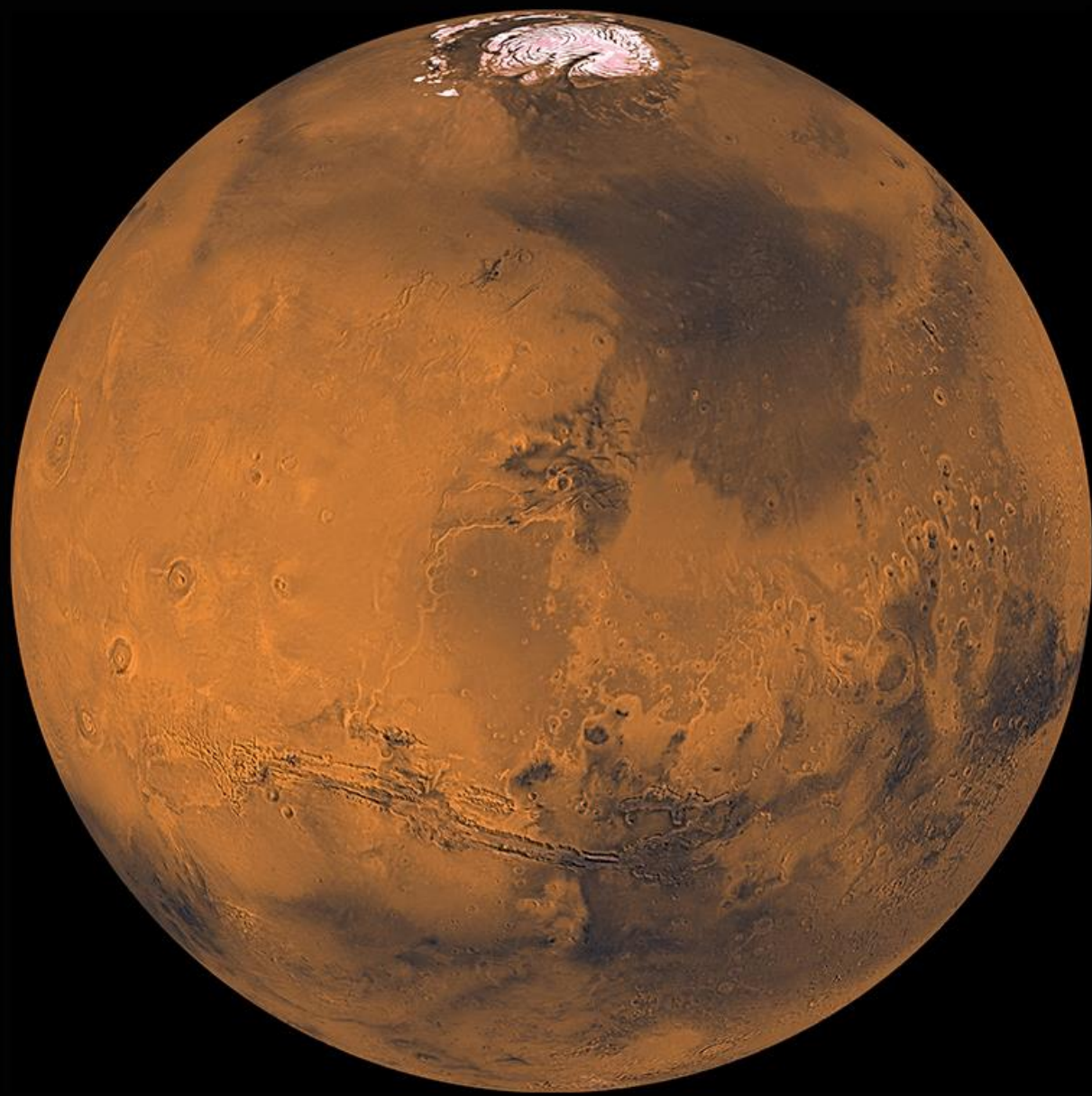
>> Human Landing System

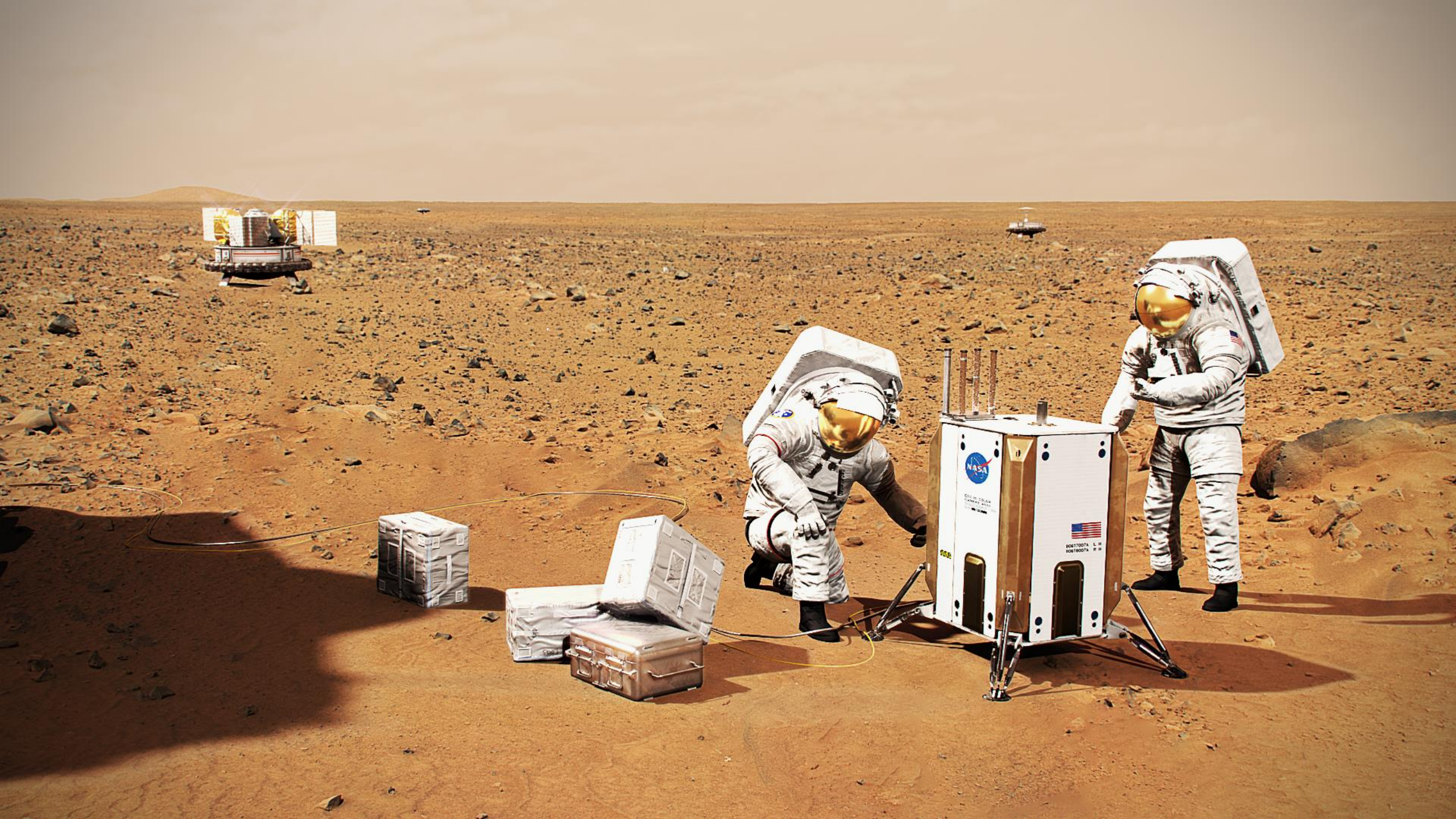


Spacesuits >>

Lunar Terrain Vehicle >>

Artist's illustration of Artemis Base Camp





Taking the Next Giant Leap

Humans on Mars



Earth



**Welding
Technician**



