2021 Spaceport Summit

February 24, 2021 - 10:30am – 12:30pm ET

Lunar and Mars Exploration Panel

Mark Kirasich (Moderator, Artemis)
Deputy Associate Administrator, Advanced Exploration Systems, Human Exploration and Operations, NASA

Joel Kearns (Commercial Lunar Payload Services)
Deputy Associate Administrator, Exploration, Science Mission Directorate, NASA

Kathryn Lueders (Artemis)
Associate Administrator, Human Exploration and Operations, NASA

Ian Fichtenbaum (Building the Infrastructure of the Solar System)
CEO, Bradford Space

Eric Ianson (Mars Exploration)
Deputy Director, Planetary Science Division and Mars Exploration Program Director, Science Mission Directorate, NASA

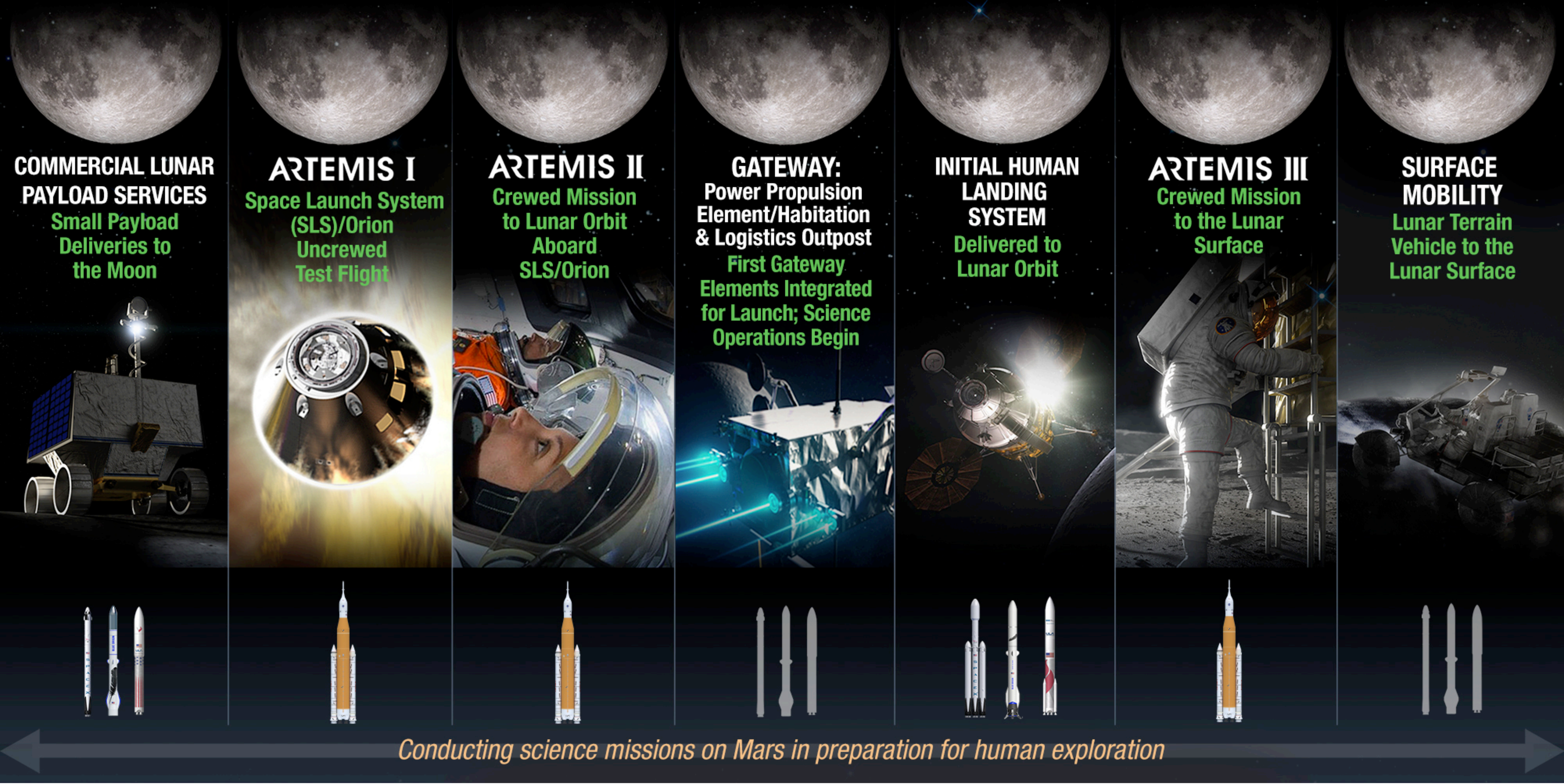
Sean Mahoney (The Moon: Get It)
CEO, Masten

Mark Kirasich (Moderator, Artemis)

Deputy Associate Administrator, Advanced Exploration Systems,
Human Exploration and Operations, NASA

ARTEMIS

NEAR TERM EXPLORATION PLANS



Gateway Status

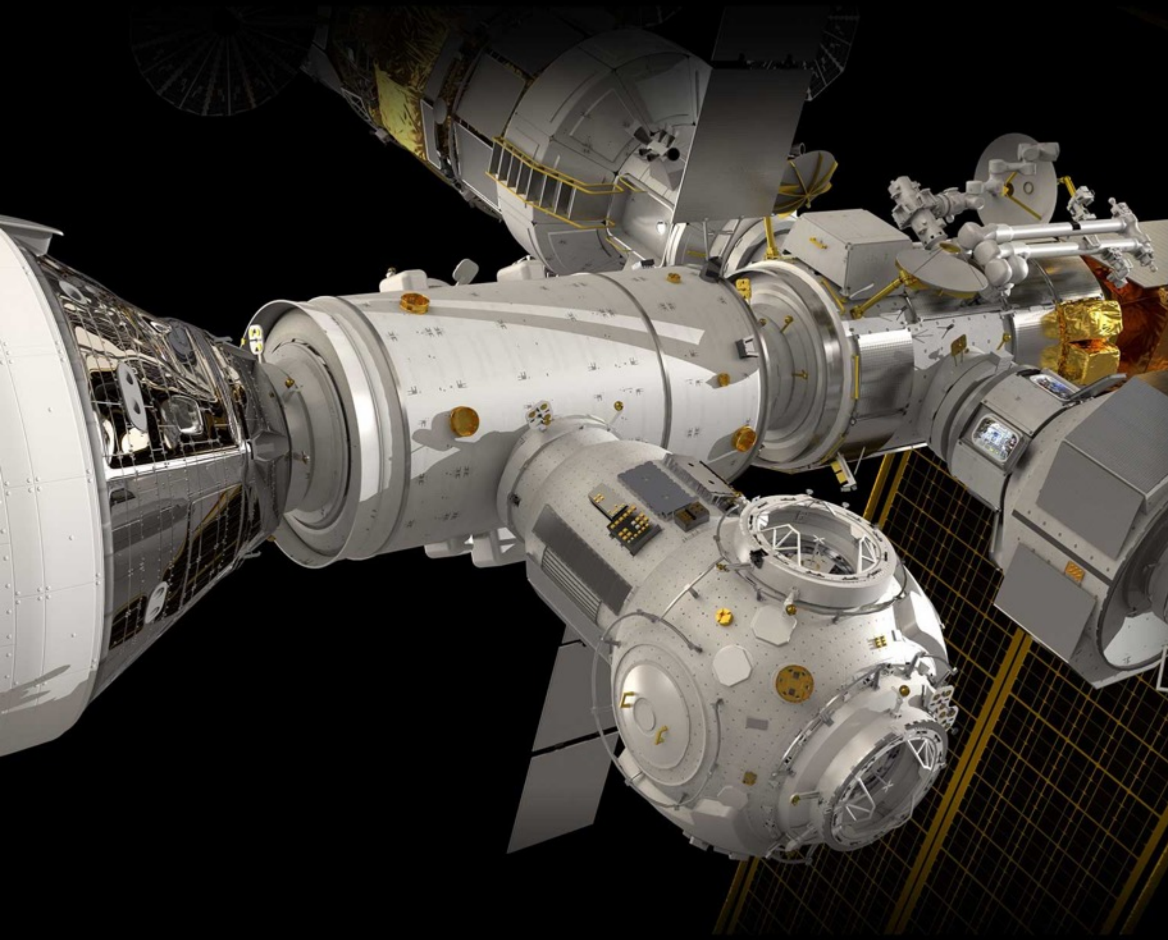


IMAGE CREDIT: ESA

OCT 2020
- ✓ Habitation and Logistics Outpost (HALO) Preliminary Design Review (PDR) Kick-Off
- ✓ Memorandum of Understanding (MOU) with the European Space Agency (ESA) signed

NOV 2020
- ✓ Maxar-led Power and Propulsion Element (PPE) Delta System Requirements and System Definition Reviews completed
- ✓ MOU with the Canadian Space Agency (CSA) signed

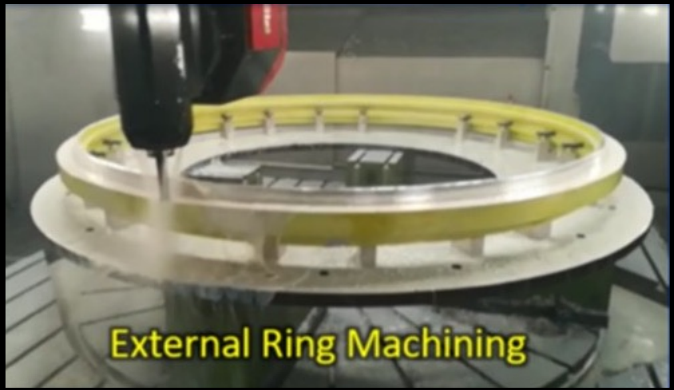
DEC 2020
- ✓ European System Providing Refueling, Infrastructure and Telecommunications (ESPRIT) contract awarded by ESA to Thales Alenia Space (France)
- ✓ Canadarm3 contract awarded by CSA to MDA
- ✓ MOU with the Japan Aerospace Exploration Agency (JAXA) signed

FEB 2021
- ✓ PPE/HALO Launch Vehicle contract award

MAR 2021
- Gateway Program Sync Review
- HALO PDR Close-out

APR 2021
- HALO final contract award (fixed price)
- Gateway Program Key Decision Point 0

HALO Hardware Progress



Human Landing System Status

NASA REFERENCE DESIGN

APR 2020 ✓ Base Period Selections Announced

MAY 2020 ✓ Base Period Contracts Awarded

AUG 2020 ✓ Contractor Certification Baseline Reviews (CBRs)

