



# Moon Mission Architecture

ASTR 5835 Planetary Seminar

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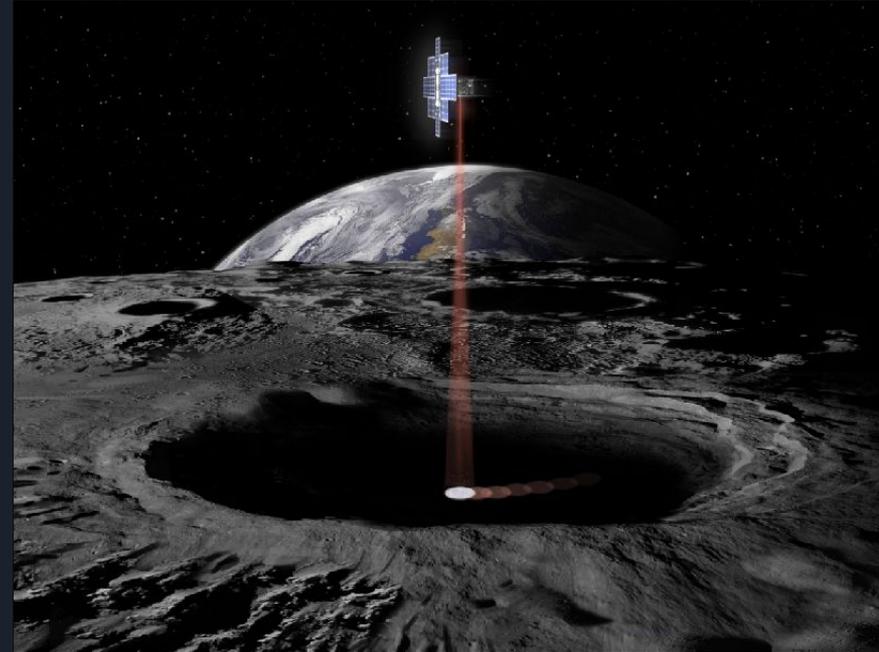


# Artemis I

- First integrated flight test of NASA's Deep Space Explorations Systems (DSES)
- Includes Orion, SLS rocket, and updated Ground Systems at Kennedy Space Center
- Mission Goal: "To assure a safe crew module entry, descent, splashdown, and recovery" - [nasa.gov](https://www.nasa.gov)
- Artemis I is a test with no crew to prepare the way for Artemis II with a crew
- Men and Women in all 50 states currently building DSES

# Payload

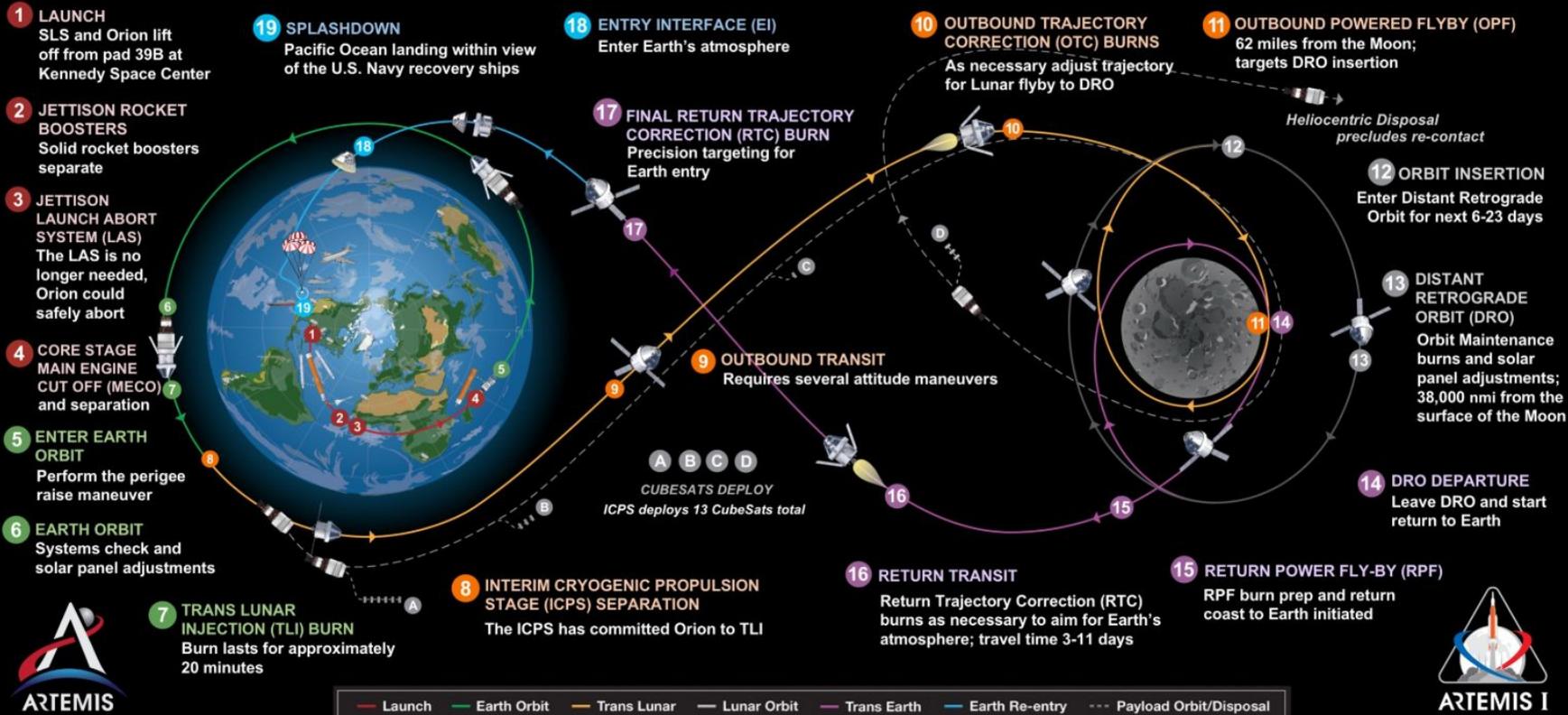
- Taking CubeSats to the Moon!
- 13 Sci-Tech satellites to test various capabilities for human existence and beyond
- Lunar Flashlight and Lunar IceCube - 62 mile orbit
- BioSentinel - uses yeast to detect radiation's effect on life
- CuSP - weather station to measure particles & B Fields