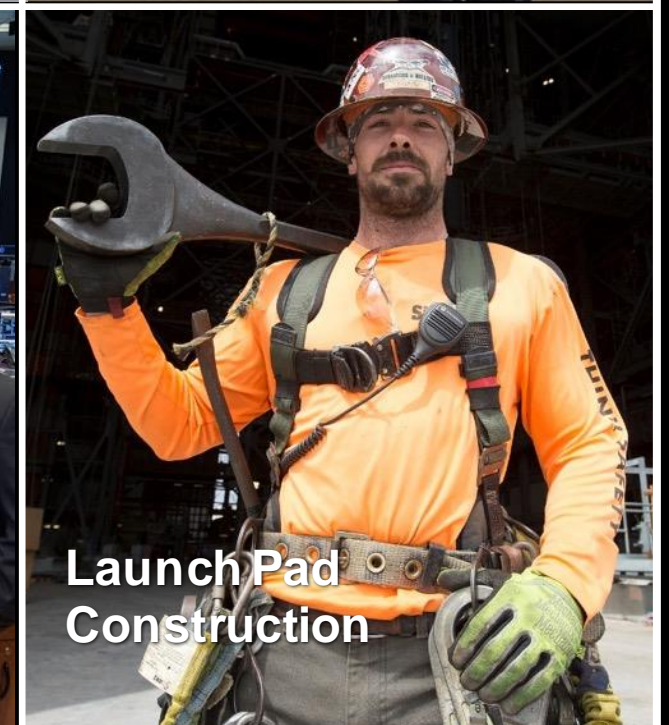
**Avionics
Technician**



**Food
Scientist**



Flight Controller



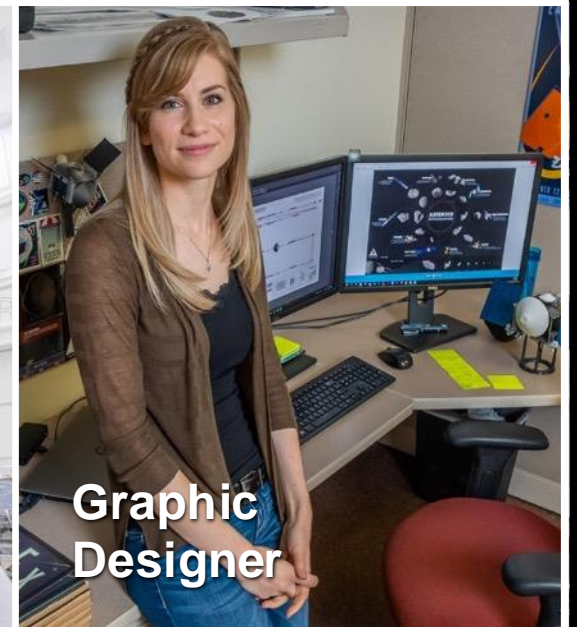
**Launch Pad
Construction**



Social Media



Robotics Designer



Graphic Designer



Spacesuit Designer



Geologist



Astronaut Trainer

Moon Hoax? – No way!