OCT 2020 ✓ Issue Option A Solicitation

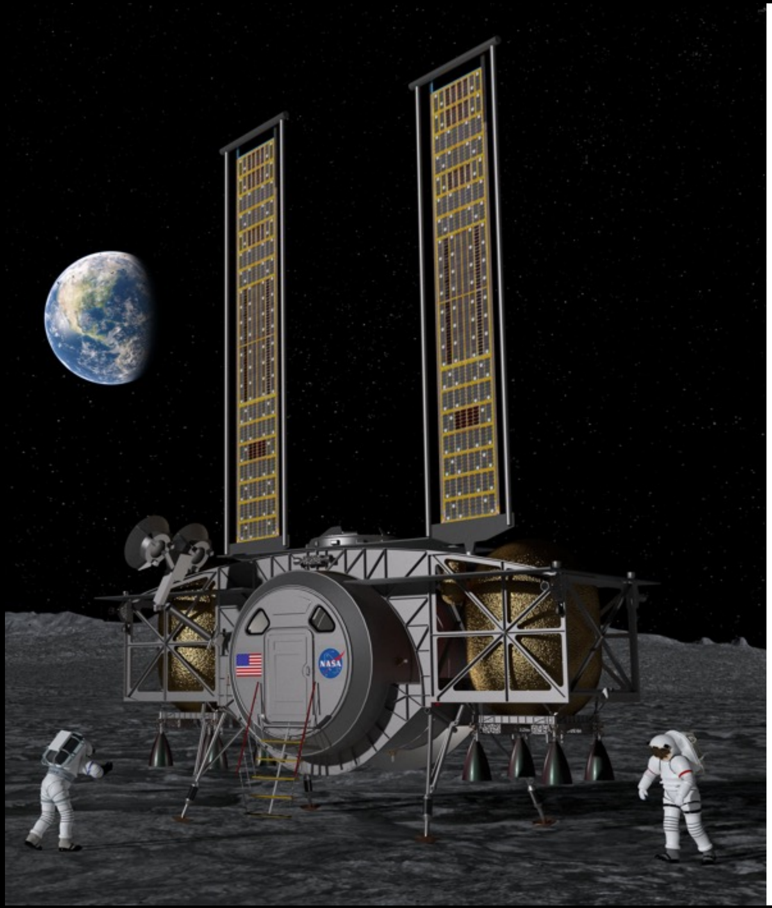
DEC 2020* ✓ Contractor Continuation Reviews (CRs)

**CR Closeouts complete Feb 2020*

MAR 2021** Up to two Option A Awards for Lander Development and a Crewed Demo Mission(s)

***Base Period was extended up to April 30, 2021*

Human Landing System Contractors



Dynetics
A Leidos Company

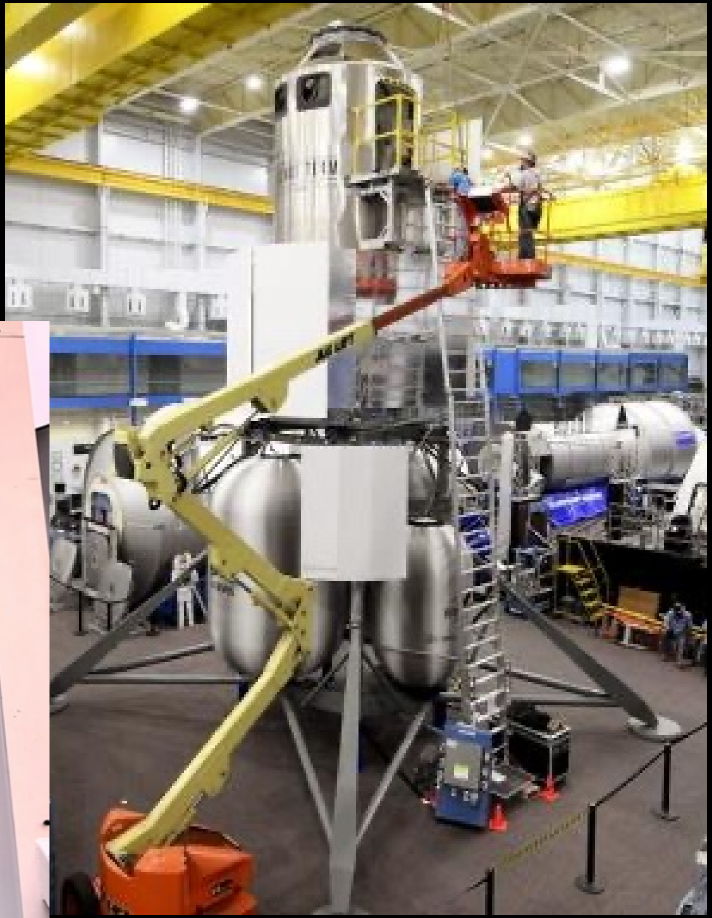
SPACEX

BLUE ORIGIN
LOCKHEED MARTIN
NORTHROP GRUMMAN
DRAPER

Human Landing System Low-Fidelity Mockups

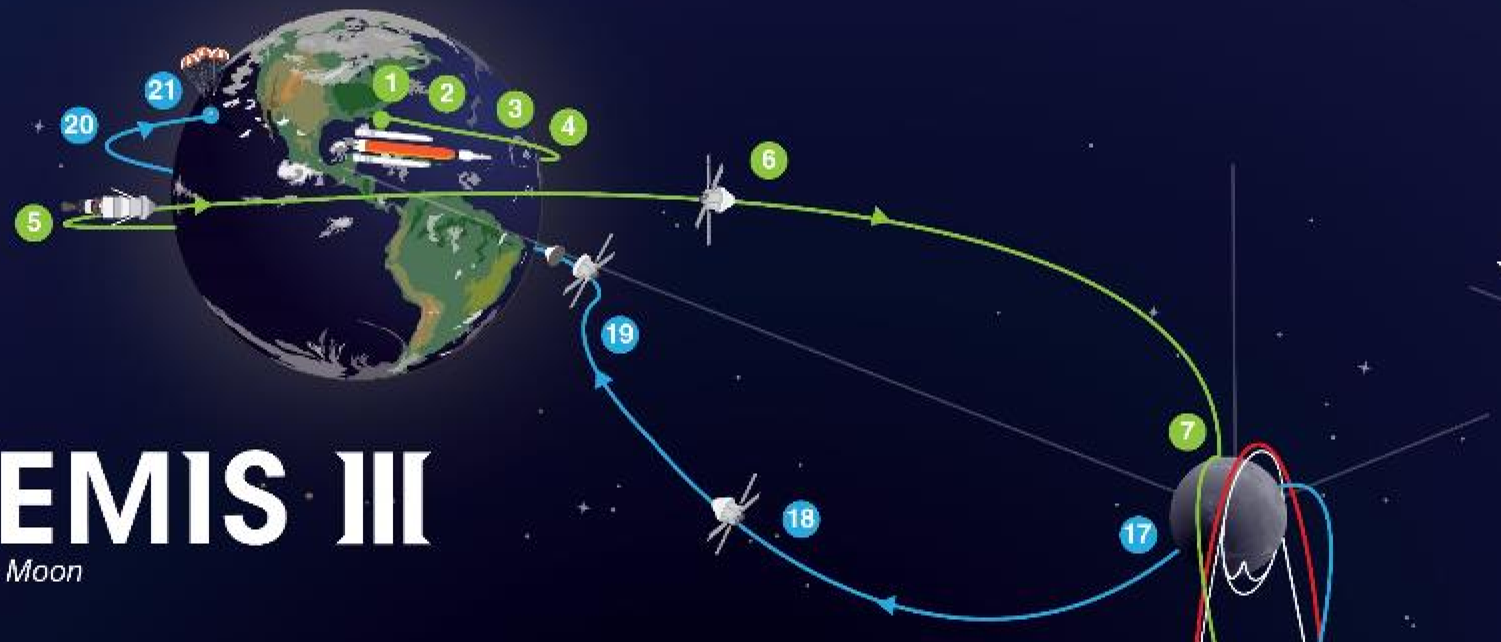
Dynetics

SpaceX



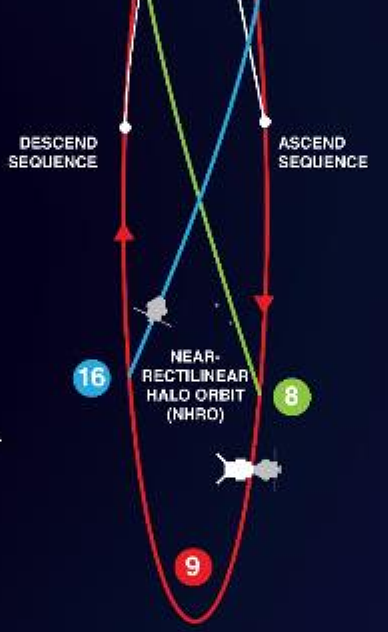
Blue Origin-led Team

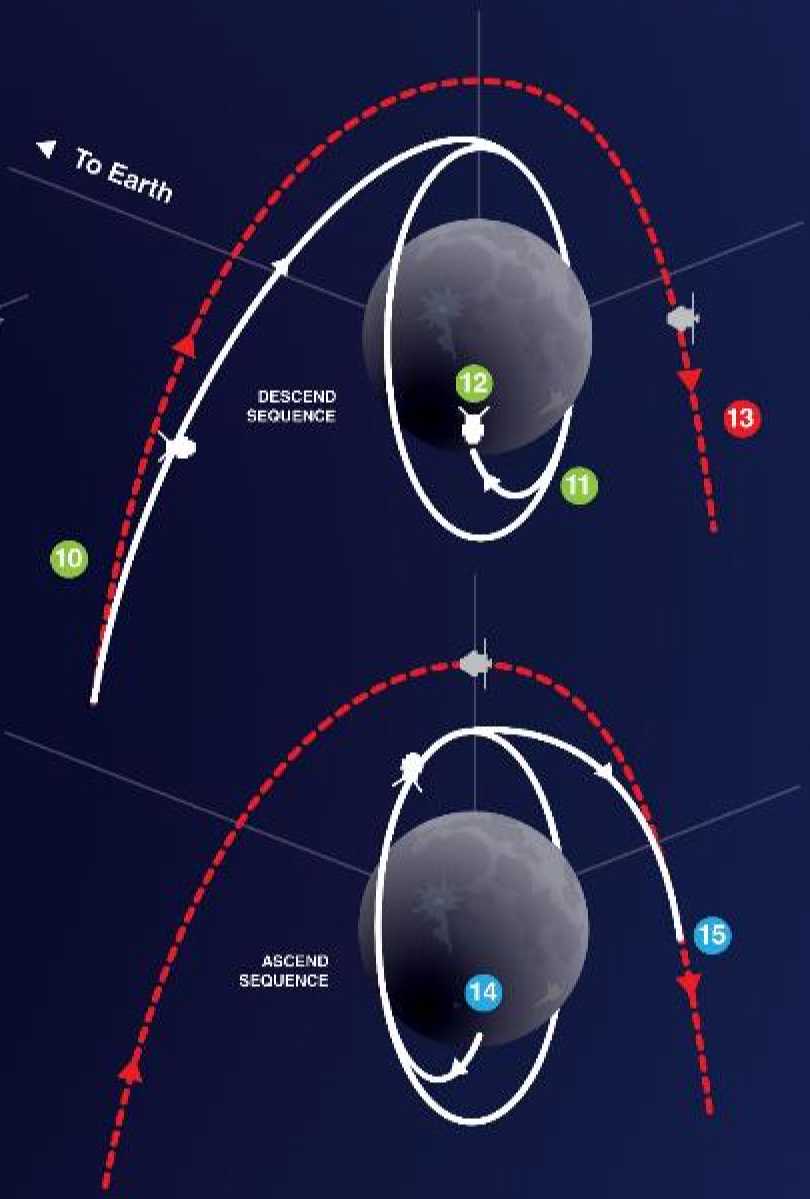
National Aeronautics and Space Administration