Lunar Flashlight

# ARTEMIS I

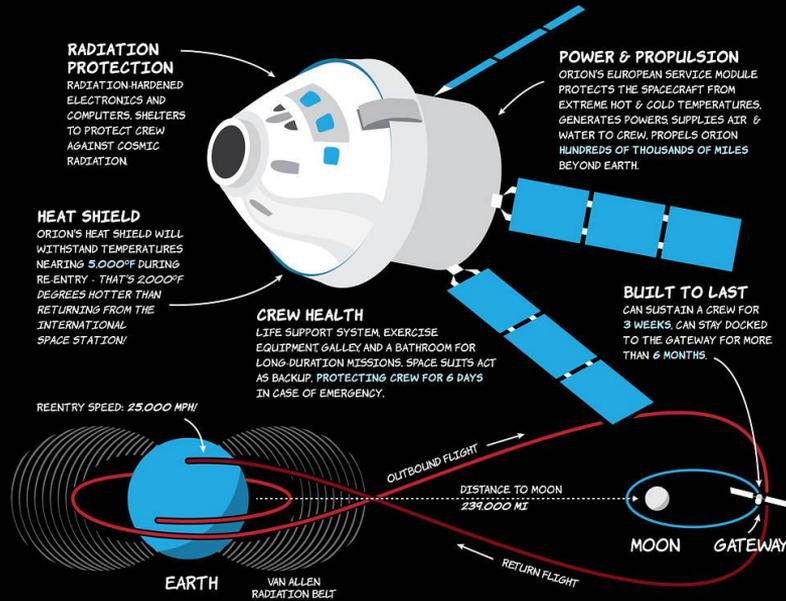
The first uncrewed, integrated flight test of NASA's Orion spacecraft and Space Launch System rocket, launching from a modernized Kennedy spaceport



Total distance traveled: 1.3 million miles – Mission duration: 26-42 days – Re-entry speed: 24,500 mph (Mach 32) – 13 CubeSats deployed

# DESIGNED FOR DEEP SPACE

# ORION



# SLS Rocket

- World's most powerful - only rocket that can send Orion, astronauts, and large cargo to the Moon on a single mission
- Offers more payload mass (26 metric tons/57,000 lbs), volume capability, and energy (8.8M lbs thrust) for space missions than any other launch vehicle



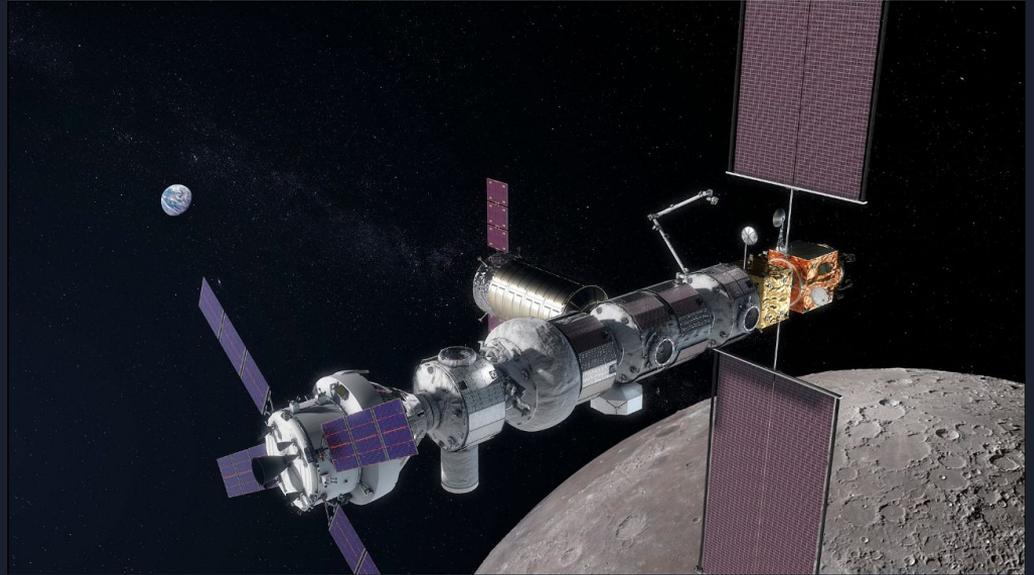


# Artemis II

- First manned crew to the moon in the 21st Century
- 2 week mission to test astronaut capability to operate Orion in deep space - won't actually land on the Moon
- Test technology to develop habitation capabilities
- Explore multiple stable staging orbits for future missions

# Gateway

- Like the ISS but for the moon - lunar orbital platform
- Serve as communications hub, laboratory, habitation model, and holding area for robots
- Developed, serviced, and utilized by international partners
- Serve as staging point for robotic and crewed exploration of lunar south pole
- Proposed staging point for concept of Moon to Mars transport