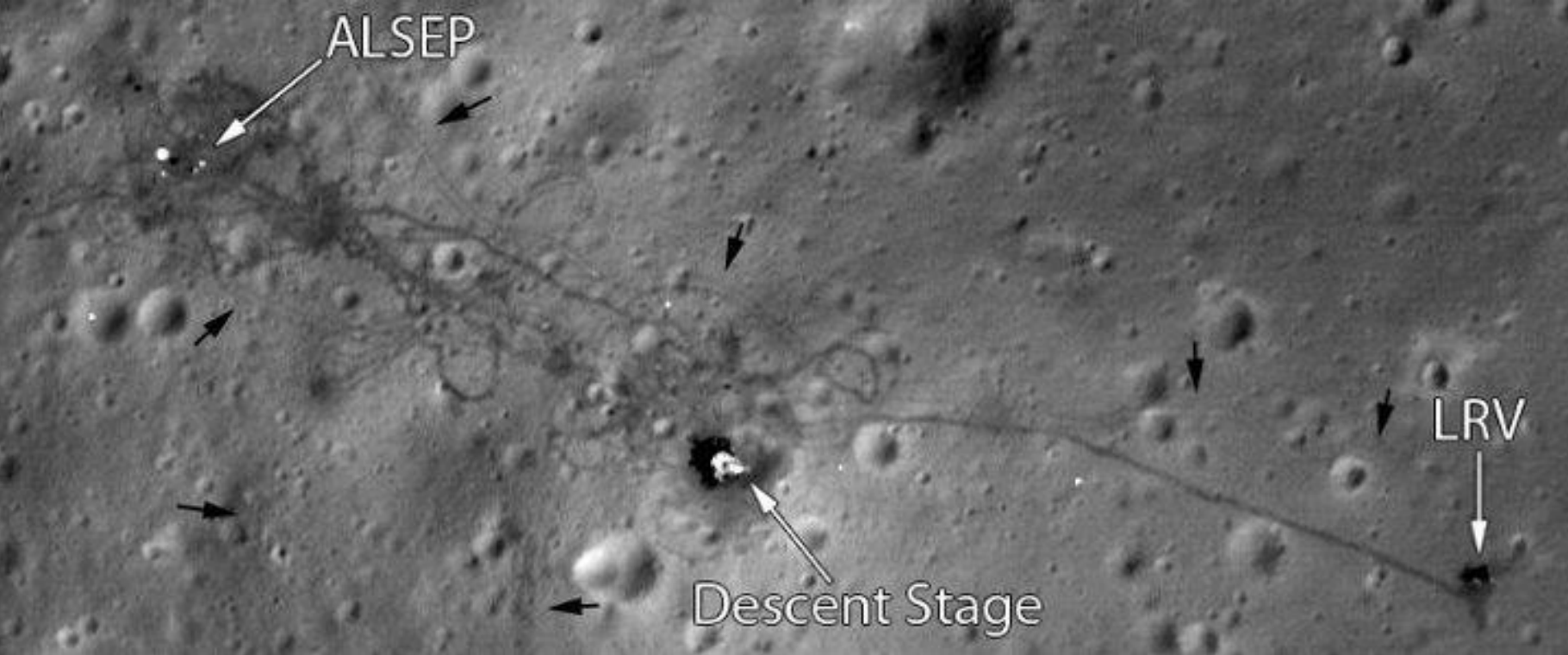


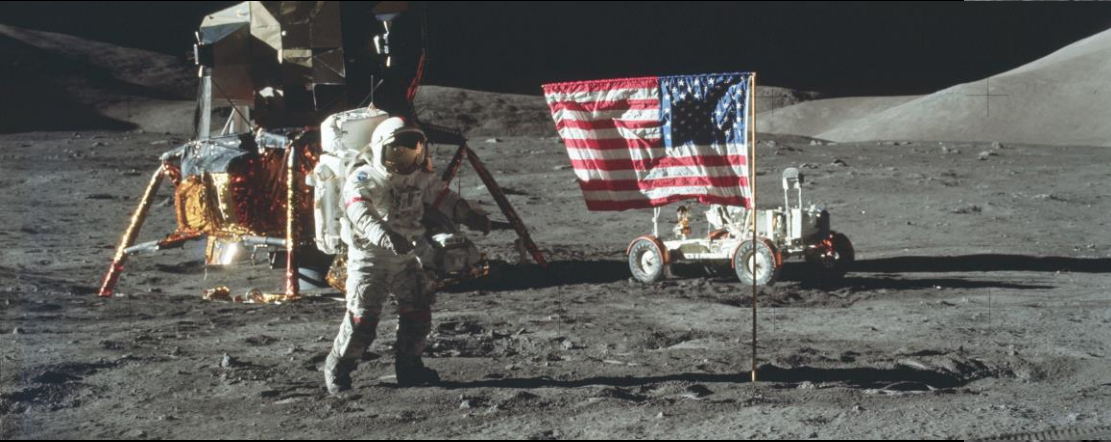
Image of the Apollo 15 landing site from the NASA/Lunar Reconnaissance Orbiter