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

CREW SURFACE OPERATIONS

Two crew live in the landing system cabin for 6.5 days on the lunar surface

Goal of up to four moonwalks, with reserves for a fifth contingency moonwalk

Collect a variety of samples to return to Earth for later research:

- Rock samples to help date the sequence of impact events on the Moon
- Core tube samples to capture ancient solar wind trapped in regolith layers
- Paired samples of material within and outside a permanently shadowed region

National Aeronautics and
Space Administration

EXPLORE MOON to MARS

Commercial Lunar Payload Services (CLPS)

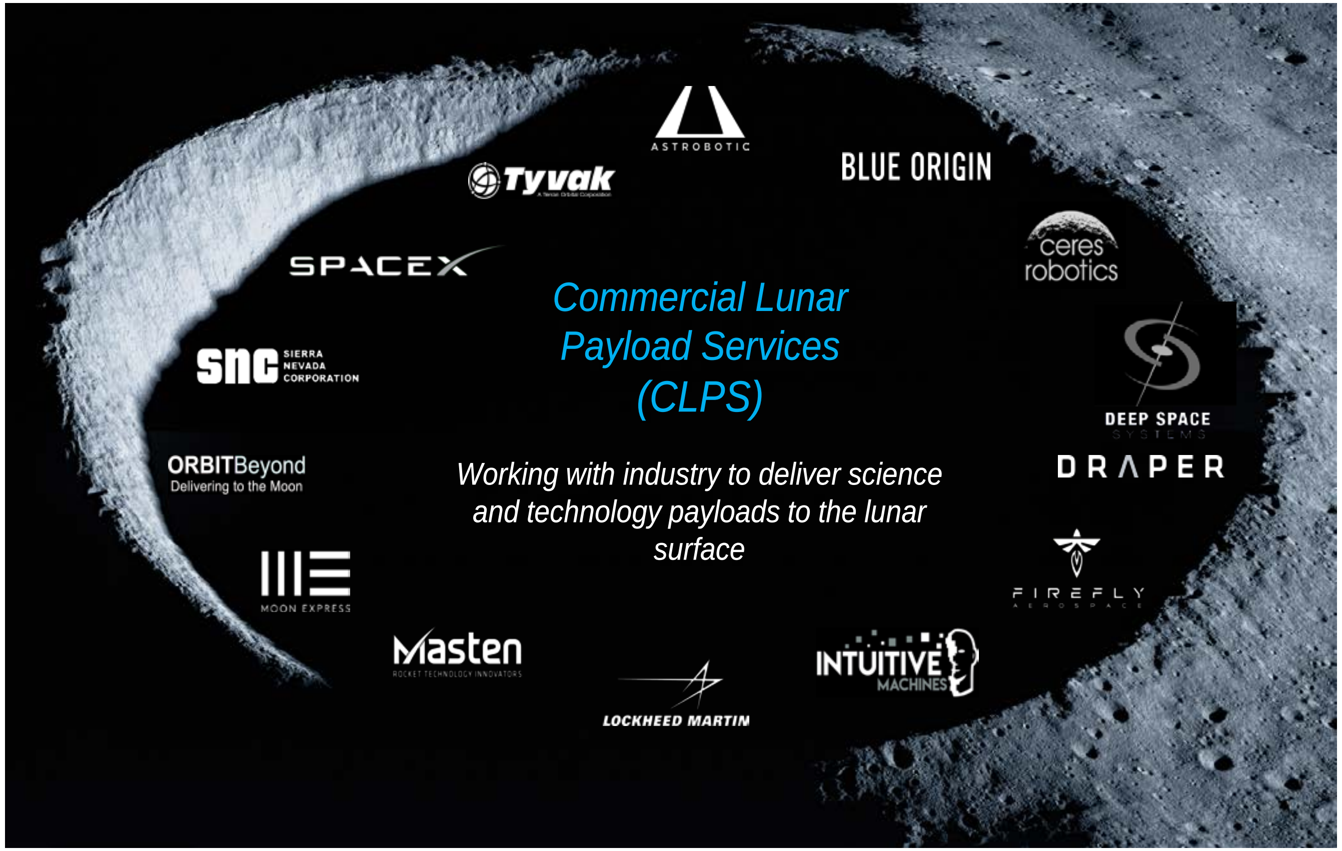
Dr. Joel Kearns
Deputy Associate Administrator for Exploration
Science Mission Directorate, NASA

February 24, 2021

Commercial Lunar Payload Services (CLPS)

Goal: Utilize commercial end-to-end delivery services to enable access to the lunar surface

- Deliveries initiated using a Task Order (TO)
  - Any of the **14 companies on the catalog** can respond to a task order
  - Planned Task Order cadence: 2 per year
- Task Orders list what NASA wants delivered and any constraints
- First 5 lunar surface delivery Task Orders awarded with deliveries commencing in 2021
  - 2021: Non-polar delivery (Astrobotic & Intuitive Machines) – TO 2A & 2B
  - 2022: Polar delivery (Masten) – TO 19C
  - 2022: PRIME-1 (Intuitive Machines)
  - 2023: Volatiles Investigating Polar Exploration Rover (VIPER) to Moon’s south polar region (Astrobotic) – TO 20A
  - 2023: Non-polar delivery (Firefly Aerospace) – TO 19D



CLPS Deliveries 2021-2024

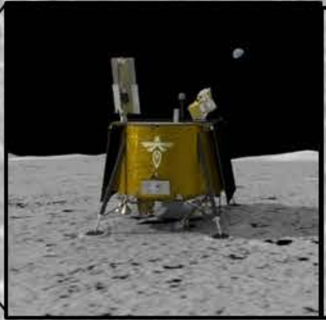
Delivery Site:
Oceanus Procellarum
Provider:
Intuitive Machines
Task Order (TO) 2 | 2021

Delivery Site:
Lacus Mortis
Provider:
Astrobotic
TO2 | 2021

Delivery Site:
Lunar Pole
Provider:
Astrobotic
VIPER | 2023

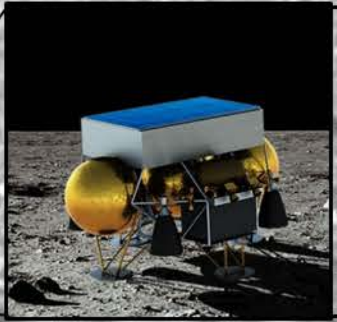
Delivery Site:
Reiner Gamma
Provider: TBD
PRISM-1a | 2023

Delivery Site:
Mare Crisium
Provider:
Firefly
TO19D | 2023



Delivery Site:
Schrödinger Basin
Provider: TBD
PRISM-1b | 2024

Delivery Site:
South Pole
Provider:
Intuitive Machines
TO PRIME-1 | 2022



Delivery Site:
South Pole
Provider:
Masten
TO19C | 2022

Payloads largely selected from NASA Provided Lunar Payloads (NPLP)

2021 CLPS Delivery Manifests

Astrobotic

- Surface Exosphere Alterations by Landers (SEAL)
- Linear Energy Transfer Spectrometer (LETS)
- Photovoltac Investigation on Lunar Surface (PILS)
- Neutron Spectrometer System (NSS)
- Near-Infrared Volatile Spectrometer System (NIRVSS)
- Neutron Measurements at the Lunar Surface (NMLS)
- Mass Spectrometer Observing Lunar Operations (Msolo)
- Fluxgate Magnetometer (MAG)
- PROSPECT Ion-Trap Mass Spectrometer for Lunar Surface Volatiles (PITMS)
- Navigation Doppler Lidar for Precise Velocity and Range Sensing (NDL)

Key

Science	green
Technology	yellow
Exploration	blue
HEOMD/STMD	red

Intuitive Machines

- Lunar Node 1 Navigation Demonstrator (LN-1)
- Stereo Cameras for Lunar Plume-Surface Studies (SCALPSS)
- Low-frequency Radio Observations from the Near Side Lunar Surface (ROLSES)
- Navigation Doppler Lidar for Precise Velocity and Range Sensing (NDL)
- Radio Frequency Mass Gauge (RFMG)

2022 CLPS Delivery Manifests

Payloads largely selected from Lunar Surface Instrument and Technology Payloads (LSITP)

Polar

Masten Space Systems - South Pole

- Sample Acquisition, Morphology Filtering & Probing of Regolith (SAMPLR) — Technology
- Camera System for lunar science on commercial vehicles (Heimdall) — Science
- Near-Infrared Volatile Spectrometer System (NIRVSS) — Science
- Linear Energy Transfer Spectrometer (LETS) — Science
- Lunar Compact Infrared Imaging System (L-CIRiS) — Science
- Moon Rover with Exploration Autonomy (Moon Ranger)
- Laser Retroreflector — Science
- Mass Spectrometer Observing Lunar Operations (Msolo) — Science
- Neutron Spectrometer System (NSS) – Deployed on Moon Ranger — Science

Non-Polar

TBD - Crisium

- Lunar Environment Heliophysics X-Ray Imager (LEXI) — Science
- Next Generation Lunar Retroreflectors (NGLR) — Science
- Radiation Tolerant Computer System — Technology
- Sample Acquisition & Delivery System for Instruments & Sample Return (PlanetVac) — Technology
- Lunar Instrumentation for Subsurface Thermal Exploration with Rapidity (LISTER) — Science
- Lunar Magnetotelluric Sounder (LMS) — Science
- Regolith Adherence Characterization (RAC) — Science

Key

Science	Green
Technology	Orange
Exploration	Blue

CLPS Deliveries & Future Payloads

Payloads for the first CLPS deliveries from the NPLP (NASA internal) and LSITP (external) calls were selected to enable research on early missions.