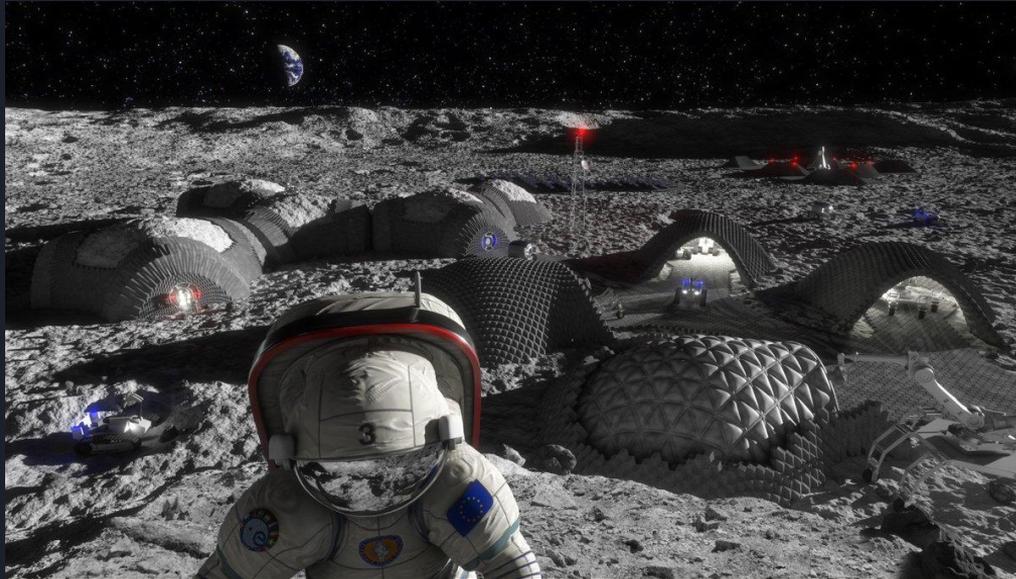
# Artemis III

- First mission to land humans on Moon since Apollo in 1972
- Challenging goal set for 2024
- Mission goal - put four astronauts in orbit and send two down to the surface on the lunar South Pole for a week
- First mission to put a woman on the moon



# Future Missions

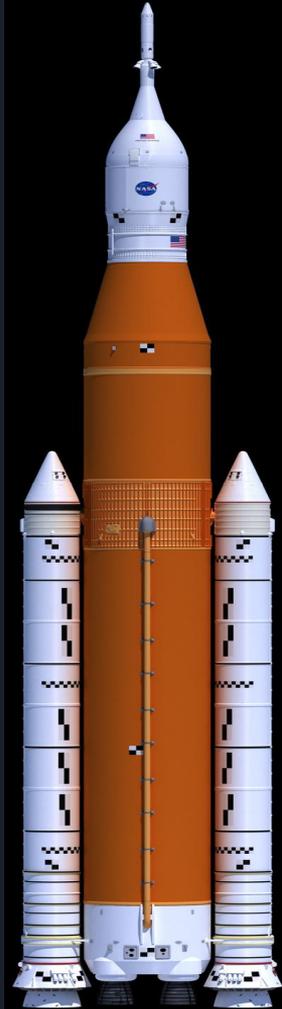
- Beyond the first few Artemis missions, NASA has plans to fly at least one crewed mission a year to the Moon in an effort to become Earth-independent, looking out long-term.



# Power, Propulsion and Communication

## Space Launch System (SLS)

- Has two of the largest and most powerful solid propellant boosters ever built for flight
- Able to burn 6 tonnes of propellant every second
- Thrust is greater than 14 full powered four-engine Boeing 747s at take-off
- The core stage is powered by 4 RS-25 engines
- Each engine is the size of a car and weighs up to 8000 lbs (3629 kg)
- Holds 196000 gallons (742000 litres) of liquid O<sub>2</sub> and 537000 gallons of liquid H<sub>2</sub>