Apollo 15
image from
the lunar
surface



Apollo 17 Landing Site
LROC NAC M168000580LR
Low Periapse orbit

100 meters



December 11 1972

Apollo 17 landing Site

ALSEP Equipment

Geophone Rock

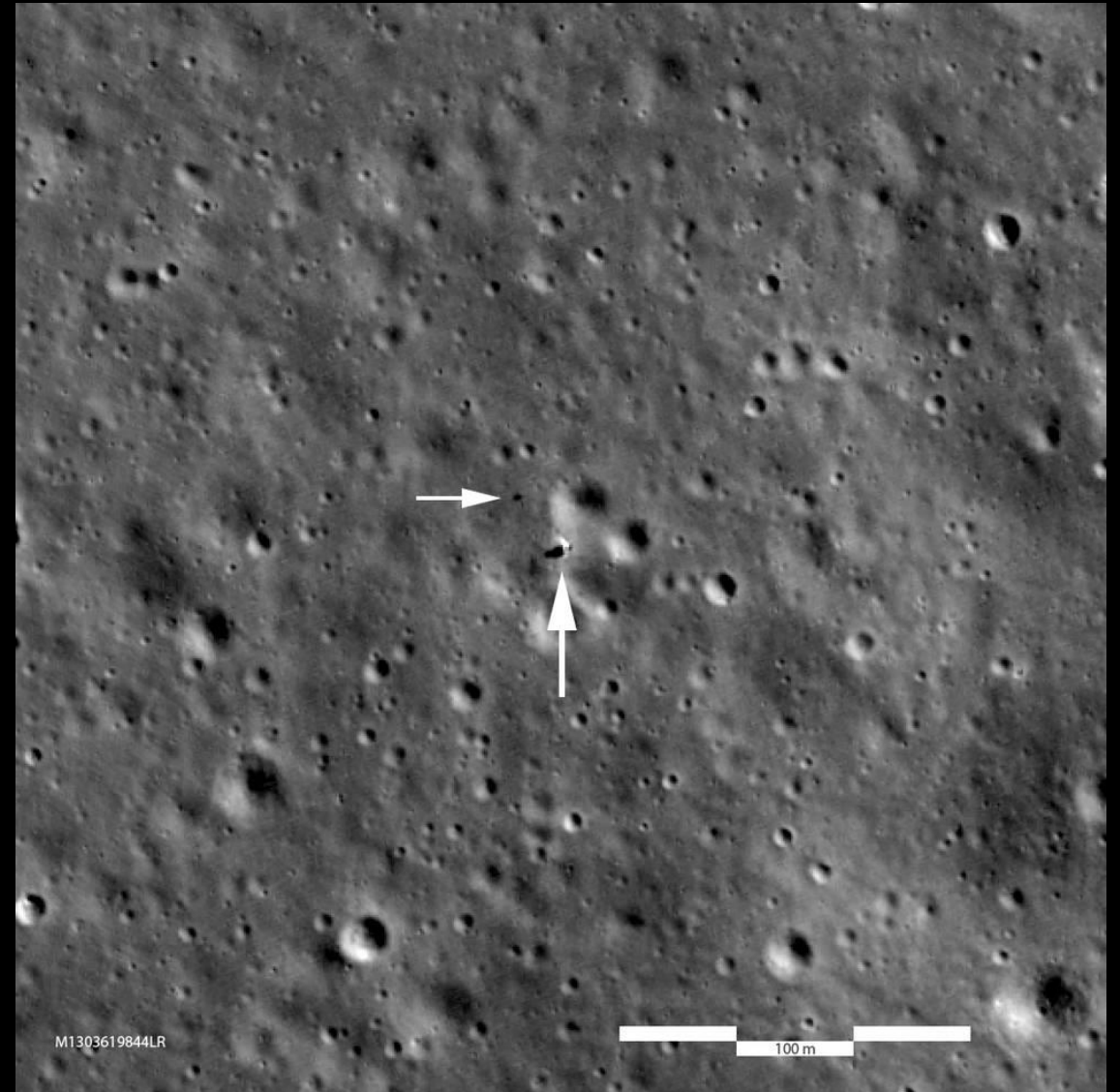
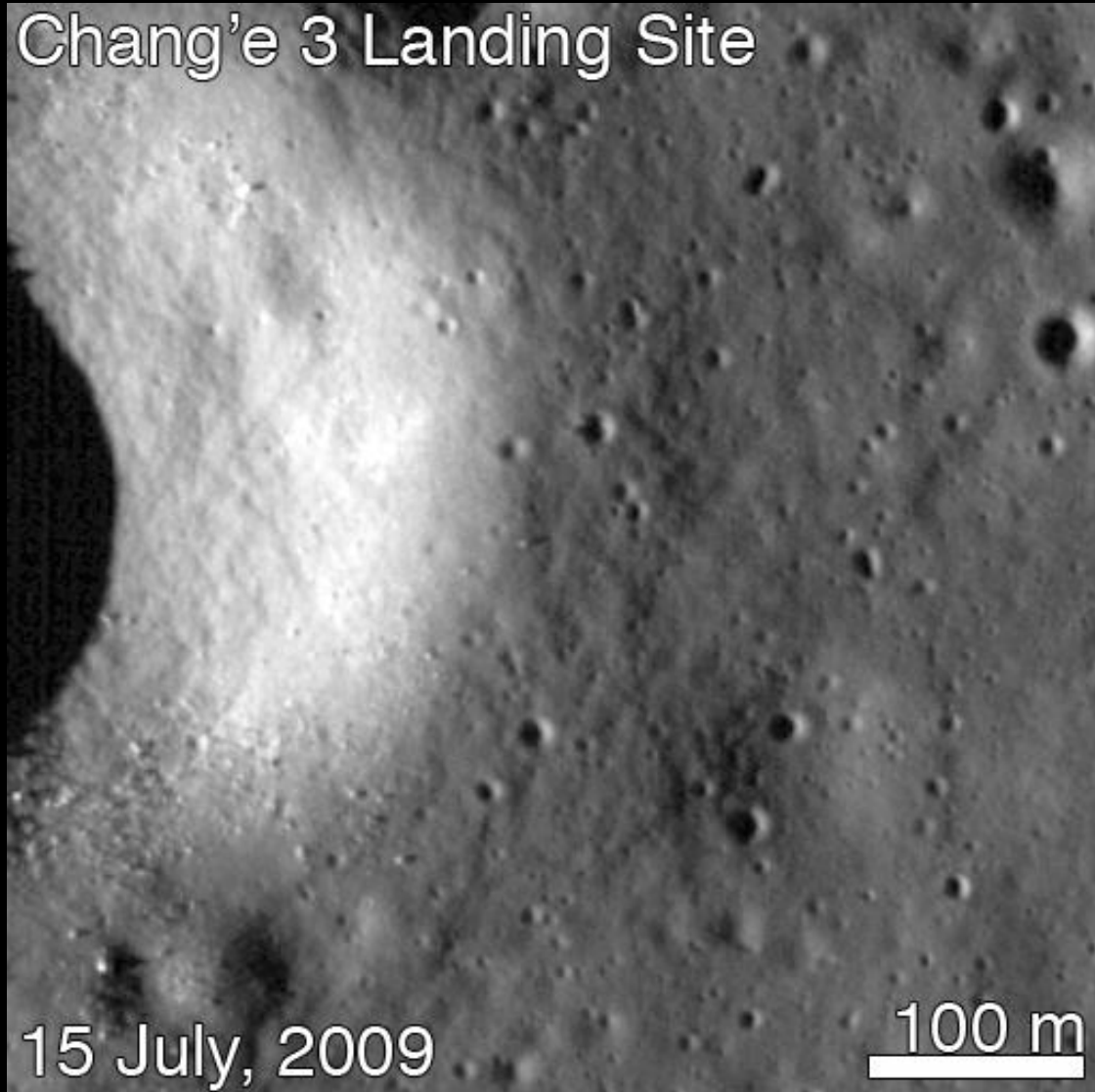
Challenger Descent Stage

LRV

Challenger 3x Enlargement

Chang'e 4 – Feb 1, 2019

Chang'e 3 Landing Site



Credit: NASA/Lunar Reconnaissance Orbiter

Other good information...

- [NASA Tournament Lab](#) - Challenges and opportunities for the public to solve problems and analyze data
- [NASA 3D objects](#) - You can make 3d prints of NASA systems or use them in modeling software tools
- [NASA X-Hab Grant Program](#) – NASA advised projects using systems engineering process
- [NASA Solicitation and Proposal Integrated Review and Evaluation System](#) – host site for most every NASA solicitation opportunity

Observations

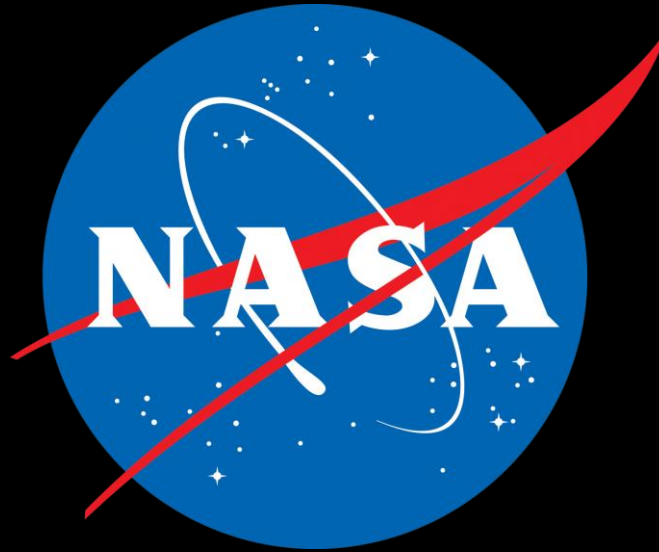
- Grad School
 - Be sure that you want to pursue specialization in a field via an advanced degree or perhaps get some experience before deciding if not sure
 - If you're working, you can probably get your employer to at least partially pay for grad school!
- Project based activity experience
 - Working on racecars, robot competitions, concrete canoes, etc. where a multidiscipline team works together on a timeline and on a budget are the best kinds of experience to have in high school and college to prepare you for the work environment
- Find problems that need to be solved and solve them proactively
 - Can be fun and usually gives you some latitude in how to solve
- Find work that you want to do. You'll do a better job and have a better life if you enjoy what you do
- My mission - aim for being one of the most productive people in my field and for being someone with whom other people want to work.
- If we're landing on the moon in the next few years, it's going to be hard to get me to retire!