Moving to a science-driven model through PRISM (Payloads and Research Investigations for the Surface of the Moon)

- PRISM calls to occur on a regular cadence
  - PRISM instruments will feed the manifests for Task Orders for CLPS deliveries from late 2023 onwards
  - The first call requests science investigations utilizing multi-instrument suites to maximize the science for named locations
  - High-value ‘location agnostic’ instruments may be called for in PRISM-2
- The locations are high science-value targets, as discussed in numerous science community documents and where significant progress can be made utilizing CLPS platforms, the locations for this call are:
  - ❖ Reiner Gamma magnetic anomaly (lunar swirl)
  - ❖ Schödinger far side basin impact melt
- The destinations for these two deliveries were announced in July, allowing potential PIs time to prepare to propose science optimized for those locations
  - Step 1 proposals received in December 2020; step 2 received February 5, 2021

Kathryn Lueders (Artemis)

Associate Administrator, Human Exploration and Operations, NASA

The Moon Lights The Way

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

HOW CAN ARTEMIS PREPARE US?

- Understand the human response to long duration, deep space environment
- Conduct mission operation simulations
- Validate Mars systems at the Moon whenever possible
- Establish technical and economic ties with intergovernmental, international, academic, and industry partners

What Will We Do On The Moon?

- Gain confidence in planetary human-robotic exploration
- Operate systems on the surface from lunar orbit
- Conduct science experiments, prospect for resources, and return samples to Earth
- Surface power technology demonstrations
- Operate autonomously with communications delay
- Establish deep space logistics supply chains
- Immerse in the lunar environment
- Prepare for Mars

Commonality and Interoperability

MOBILITY

SUITS

ASCENT SYSTEMS

PROPULSION

HABITATION SYSTEMS

DEEP SPACE AGGREGATION

– Orbiting outpost with landing system
– Scientific exploration of a planetary surface
– Automation and robotics to assist/maximize human-led science

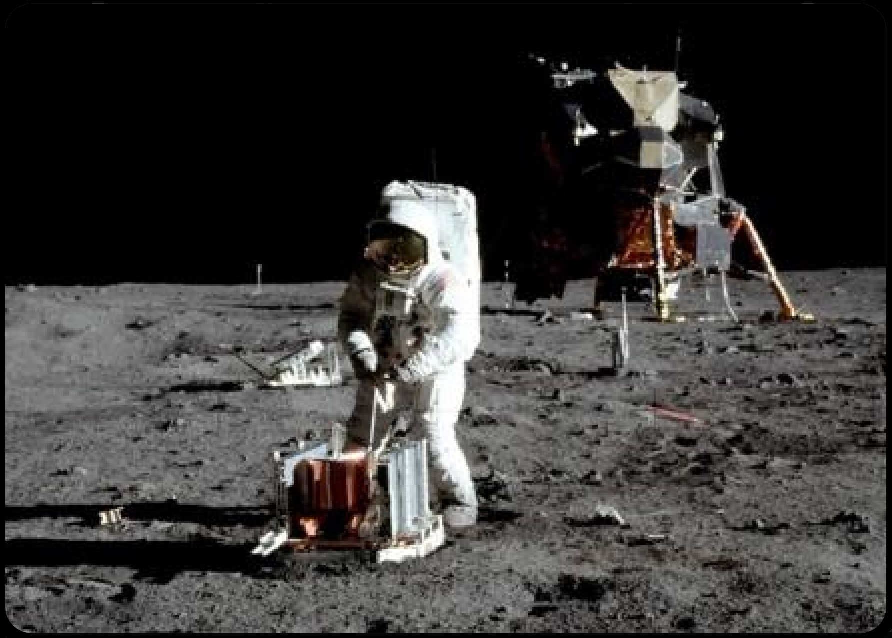
– End-to-end dust mitigation
– Physical and behavioral health operations
– Communications and navigation
– Power systems

xEVA System: Spacesuits, Tools, Vehicle Interfaces

Exploration Extravehicular Activity System

Testing suit on ISS in 2023 • In-house build for Artemis III lunar mission • xEVA services contracts with U.S. industry for missions beyond 2024

Validating Crew Health and Performance in Artemis Spacecraft Will Help Prepare Us to Live and Work on Mars



Transitioning from microgravity to partial gravity and mitigating threats to the human physiological experience

Lunar Surface	5 Hazards	Mars Surface
1/6 Earth Gravity	Altered Gravity	3/8 Earth Gravity
Galactic Cosmic Rays	Radiation	Galactic Cosmic Rays
Different Atmospheres, Environments, Dust	Hostile, Closed Environment	Different Atmospheres, Environments, Dust
Fast Communications, 2-3 Day return	Distance from Earth	20 min Comm. Delay, > 9-month return
Small volumes, 2 days-30 days on Surface	Isolation & Confinement	Small volumes, 30 days-18 months on Surface

A New Infrastructure In Deep Space

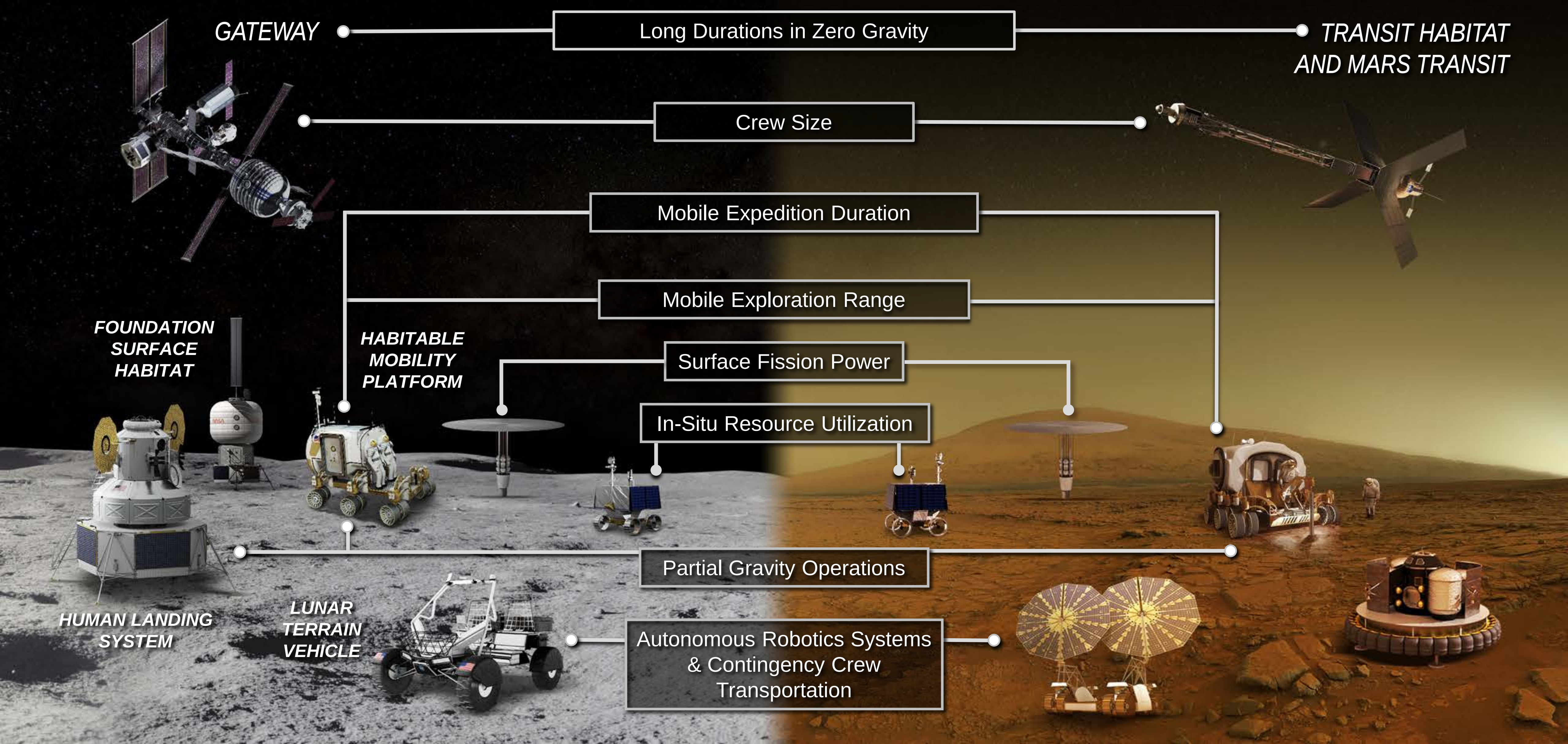
Transportation

Communications

Orbital Operations

Surface Operations

It's Not The Moon or Mars – It's The Moon and Mars



Lunar Missions Prepare Us For Mars

IN ORBIT

DEEP SPACE AGGREGATION
Assembling a complex ship in deep space

MARS TRANSIT HABITAT
Round the clock, years-long operations of a Mars-class habitat and life support system

ORBIT TO SURFACE OPERATIONS
Operating an orbiting outpost that deploys a lander and its crew to a planetary surface

COMMERCIAL RESUPPLY AND REFUELING
Leveraging the space logistics supply chain for industry provided cargo deliveries

CREW HEALTH & PERFORMANCE
Studying how the human body and mind adapt to deep space hazards

A roundtrip mission to Mars will take about two years—and once the ship's course is set, there's no turning back.

As much as is possible, lunar systems will be designed for dual Moon-Mars operations.