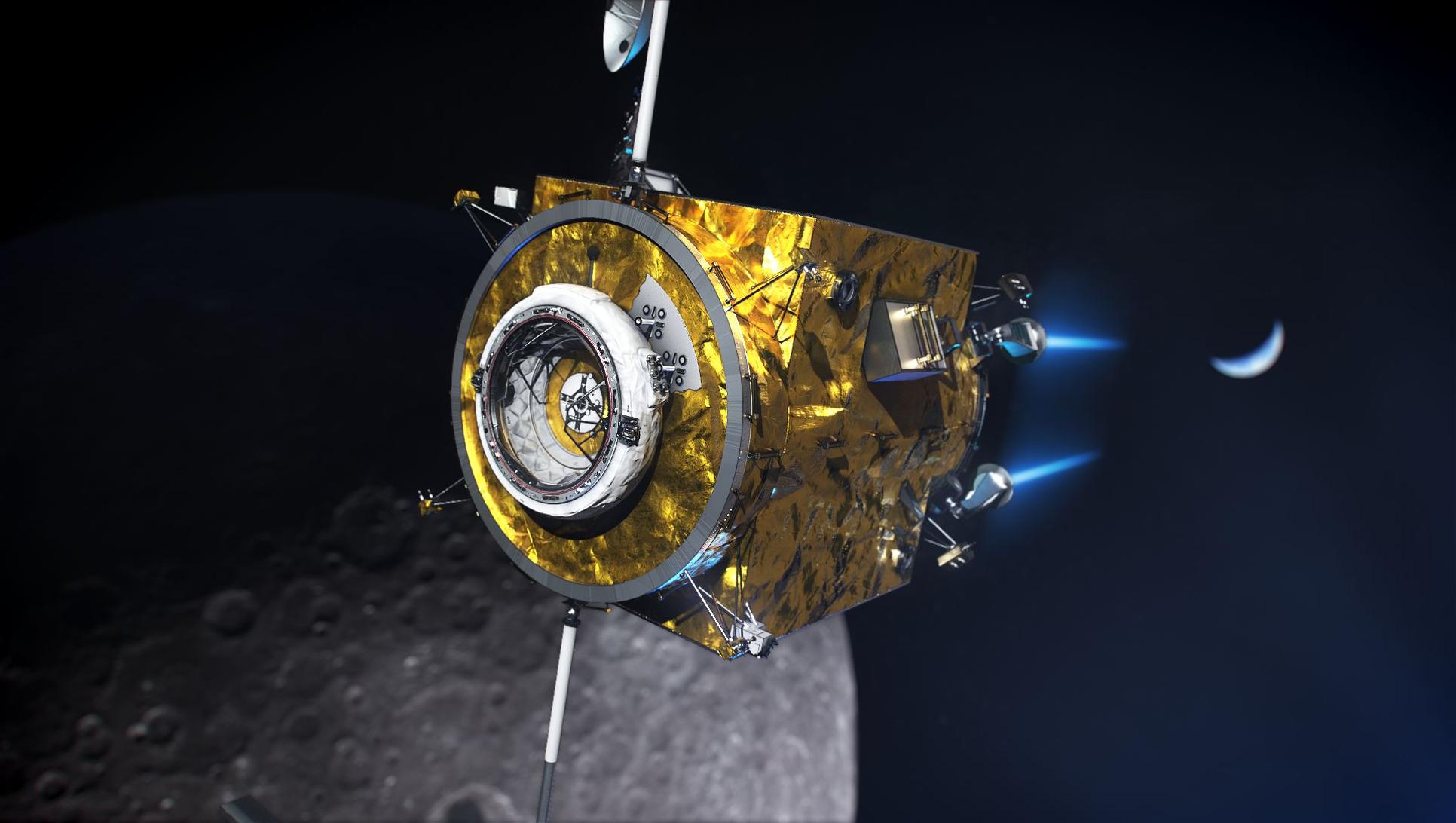
# Power, Propulsion and Communication



# MAXAR

## Lunar Gateway Power Propulsion Element (PPE)

- The first element of Gateway - will be launched in 2022
- Maxar Technologies, Westminster, Colorado
- Provide electric power for future elements of Gateway
- Orbiting the moon using Solar Electric Propulsion