QUESTIONS?



ARTEMIS



Back Up Slides and Supplemental Resources



Artemis: a Foundation for Deep Space Exploration



Space Launch System



Orion spacecraft



Human Landing System



Surface Operations



Gateway



Exploration Ground Systems



Space Communications
& Navigation



Surface Mobility

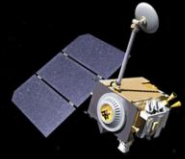


Space Suits



Artemis Base Camp

Artemis: Landing Humans On the Moon



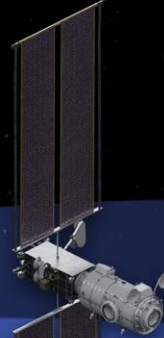
Lunar Reconnaissance Orbiter: Continued surface and landing site investigation



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



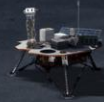
Gateway begins science operations with launch of Power and Propulsion Element and Habitation and Logistics Outpost



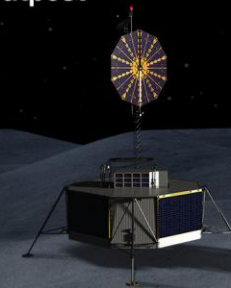
Artemis III-V: Deep space crew missions; cislunar buildup and initial crew demonstration landing with Human Landing System



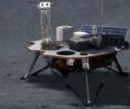
Early South Pole Robotic Landings
Science and technology payloads delivered by Commercial Lunar Payload Services providers



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



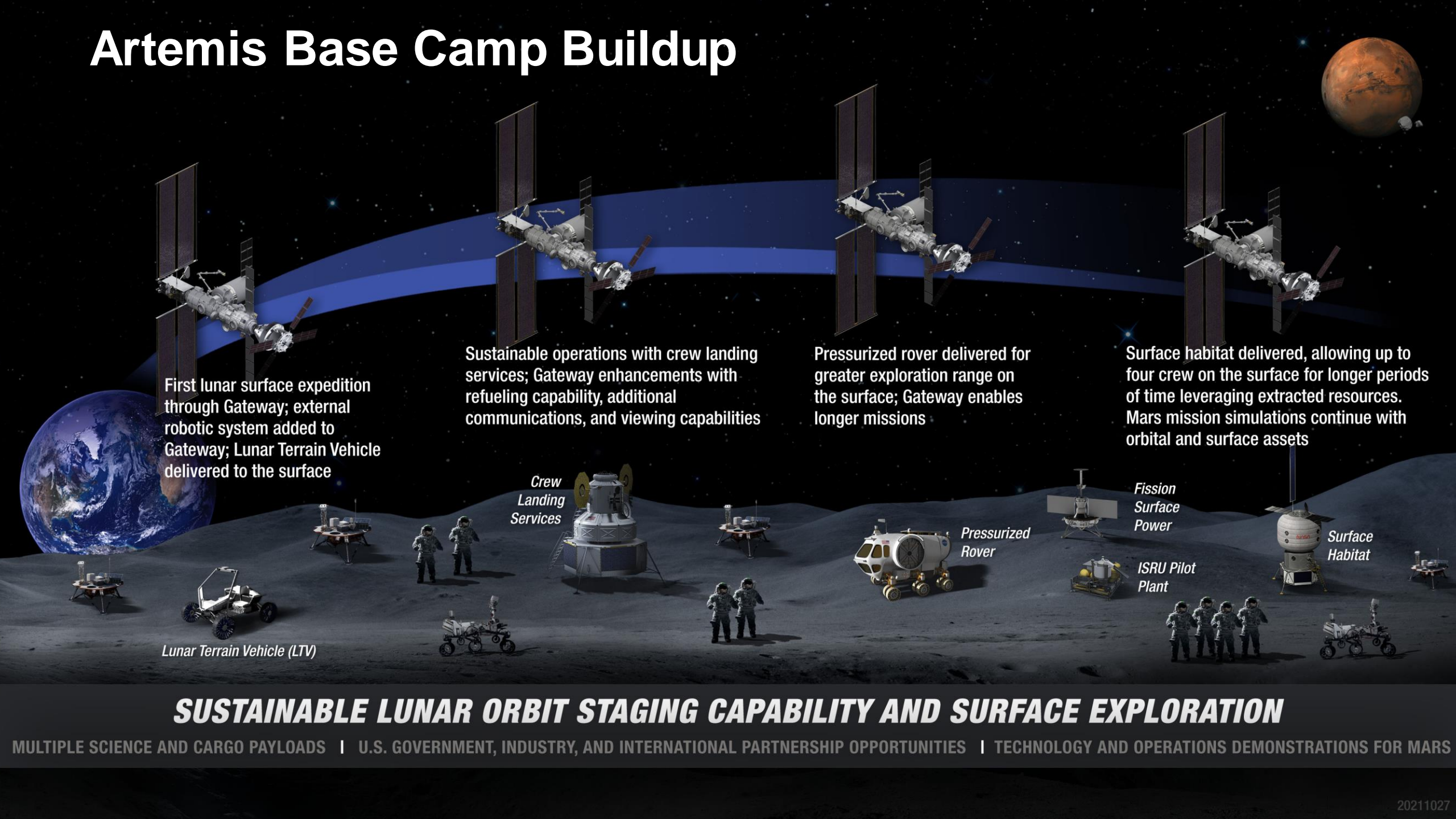
Uncrewed HLS Demonstration



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

LUNAR SOUTH POLE TARGET SITE

Artemis Base Camp Buildup

A diagram illustrating the four stages of the Artemis Base Camp buildup. The background shows a curved blue band representing the lunar orbit, with four Gateway stations at different points. The foreground shows the lunar surface with various assets. The Earth is visible on the left, and Mars is in the top right corner.