Integrated missions in the lunar vicinity prepare us for successful Mars missions

ON THE SURFACE

SPACESUIT ADVANCEMENTS
Improving spacesuit design across Artemis missions with astronaut input and private sector innovation

MOBILE OPERATIONS
Living and working 'on the go' inside a mobile habitat for weeks at a time

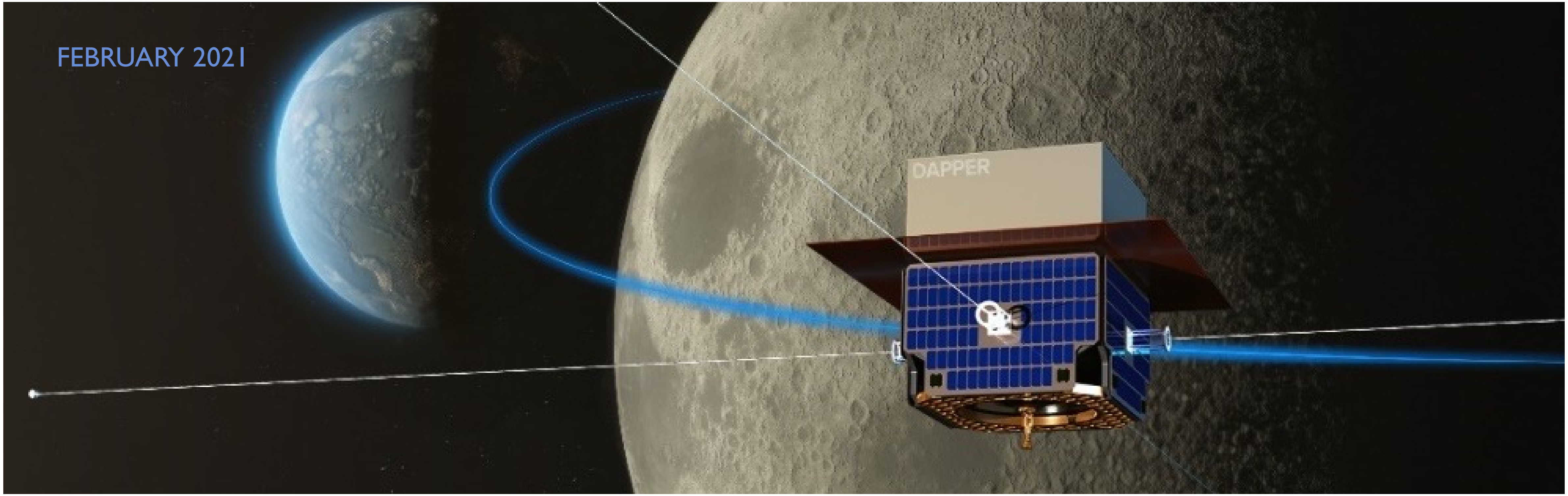
PLANETARY PROTECTION
Mitigating dust transfer and establishing pristine sample curation protocols

HUMAN ROBOTIC EXPLORATION
Robots pre-positioning surface assets and conducting reconnaissance for astronauts

HUMAN RESILIENCE
Learning how humans can survive and thrive in a partial gravity environment

Exploration Is A Team Sport

We have the right plans
and the right teams in place
to push farther, together,
ensuring that collateral benefits
are global and inclusive.



SPACEPORT SUMMIT: BUILDING OUT THE SOLAR SYSTEM

IAN FICHTENBAUM

CEO, BRADFORD SPACE

BRADFORD FULL STACK SPACECRAFT DEVELOPMENT

- Trusted for quality space systems
- Proprietary **high-performance propulsion** and avionics technologies and products
- Over 2000 products launched to space
- 44k sq ft of facilities
- Over 75 engineering, R&D, production and admin staff
- Close relationships with space customers around the world
- www.bradford-space.com

New York and Seattle, USA

Spacecraft design, corporate management and business development
Spacecraft production center in Southeast US in planning and development

Grinsjon, Sweden

Three fully-equipped propulsion test fire facilities

Belval, Luxembourg

Avionics development center

Heerle, Netherlands

Fully equipped engineering and production center for attitude control and integrated propulsion systems

Solna, Sweden

High performance thruster production and development center

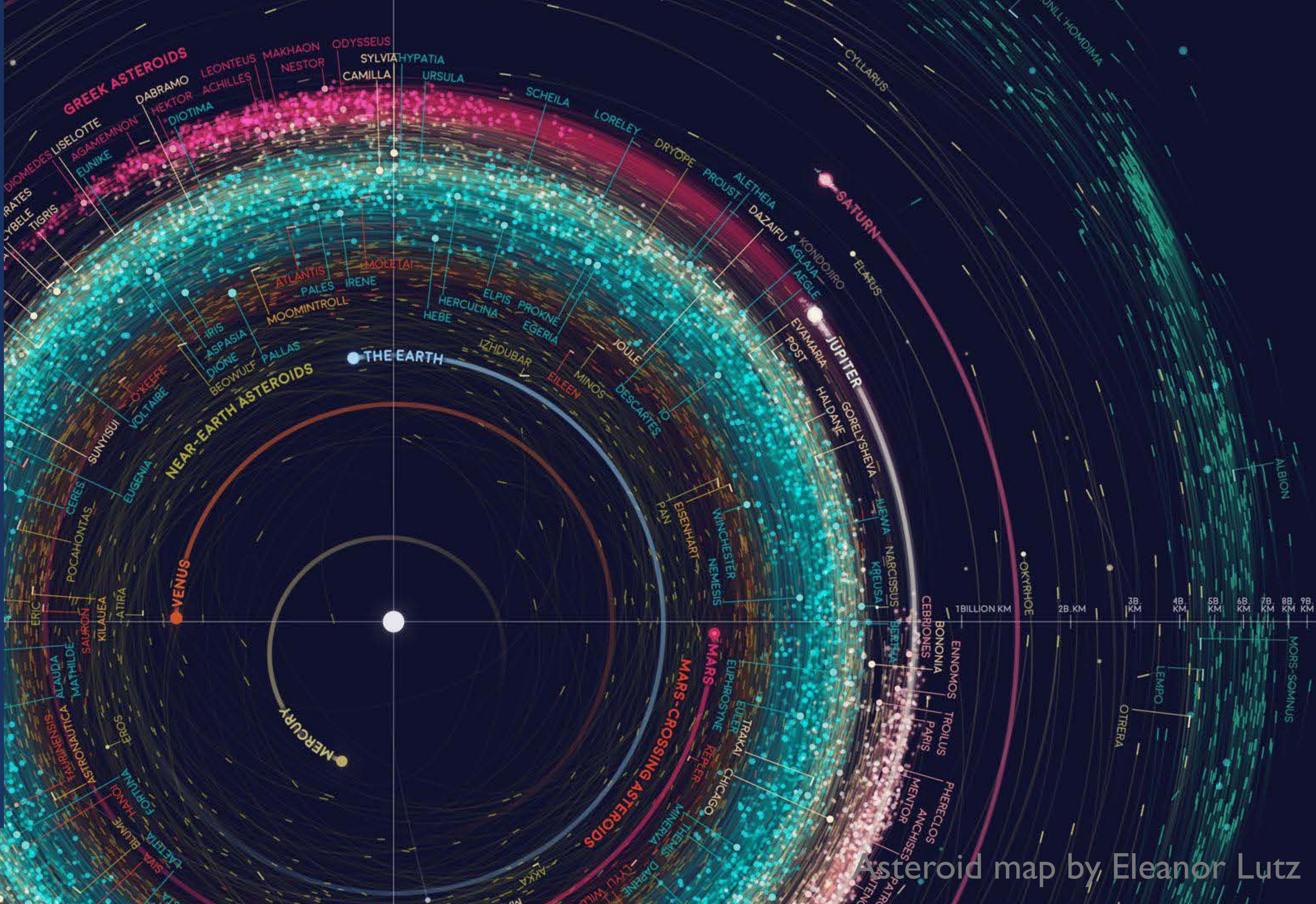
VALUE IN SPACE IN TWO RINGS

Ring 1: Historical value in the GEO belt

An abundance of value
But you first need to get there

Ring 2: Future Value in the rings of the Inner Solar System

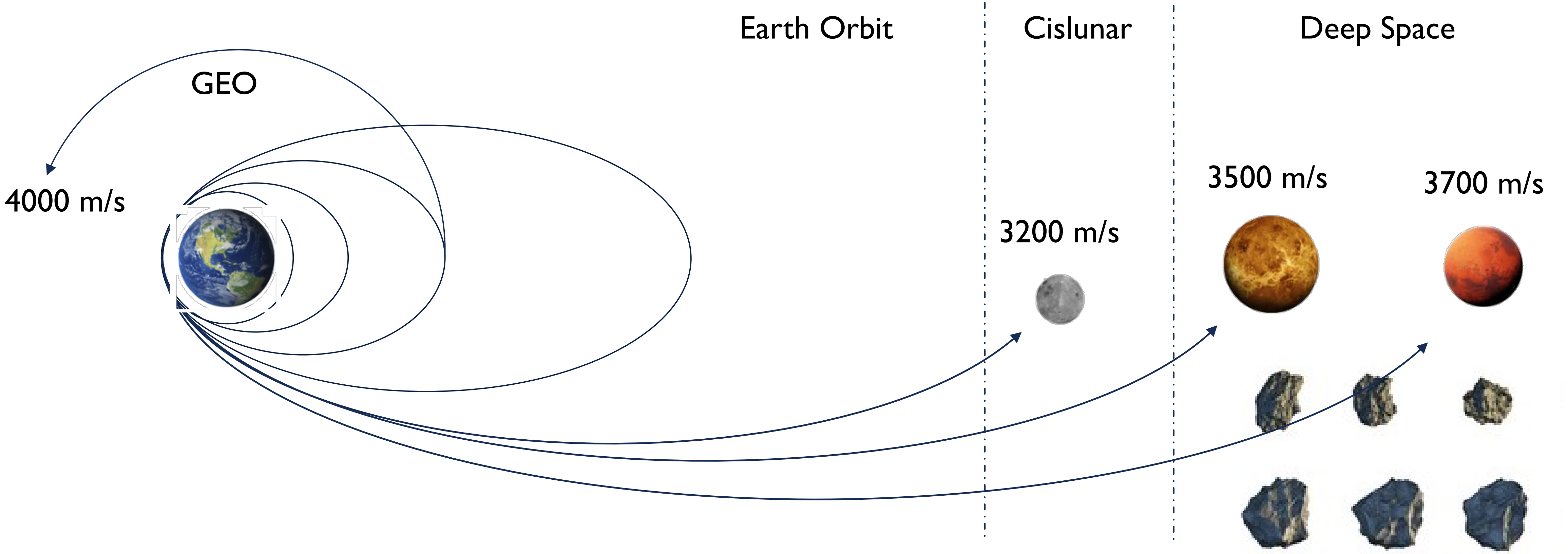
- Transport
- Navigation
- Communications
- Surveillance
- Science
- Exploration
- Resources



Asteroid map by Eleanor Lutz

THE INNER SOLAR SYSTEM ON DEMAND

GOING FROM LEO TO ANYWHERE YOU WANT



HOW TO GET THERE (COST EFFECTIVELY)