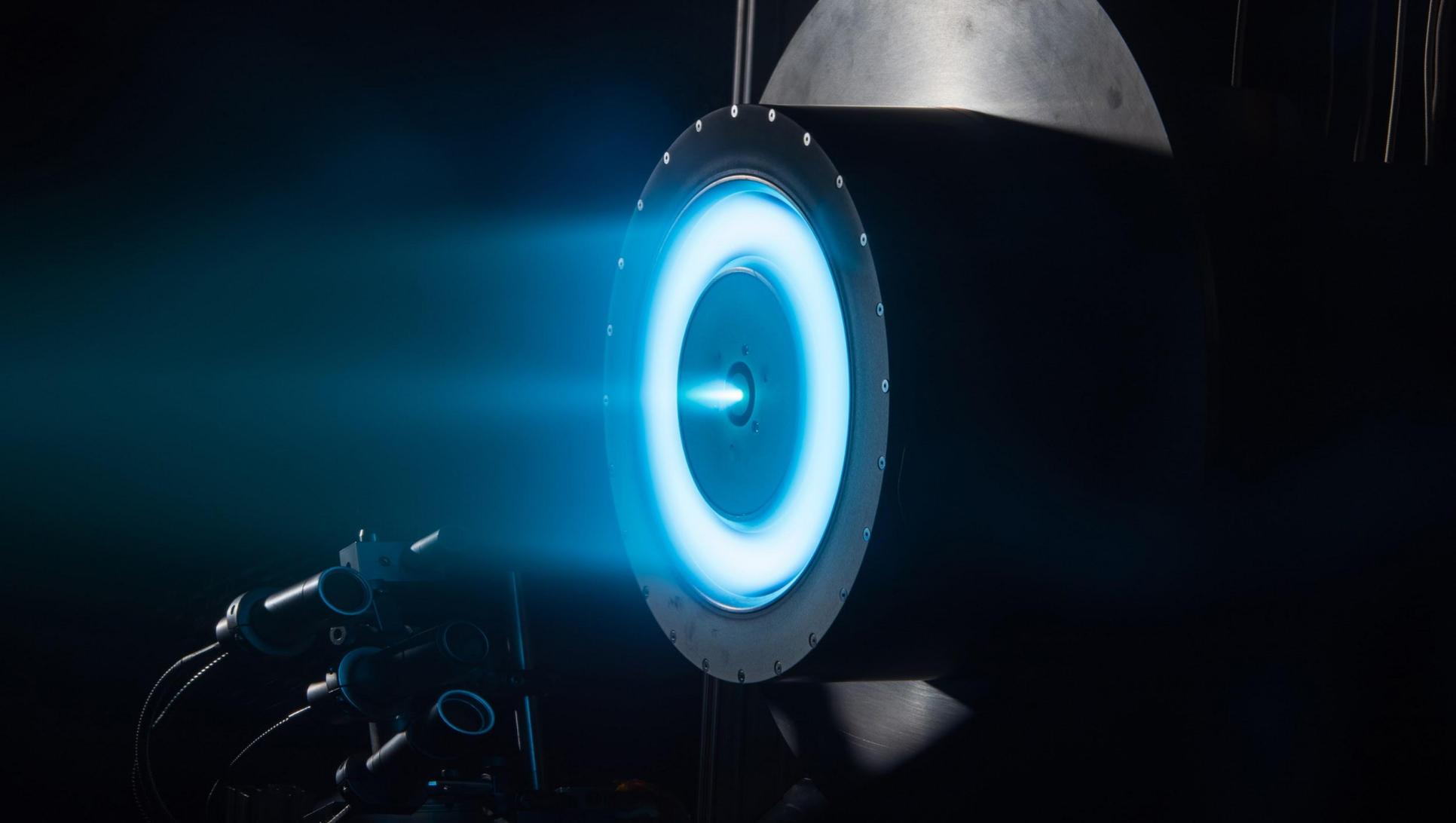




# NASA's Solar Electric Propulsion (SEP) Project

*'Right mix of cost savings, safety and superior propulsive power'*

- Energized by the electric power from onboard solar arrays
- Solar arrays are built to be radiation resistant and small and lightweight for launching
- Two current designs: folds out, rolls out
- Energy is fed to electrostatic Hall thrusters that provide nonstop thrust
- Hall thrusters generate and trap electrons in a magnetic field
- The electrons ionize the inert gas Xenon (the propellant)
- Causes an exhaust plume of plasma to accelerate spacecraft forward
- 10x times less propellant than the conventional chemical propulsion system



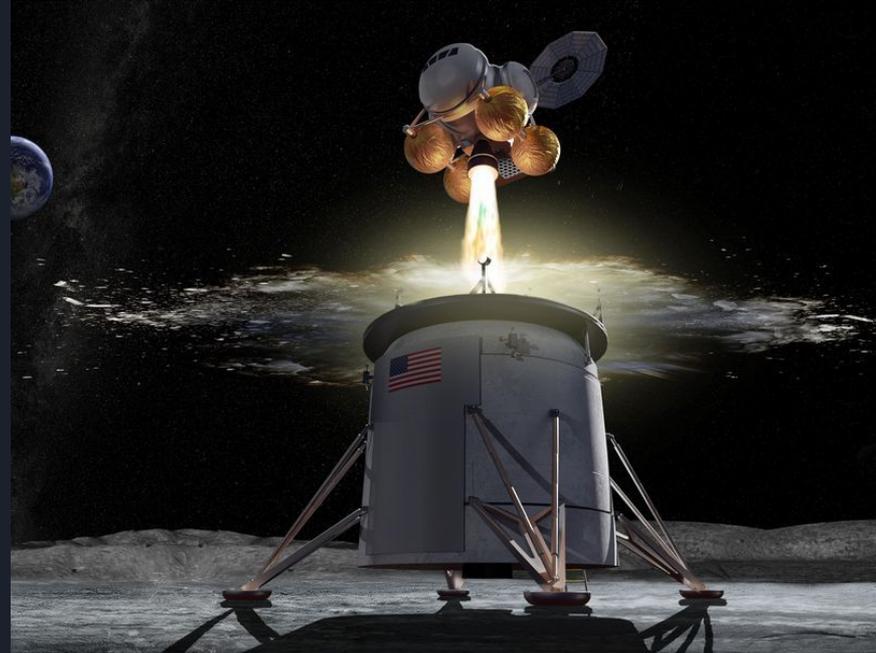
# Lunar Lander - Blue Origin

- Uses liquid hydrogen and liquid hydrogen propellants
- Ultimately use water from the surface of the moon to refuel the vehicles
- The propellants will be used by the BE-7 engine which will produce 10,000 pounds force of thrust



# Lunar Lander - Lockheed Martin

- Accelerated Lander - Lockheed
- Descent from moon - likely use cryogenic propellants (H, O)
- Technology for propellants to stay liquid for a week or two
- Makes cryogenics attractive for a moon mission





# Communications

## Lunar Gateway - PPE

- Solar powered communications hub
- High rate communications to and from Earth with lunar far side
- S-band communication system to provide a radio link with nearby vehicles
- Initial communication support for lunar surface systems