First lunar surface expedition through Gateway; external robotic system added to Gateway; Lunar Terrain Vehicle delivered to the surface

Sustainable operations with crew landing services; Gateway enhancements with refueling capability, additional communications, and viewing capabilities

Pressurized rover delivered for greater exploration range on the surface; Gateway enables longer missions

Surface habitat delivered, allowing up to four crew on the surface for longer periods of time leveraging extracted resources. Mars mission simulations continue with orbital and surface assets

Lunar Terrain Vehicle (LTV)

Crew
Landing
Services

Pressurized
Rover

Fission
Surface
Power

ISRU Pilot
Plant

Surface
Habitat

SUSTAINABLE LUNAR ORBIT STAGING CAPABILITY AND SURFACE EXPLORATION

MULTIPLE SCIENCE AND CARGO PAYLOADS | U.S. GOVERNMENT, INDUSTRY, AND INTERNATIONAL PARTNERSHIP OPPORTUNITIES | TECHNOLOGY AND OPERATIONS DEMONSTRATIONS FOR MARS

GATEWAY ORBIT

Cislunar space offers innumerable orbits for consideration, each with merit for a variety of operations. The Gateway will support missions to the lunar surface and serve as a staging area for exploration farther into the solar system, including Mars.

ORBIT TYPES

LOW LUNAR ORBITS

Circular or elliptical orbits close to the surface; excellent for remote sensing, difficult to maintain in gravity well.

» Orbit period: 2 hours

DISTANT RETROGRADE ORBITS

Very large, circular, stable orbits; easy to reach from Earth, but far from the lunar surface

» Orbit period: 2 weeks

HALO ORBITS

Fuel-efficient orbits revolving around Earth-Moon neutral-gravity points

» Orbit period: 1-2 weeks

NEAR-RECTILINEAR HALO ORBIT (NRHO)

ACCESS

Easy to access from Earth orbit with many current launch vehicles; staging point for both lunar surface and deep space destinations

ENVIRONMENT

The deep space environment is useful for radiation testing and experiments in preparation for missions to the lunar surface and Mars

SCIENCE

Favorable vantage point for Earth, sun and deep space observations

COMMUNICATIONS

Provides continuous view of Earth and communication relay for lunar farside

SURFACE OPERATIONS

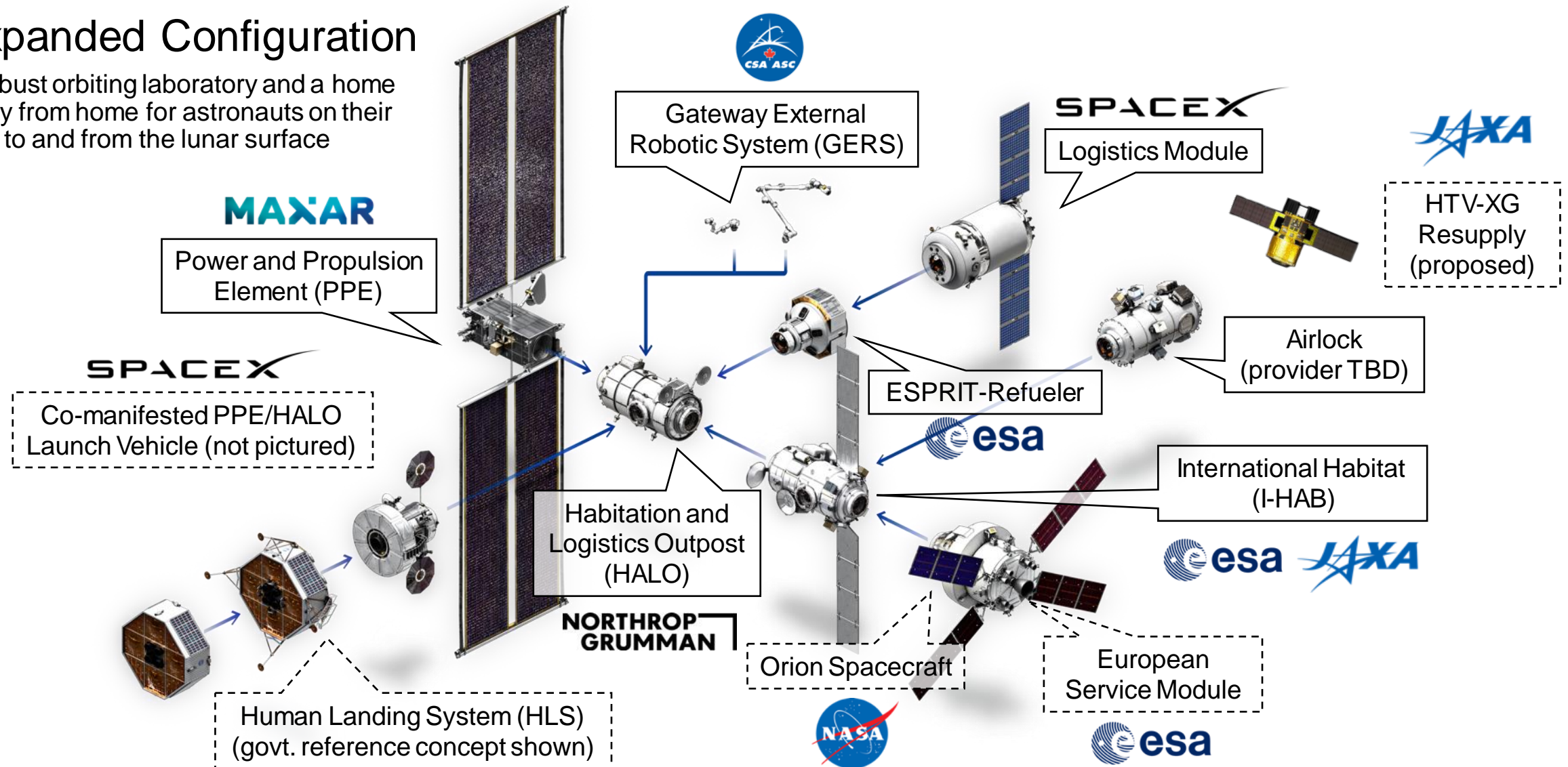
Supports surface telerobotics, including lunar farside; provides a staging point for planetary sample return missions

NRHO

GATEWAY

Expanded Configuration

A robust orbiting laboratory and a home away from home for astronauts on their way to and from the lunar surface





ARTEMIS ACCORDS

United for Peaceful Exploration of Deep Space



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

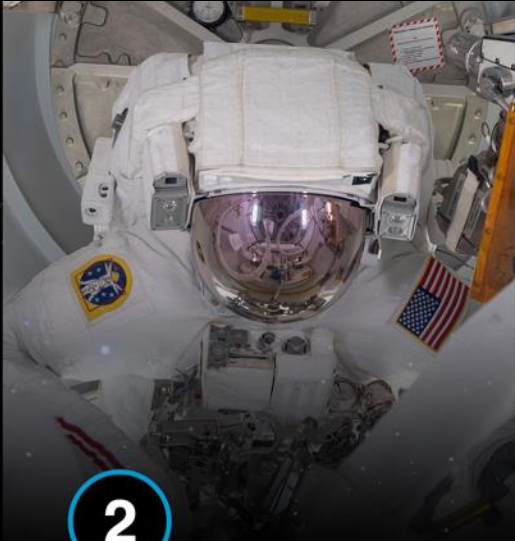
Gravity (or lack thereof)

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.