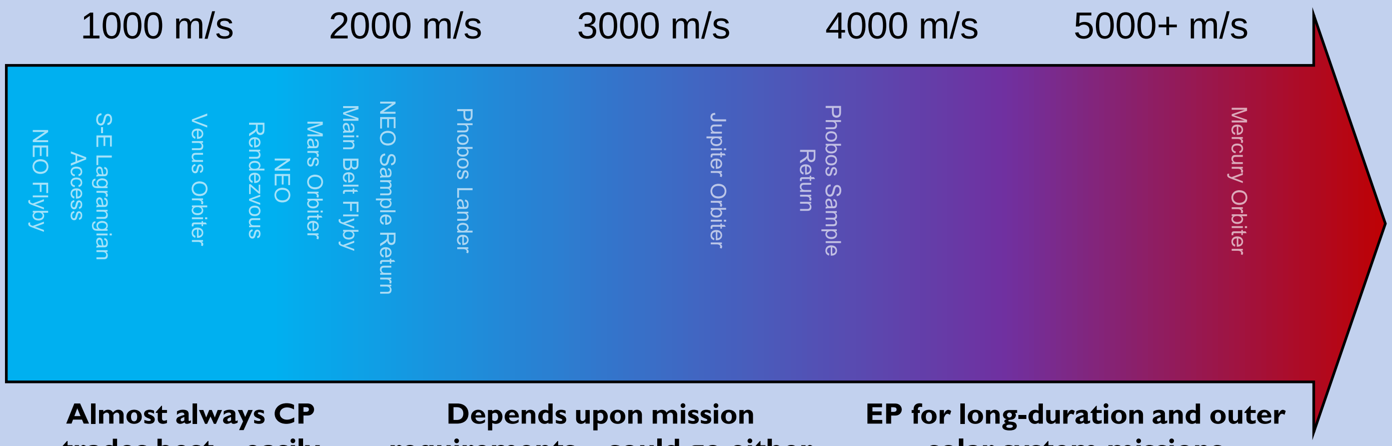
THE CP VS. EP DEBATE: OUR HUMBLE OPINION

Building the Solar System will require a new class of spacecraft

- Launch system adaptability
- "Off the shelf" modular avionics stack for deep space (nav, comms, attitude)
- Lots of delta-V
- Lots of thrust – which means chemical propulsion or lots of power

Nuclear power or propulsion not cost effective yet, so high performance chemical systems have to do

Delta-V beyond C3 = 0



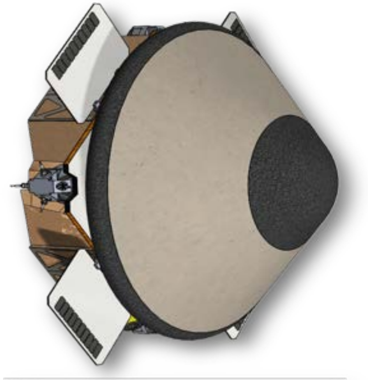
Almost always CP trades best – easily achievable

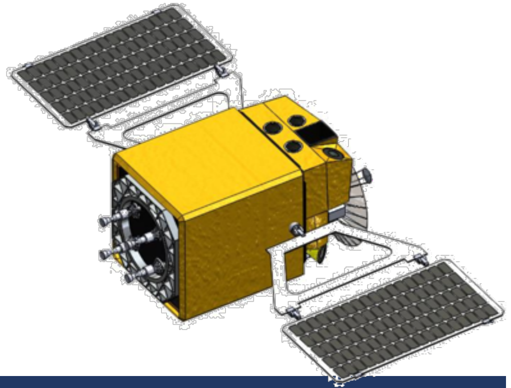
Depends upon mission requirements – could go either way

EP for long-duration and outer solar system missions

- **EP drives time-of-flight, and time-of-flight drives mission cost**
  - High-thrust spacecraft are "fire and forget". Minutes-to-hours-long burns and then **upset-tolerant cruise**
  - CP spacecraft designs have simplified testing and qual campaigns
- **Pointing and power requirements are reduced**
- **Fast deployment of infrastructure and deployment on demand**

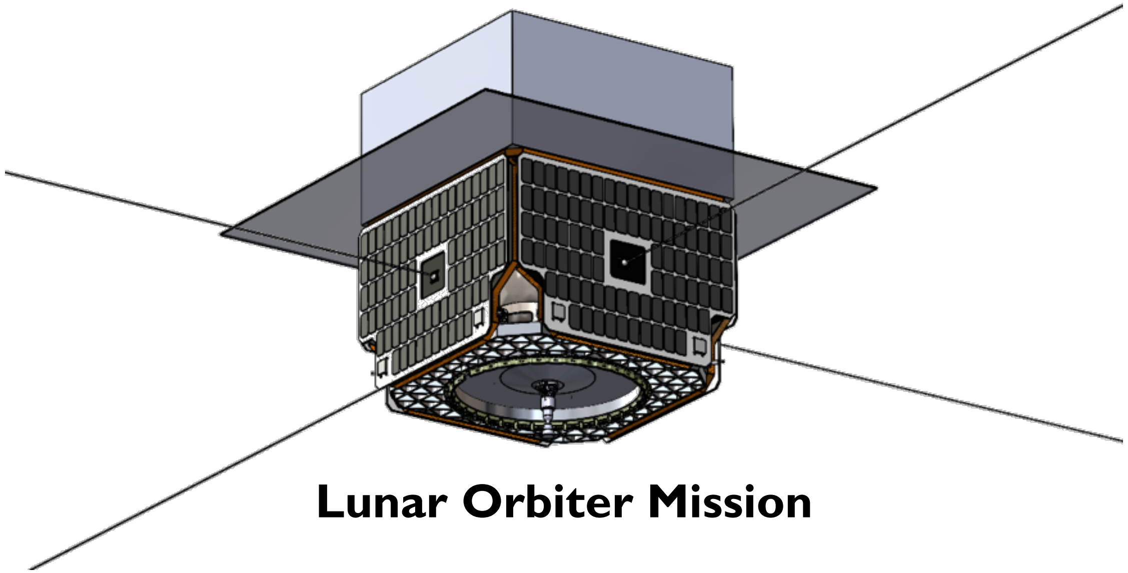
www.ecaps.space





MULTIPLE SOLUTIONS EXIST, BUT BRADFORD MONOPROP ECAPS PROPULSION FITS LOTS OF IMPORTANT REQUIREMENTS (AND HAS PLENTY OF HERITAGE)

FAST AND NIMBLE PLANETARY EXPLORATION - CASE STUDY



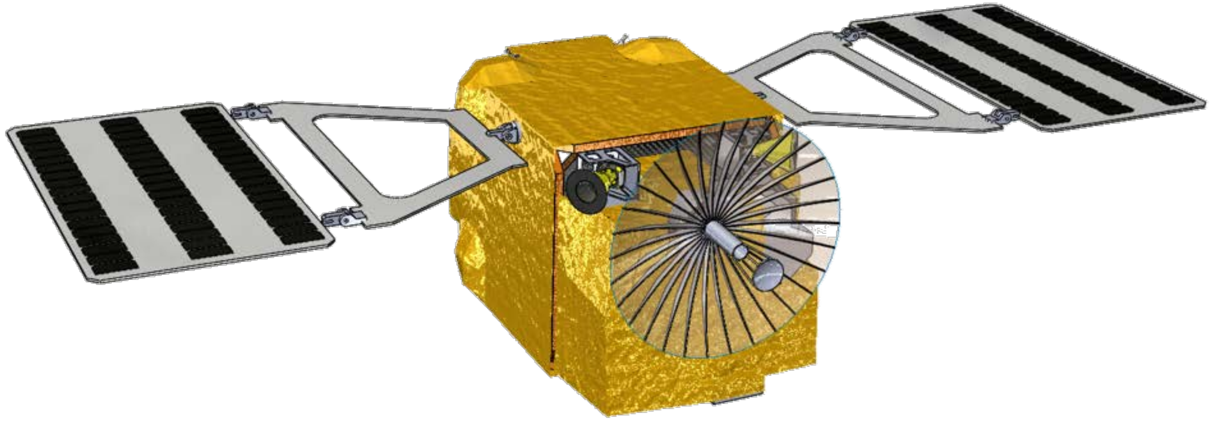
Lunar Orbiter Mission

Rideshare to cislunar space – self-propelled to science orbit

Bus provides all payload services – power, pointing, comms etc.

Comfortably fits within SIMPLEx cost envelope

Two-year science mission in 125 km Low Lunar Orbit



Venus Orbiter Mission

Maneuvers to Hohmann transfer to Venus (Venus Transfer Insertion)

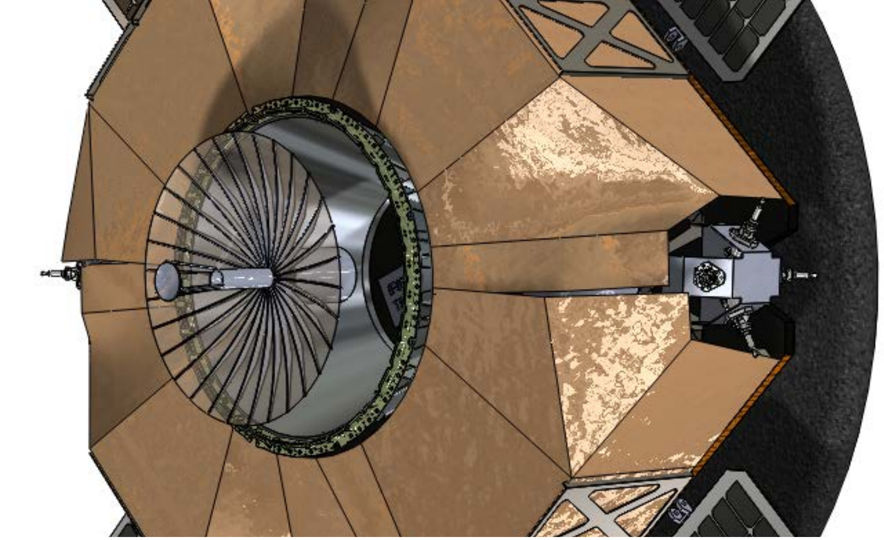
176 day cruise to Venus – 10 months less than EP-driven system