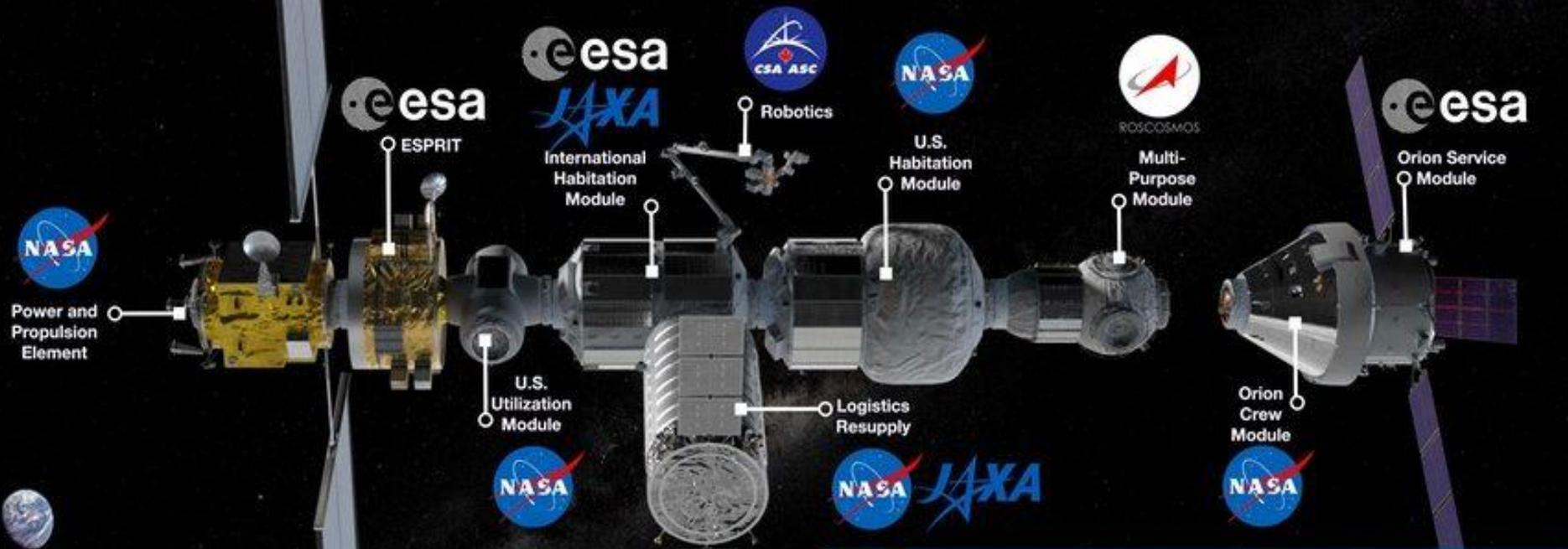
# Communications



ESPRIT (European System Providing Refueling, Infrastructure and Telecommunications)

- Carries a communications antennae to maintain contact with the lunar surface
- Separate s-band radio link for inter spacecraft communications
- High data rate channel for communications with Earth
- Capability to use ESPRIT as a relay station between ground control and lunar surface hardware

# GATEWAY CONFIGURATION CONCEPT



EXPLORE  
MOON to MARS

A DEEP SPACE HUB FOR SCIENCE AND EXPLORATION COLLABORATION



Command Module for Lunar Surface Assets



Internal and External Payloads



Internal and External Robotics



Mixed Fleet Deliveries



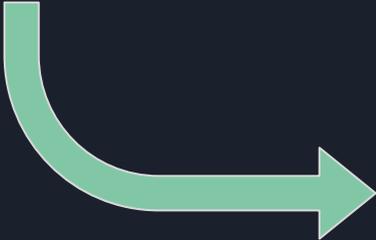
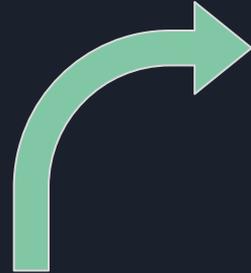
Human Lunar Surface Systems



International Crew



So if we go up there,  
what will happen  
down here?

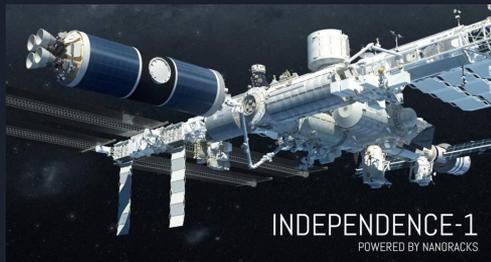


# New Space Technologies for Exploration Partnerships (NextSTEP)

- “Public-private partnership model that seeks commercial development of deep space exploration capabilities to support more extensive human spaceflight missions in and beyond cislunar space”
- 12 partnerships announced in 2015
  - Ad Astra, Aerojet Rocketdyne, MSNQ, Bigelow, Boeing, Dynetics, Hamilton Sundstrand Space Systems, Lockheed Martin, Orbital ATK, Orbital Technologies, Morehead State University
- In 2016, 11 appendices were added that solicited proposals in specific research areas
  - Including habitation Systems, power and propulsion element studies, human landing system studies, trash compaction and processing,...



# NextSTEP-Habitation



NanoRacks



Bigelow



Boeing



Lockheed Martin



Northrop Grumman



Sierra Nevada

# NextSTEP-Human Landers

Solicitation for human landers made in August.

Responses were due September 6, and winners will be selected this winter.

NASA is currently working with 11 companies on a human landing system.

- Aerojet, Blue Origin, Boeing, Dynetics, Lockheed Martin, Masten, Northrop Grumman, Orbit Beyond, Sierra Nevada, SpaceX, SSL



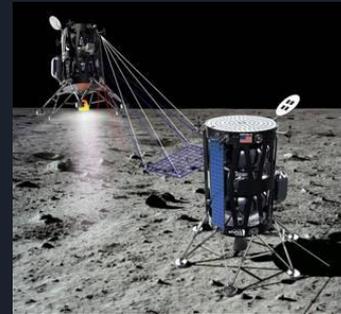
Lockheed Martin



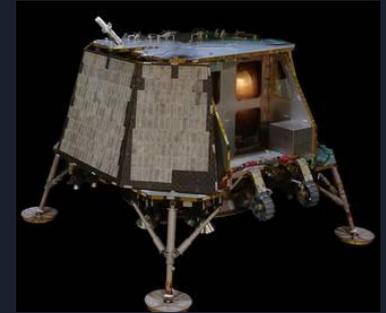
Blue Moon

# Commercial Lander Payload Services (CLPS)

- Launched in April 2018 to “contract transportation services able to send small robotic landers and rovers to Mars”
- November 2018, 9 US companies selected for eligibility to bid on NASA delivery services
  - Astrobotic, Deep Space Systems, Draper, Firefly, Intuitive Machines, Lockheed Martin, Masten, Moon Express, Orbit Beyond
- June 2019 NASA selected 3 commercial Moon landing service providers that will deliver science technology payloads
  - Astrobotic, Intuitive Machines, Orbit Beyond
- Latest CLPS announcement made at end of July 2019