LTV

Lunar Terrain Vehicle Unpressurized Rover



PRESSURIZED ROVER



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

Advanced SPACE SUITS

- Increased flexibility to enable lunar surface exploration and advanced sample collection
- Increased anthropomorphic range to accommodate a wider range of crew members
- Rechargeable system and life support subsystems enabling high frequency spacewalks and long duration stays on the Moon's surface
- Specialized tools ensure quality samples are collected and returned safely to Earth

Pictured left: Kristine Davis, a spacesuit engineer at NASA's Johnson Space Center, wears a ground prototype of NASA's Exploration Extravehicular Mobility Unit (xEMU)



Bots Before Boots

Robots living and working on Mars today pave the way for smarter, safer human exploration of the lunar south pole



Evolving Habitation Systems for SUSTAINABLE HUMAN EXPLORATION

Use ISS as Testbed for Evolution
of ECLSS and CHPS



International Space Station (ISS)

Continue Testbeds on
Commercial Platforms in LEO



*Notional Commercial
Platform in LEO*

Infuse Technologies
into Gateway

*Orion and
Gateway*

- Toilet
- CO₂ removal
- Environmental monitoring
- Exercise technology
- Radiation protection and monitoring
- Medical system
- Fire suppression and cleanup

Infuse Full Long Duration Microgravity
ECLSS and CHPS into Mars Transport



Mars-class Transportation

- Highly-reliable regenerative ECLSS from ISS demonstration
- Environmental monitors
- Exploration food system
- Countermeasures
- Medical system
- Radiation protection

Complementary Ground
Tests and Analogs

- Food system performance and reliability testing
- CHPS integrated analogs



Human Landing System and Sustained
Lunar Surface ECLSS-CHP Infusion

- Partial gravity and exploration atmosphere fire safety
- Exploration spacewalk pre-breathe and conops
- Surface habitat: regenerative ECLSS and CHPS adapted for surface
- Pressurized rover: ECLSS waste collection and transfer



Mars Surface ECLSS-CHPS

- Robust microbial and chemical monitoring
- Planetary protection compatible waste strategy

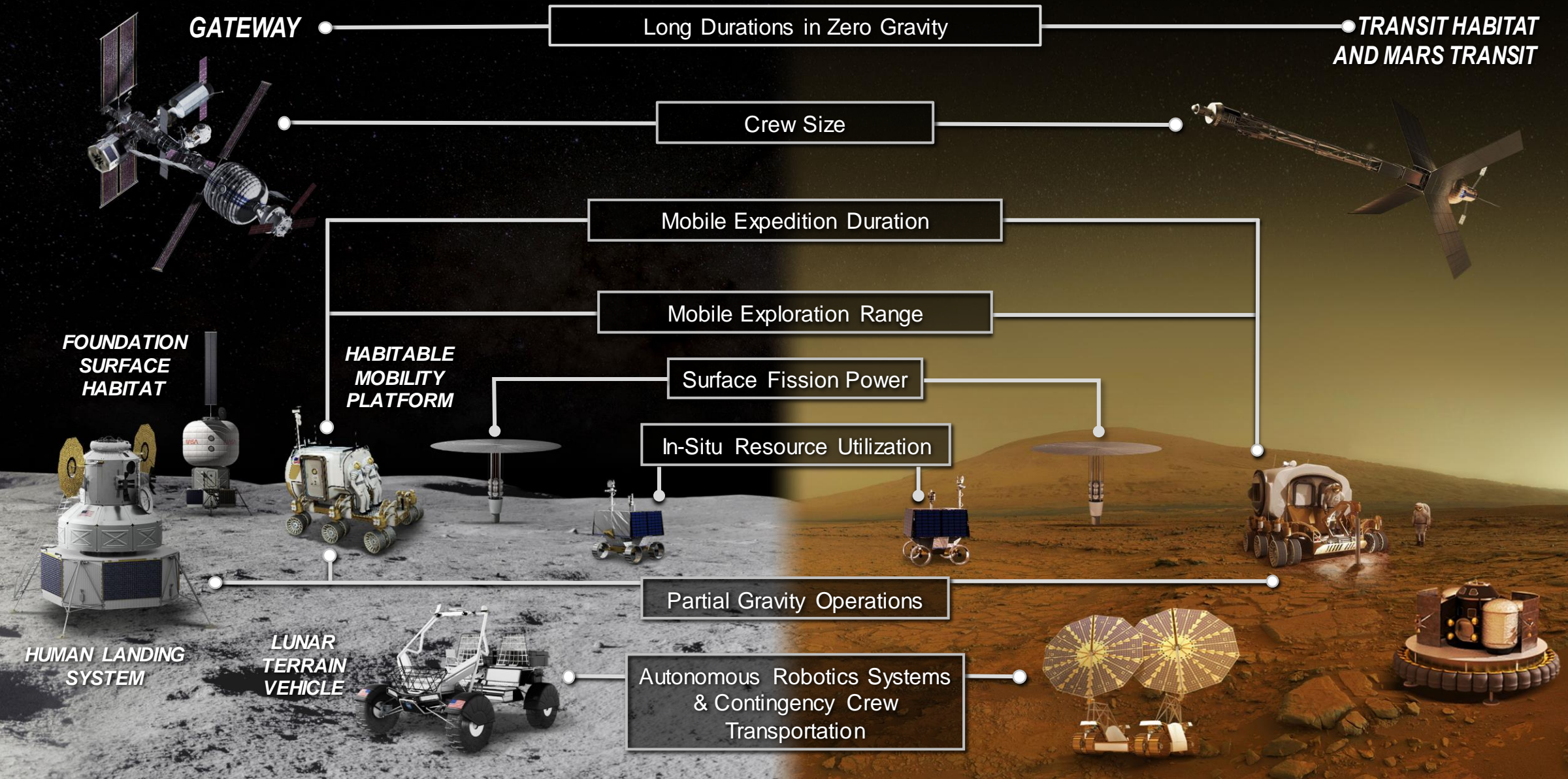


ECLSS = Environmental Control and Life Support Systems | CHPS = Crew Health and Performance Systems | LEO = Low-Earth Orbit