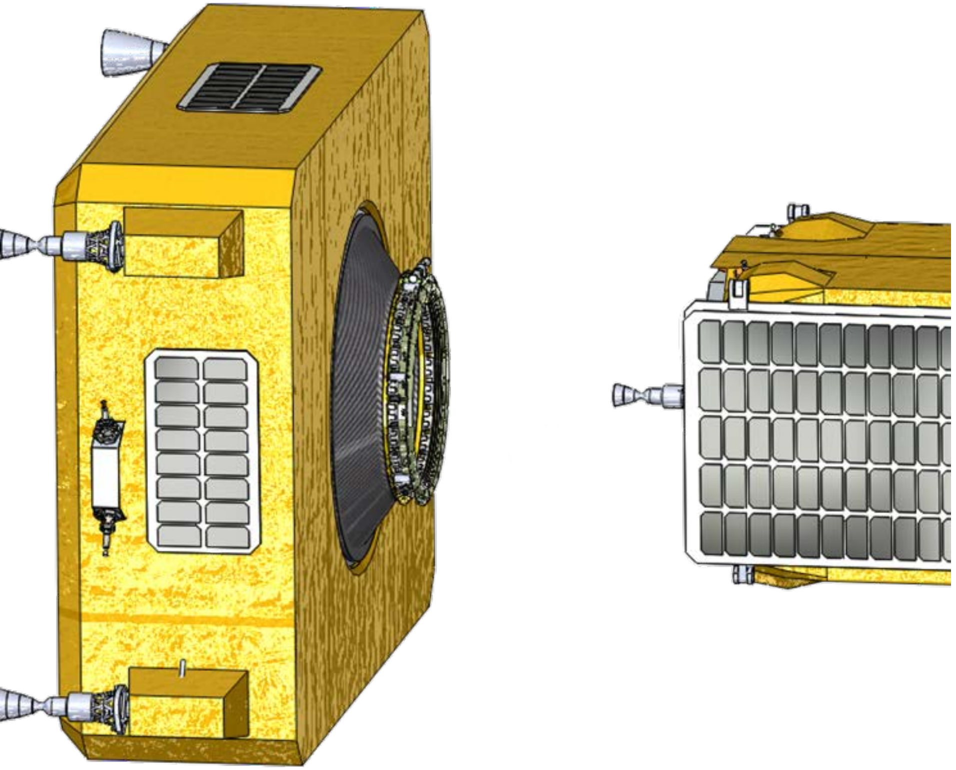
Venus Orbit Insertion and propulsive lowering to 150 Mm x 2 Mm altitude

Circular orbits at 150 Mm or 300 Mm

4+ years at Venus: 122 orbits in first year baseline mission

Up to 3-years of mission extension





FAST AND NIMBLE TRANSPORTATION

Earth → Mars space transport

- “Squire” orbital transfer stage for Earth to Mars transit
- 1 kb/s downlink + 50W power availability throughout 11-month Mars transfer
- Handles cruises launched outside of optimal transfer windows, to exploit rideshare opportunities

LEO → MEO, GEO and cislunar space

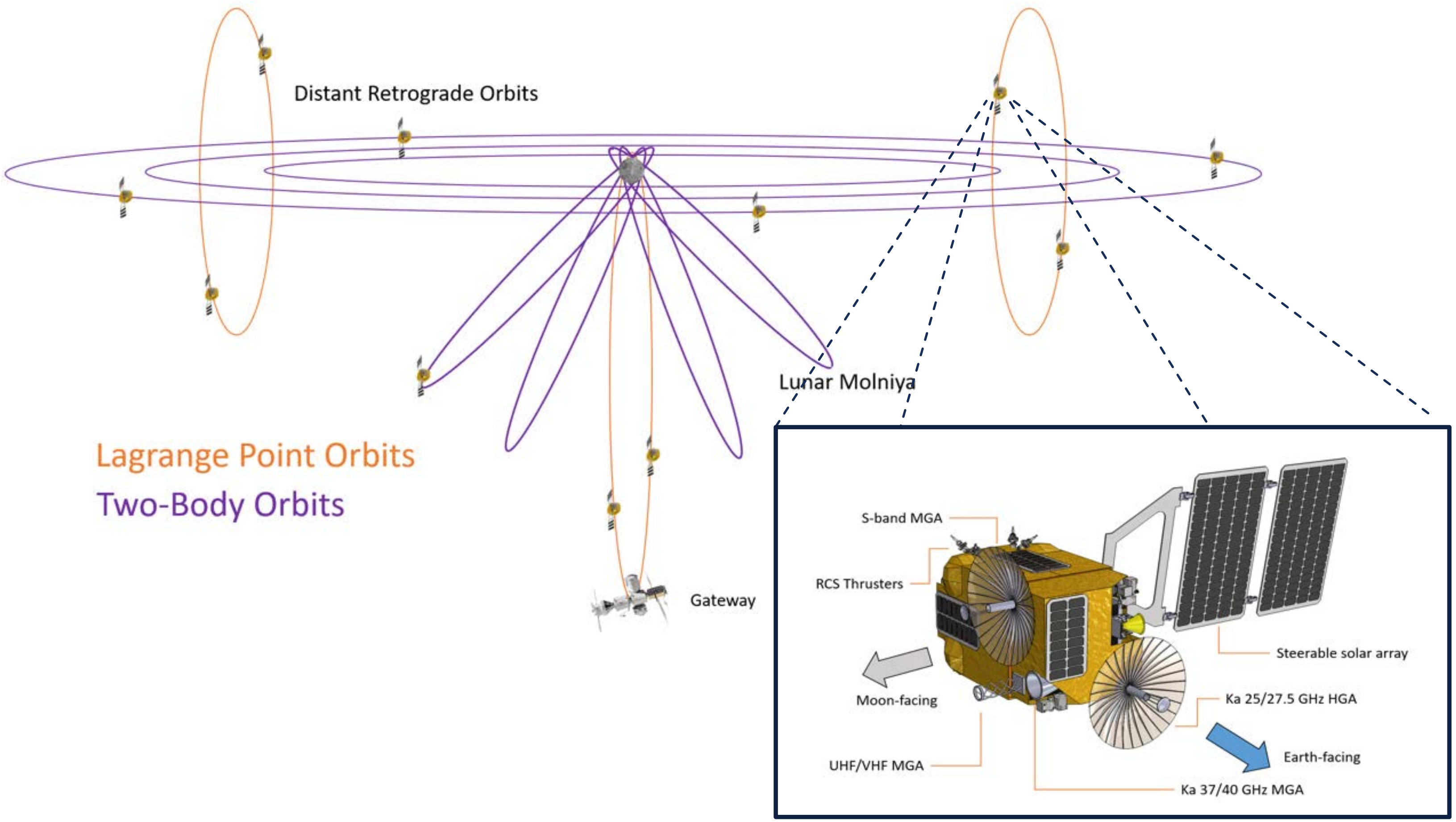
- “SqRt” rideshare space tug
- Up to 3200 m/s dV @ 80kg satellite payload
- High thrust → fast response and quick radiation belt transition

The “space tug” as a commoditized service, implemented with proven and cost-efficient technologies

RAPID DEPLOYMENT LUNAR COMMUNICATIONS NETWORK

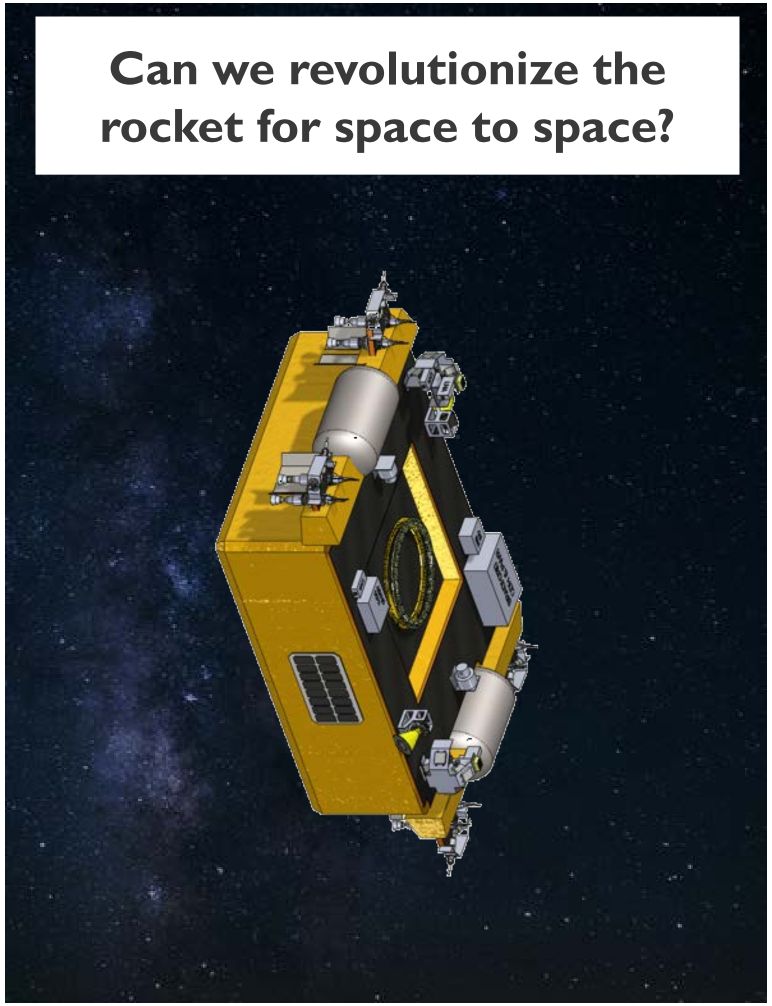
- 180 kg, 200 W, "Explorer" spacecraft capable of carrying up to 40 kg of communication payload
- **Deployment from LEO. 1 month to DRO or NRHO**
- Full quality coverage of the Moon with 6 Explorer vehicles.
  - 2 @ EML-1 halo
  - 2 @ EML-2 halo
  - 2 @ Southern NRHO.
- Enough propellant for 5 years of lifetime or orbit relocation
- **Initial 2 Explorer lunar deployment for ~$50m**

	Band	Purpose	Uplink (to Relay)		Downlink (from Relay)	
Earth – Relay	Ka	Earth Trunk	40-40.5 GHz		37-38 GHz	
Relay - Moon	UHF	Lunar Surface Users	0.435-0.450 GHz	5 kb/s	0.39 – 0.405 GHz	10 kb/s
	S	Lunar Surface Users	2.2-2.29 GHz		2.483-2.5 GHz	5 kb/s
	Ka	Lunar Orbital & Surface Users	27.0-27.5 GHz	2.5 Mb/s	23.15 – 23.55 GHz	5 kb/s



WHAT'S NEXT?

As SpaceX revolutionized the rocket from Earth to space



Can we revolutionize the rocket for space to space?

TELL US MORE ABOUT YOUR MISSION INTERESTS OR NEEDS!