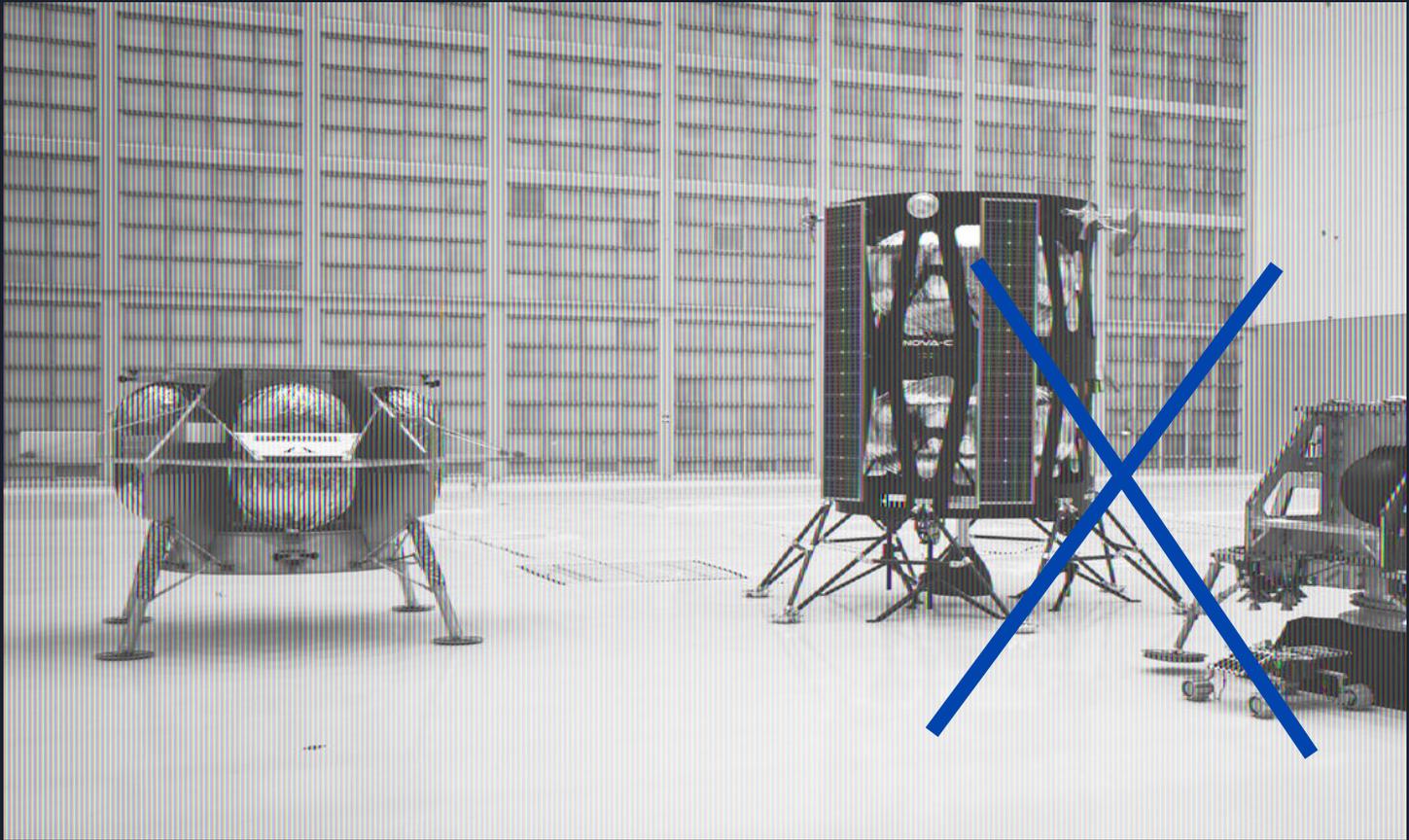
Intuitive Machines



Orbit Beyond



Astrobotic





# 12 Payloads selected by NASA for the first 3 CLPS missions:

1. MoonRanger (Astrobotic)
  2. Heimdall (Planetary Science Institute, Tucson, Arizona)
  3. Lunar Demonstration of a Reconfigurable, Radiation Tolerant Computer System (Montana State University, Bozeman)
  4. Regolith Adherence Characterization (Alpha Space Test and Research Alliance, LLC, Houston)
  5. Lunar Magnetotelluric Sounder (Southwest Research Institute, San Antonio)
  6. Lunar Surface Electromagnetics Experiment (University of California, Berkeley)
  7. Lunar Environment heliospheric X-ray Imager (Boston University)
  8. Next Generation Lunar Retroreflectors (University of Maryland, College Park)
  9. Lunar Compact InfraRed Imaging System (CU Boulder)
  10. Lunar Instrumentation for Subsurface Thermal Exploration with Rapidity (Texas Tech University, Lubbock)
  11. PlanetVac (Honeybee Robotics, Ltd., Pasadena, California)
  12. Sample Acquisition, Morphology, Filtering, and Probing of Lunar Regolith (Maxar Technologies, Westminster, Colorado)
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# International Collaboration

- This past weekend, the Australian Space Agency signed a joint statement of intent
- Australian Space Agency's budget to triple in support of Artemis and Moon to Mars.
- Australian Space Agency just over a year old





Ispace





All of the partnerships!





Introducing a new perspective...  
Let's stir the pot.