GRAPHICS NOT TO SCALE 20210116

MOON AND MARS EXPLORATION

Operations on and around the Moon will help prepare for the first human mission to Mars



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

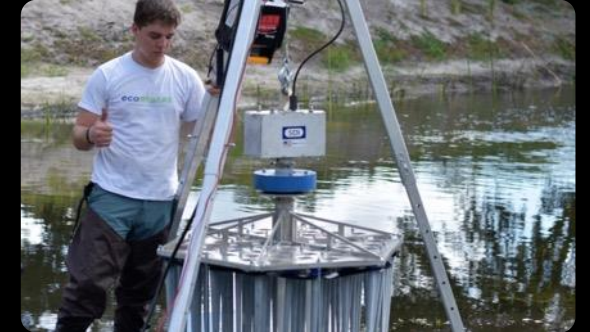
Everyone
benefits:



Students



Construction Workers



Conservationists



Farmers



Doctors and Patients



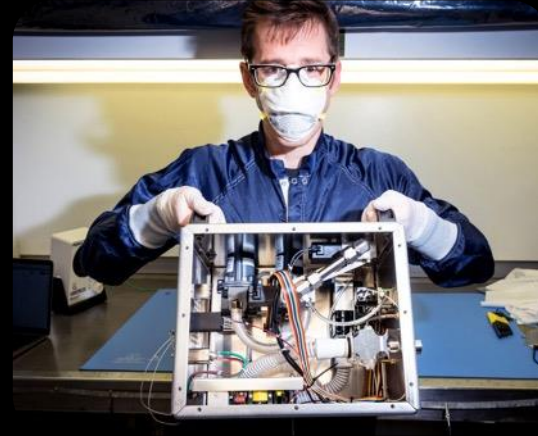
Airplane Passengers



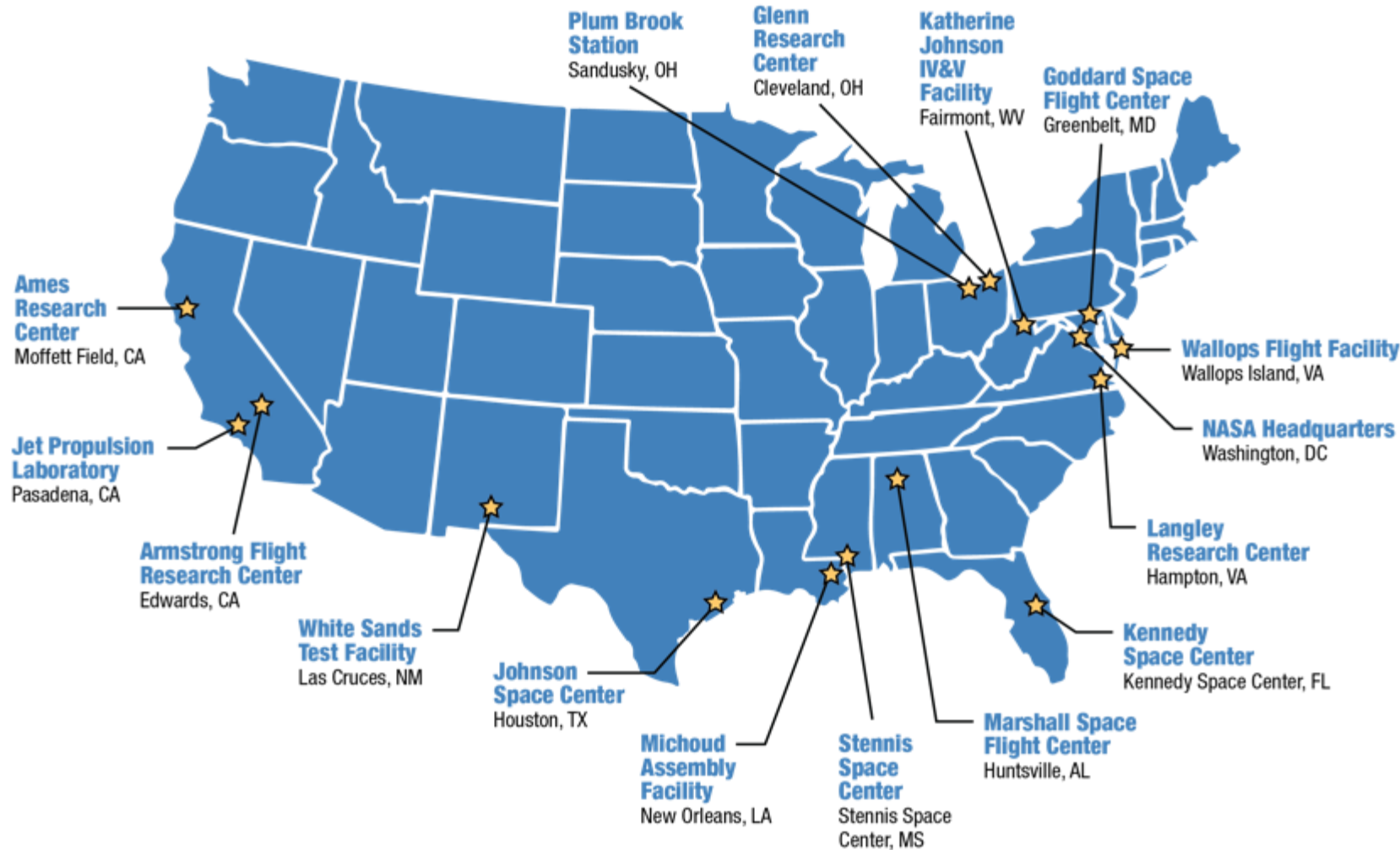
First Responders

NASA spinoff technologies:

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



Every NASA Center Contributes to Artemis



Suppliers and small businesses across America have made contributions to the success of NASA's Artemis program.

Private companies are hard at work on innovations that will help establish a sustainable human presence at the Moon. The Artemis endeavor also extends beyond our borders.

For detailed information about NASA's partners and where to find them, visit the Artemis partners map at www.nasa.gov/content/artemis-partners