# Things to consider...

Trash

Recent failed attempts

Space tourism

Interests of private companies: depends on investors; b/c of proprietary issues, companies seldom share reasons for failed projects publicly

Protest to CLPS program by Deep Space Systems

Token female astronaut

(Current) American political leadership

Personal enlightenment

Non-regulated deals

Communication with the public

Government shutdowns

Night sky and Moon system

SOS missions and lawsuits

Military presence

Environmental activism

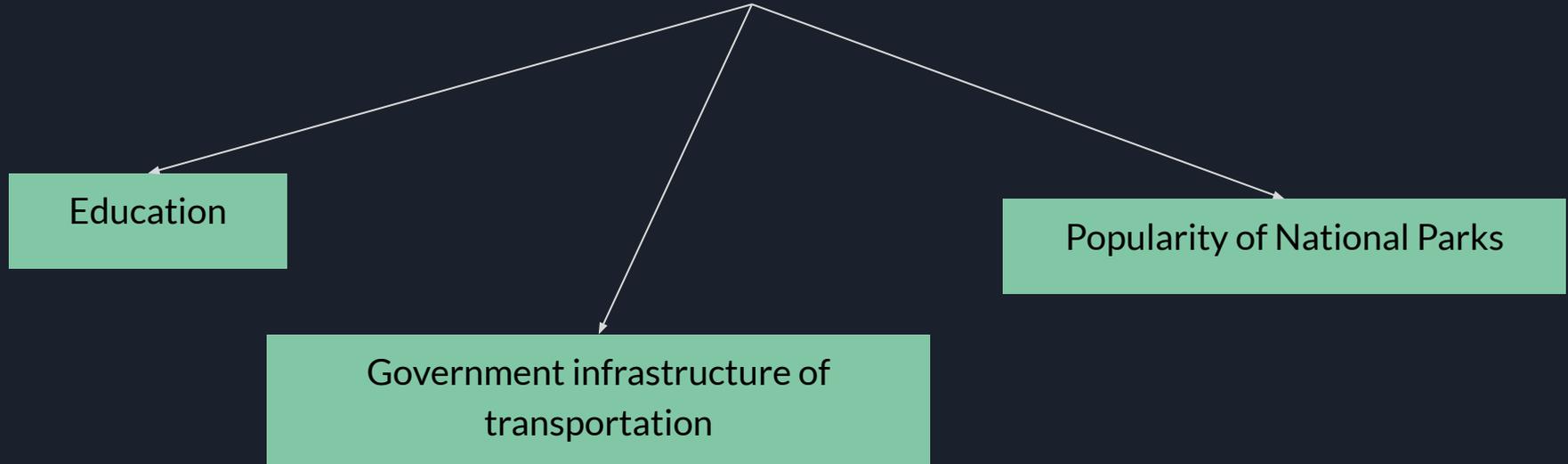
Nationalism

Cultural/social divide between general populus and science community



# Thought experiment

Is privatizing space exploration good or bad?  
Let's make some analogies.





# Resources I

<https://www.nasa.gov/content/artemis-1-overview>

<https://www.nasa.gov/feature/lunar-flashlight-selected-to-fly-as-secondary-payload-on-exploration-mission-1>

<https://www.nasa.gov/press-release/nasa-space-launch-system-s-first-flight-to-send-small-sci-tech-satellites-int-o-space>

<https://www.nasa.gov/sites/default/files/thumbnails/image/artemis-1-update.jpg>

[https://www.nasa.gov/sites/default/files/atoms/files/2018\\_esd\\_factsheet\\_v6tagged.pdf](https://www.nasa.gov/sites/default/files/atoms/files/2018_esd_factsheet_v6tagged.pdf)

<https://www.nasa.gov/image-feature/orion-capabilities-for-deep-space-enable-crewed-artemis-moon-missions>

<https://www.nasa.gov/johnson/exploration/gateway>

<https://www.nasa.gov/exploration/systems/sls/overview.html>

[https://www.nasa.gov/mission\\_pages/tdm/sep/index.html](https://www.nasa.gov/mission_pages/tdm/sep/index.html)

<http://lasp.colorado.edu/home/mop/files/2019/09/Planetary-Science-Seminar-2019.pdf>

<https://www.nasa.gov/feature/nasa-s-first-flight-with-crew-important-step-on-long-term-return-to-the-moon-missions-to>



# Resources II

<https://www.nasa.gov/moontomars/#gateway>

<https://www.nasa.gov/press-release/nasa-awards-artemis-contract-for-lunar-gateway-power-propulsion>

<http://www.russianspaceweb.com/imp-lcub.html>

[https://www.esa.int/Our\\_Activities/Human\\_and\\_Robotic\\_Exploration/Exploration/Gateway](https://www.esa.int/Our_Activities/Human_and_Robotic_Exploration/Exploration/Gateway)

<https://spacenews.com/nasa-selects-maxar-to-build-first-gateway-element/>

[https://en.wikipedia.org/wiki/Lunar\\_Orbital\\_Platform\\_-\\_Gateway](https://en.wikipedia.org/wiki/Lunar_Orbital_Platform_-_Gateway)

[https://en.wikipedia.org/wiki/Artemis\\_3](https://en.wikipedia.org/wiki/Artemis_3)

<https://www.nasa.gov/content/nextstep-overview>

<https://www.nasa.gov/press/2015/march/nasa-announces-new-partnerships-with-us-industry-for-key-deep-space-capabilities>

<https://www.nasa.gov/feature/nasa-begins-testing-habitation-prototypes>

<https://bigelowaerospace.com/pages/beam/>



# Resources III

<https://www.nasa.gov/press-release/nasa-taps-11-american-companies-to-advance-human-lunar-landers>

<https://www.space.com/42011-lockheed-martin-unveils-huge-moon-lander.html>

[https://en.wikipedia.org/wiki/Commercial\\_Lunar\\_Payload\\_Services](https://en.wikipedia.org/wiki/Commercial_Lunar_Payload_Services)

<https://www.nasa.gov/press-release/nasa-selects-12-new-lunar-science-technology-investigations>

<https://www.nasa.gov/press-release/australian-government-commits-to-join-nasa-in-lunar-exploration-and-beyond>

<https://www.nasaspaceflight.com/2019/08/inspace-moon-mission-timelines-greater-response-customer/>