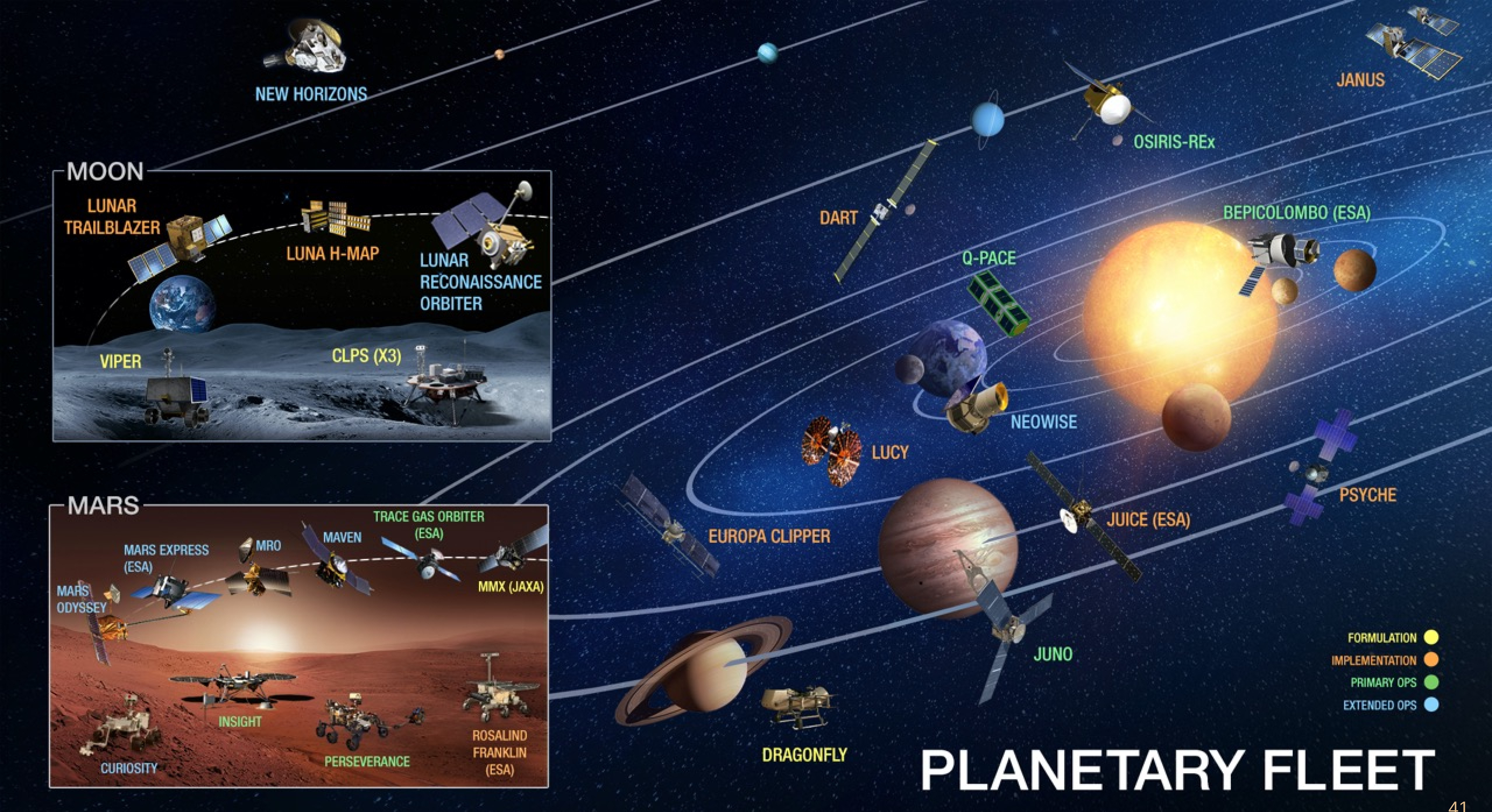
CONTACT:
IAN.FICHTENBAUM@BRADFORD-SPACE.COM

National Aeronautics and Space Administration

EXPLORE MARS

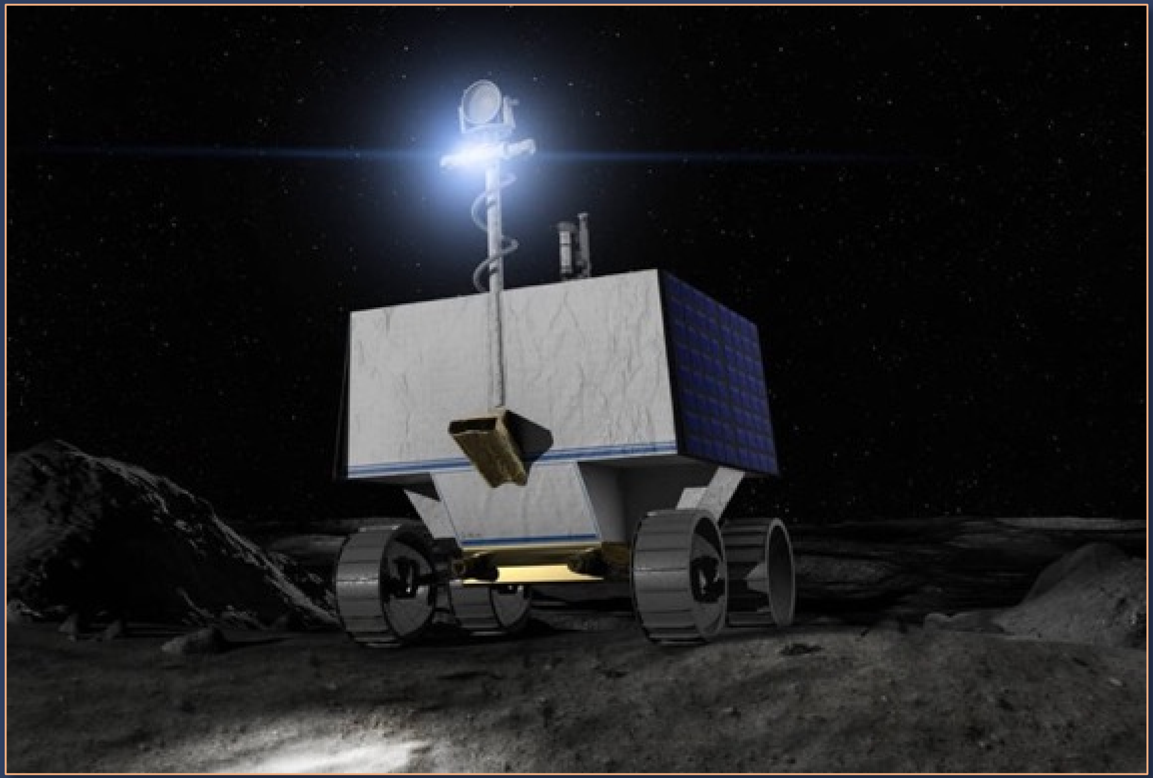
Eric Ianson
NASA Planetary Science Division Deputy Director
Mars Exploration Program Director

Spaceport Summit, Lunar/Mars Exploration Panel
February 24, 2021



NEW HORIZONS
JANUS
OSIRIS-REx
MOON
LUNAR TRAILBLAZER
LUNA H-MAP
LUNAR RECONAISSANCE ORBITER
VIPER
CLPS (X3)
DART
BEPICOLOMBO (ESA)
Q-PACE
NEOWISE
LUCY
PSYCHE
JUICE (ESA)
EUROPA CLIPPER
MARS
TRACE GAS ORBITER (ESA)
MAVEN
MARS EXPRESS (ESA)
MRO
MARS ODYSSEY
MMX (JAXA)
INSIGHT
CURIOSITY
PERSEVERANCE
ROSALIND FRANKLIN (ESA)
DRAGONFLY
JUNO
FORMULATION
IMPLEMENTATION
PRIMARY OPS
EXTENDED OPS
PLANETARY FLEET

Volatiles Investigation Polar Exploration Rover (VIPER)

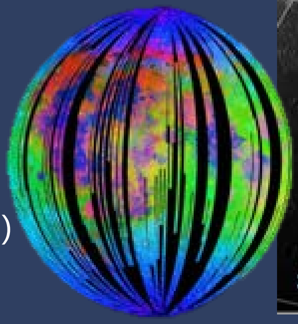


- Golf-cart-sized rover – first ever resource mapping mission on another body
- Will be delivered by Astrobotic (CLPS) late 2023 for 100-day mission
- Will explore the South Pole of the Moon in search of water ice and other potential resources, to:
  - Learn about origin and distribution of water on the Moon
  - Determine how to harvest lunar resources for future human exploration
- Equipped with 1-meter drill and three instruments:
  - Neutron spectrometer
  - Near-IR spectrometer
  - Mass spectrometer

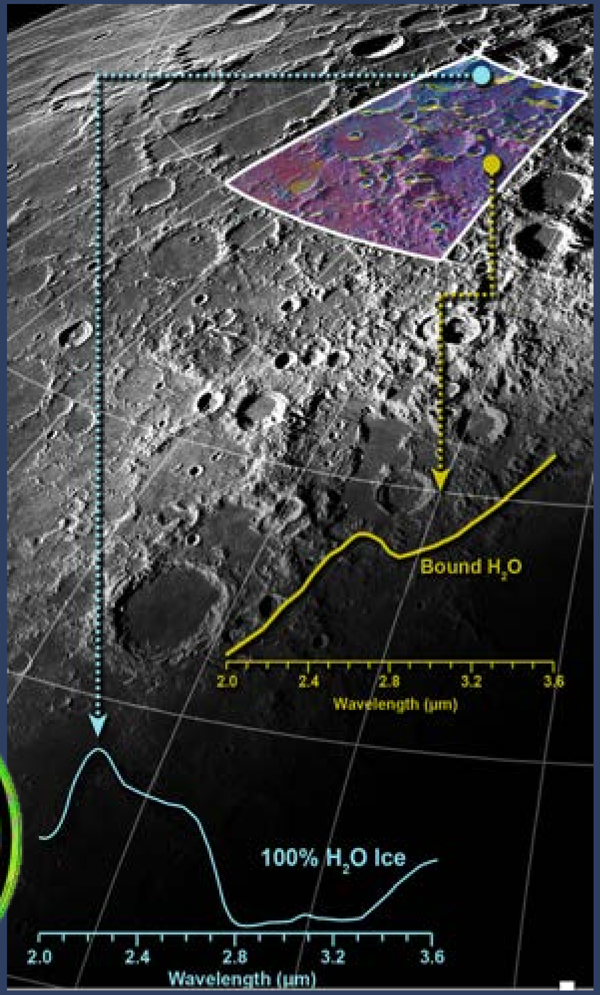
Lunar Trailblazer

CubeSat mission to launch on a rideshare to the Moon in ~2022 to study lunar volatiles

- Measure the form, abundance, and distribution of water on the sunlit Moon as a function of latitude, lithology, soil maturity
- Measure for potential time variation of lunar volatiles on the sunlit surface
- Measure the form, abundance, distribution of volatiles in the shadowed polar regions
- Relate water abundance to fine-scale temperature variation and search for small cold traps



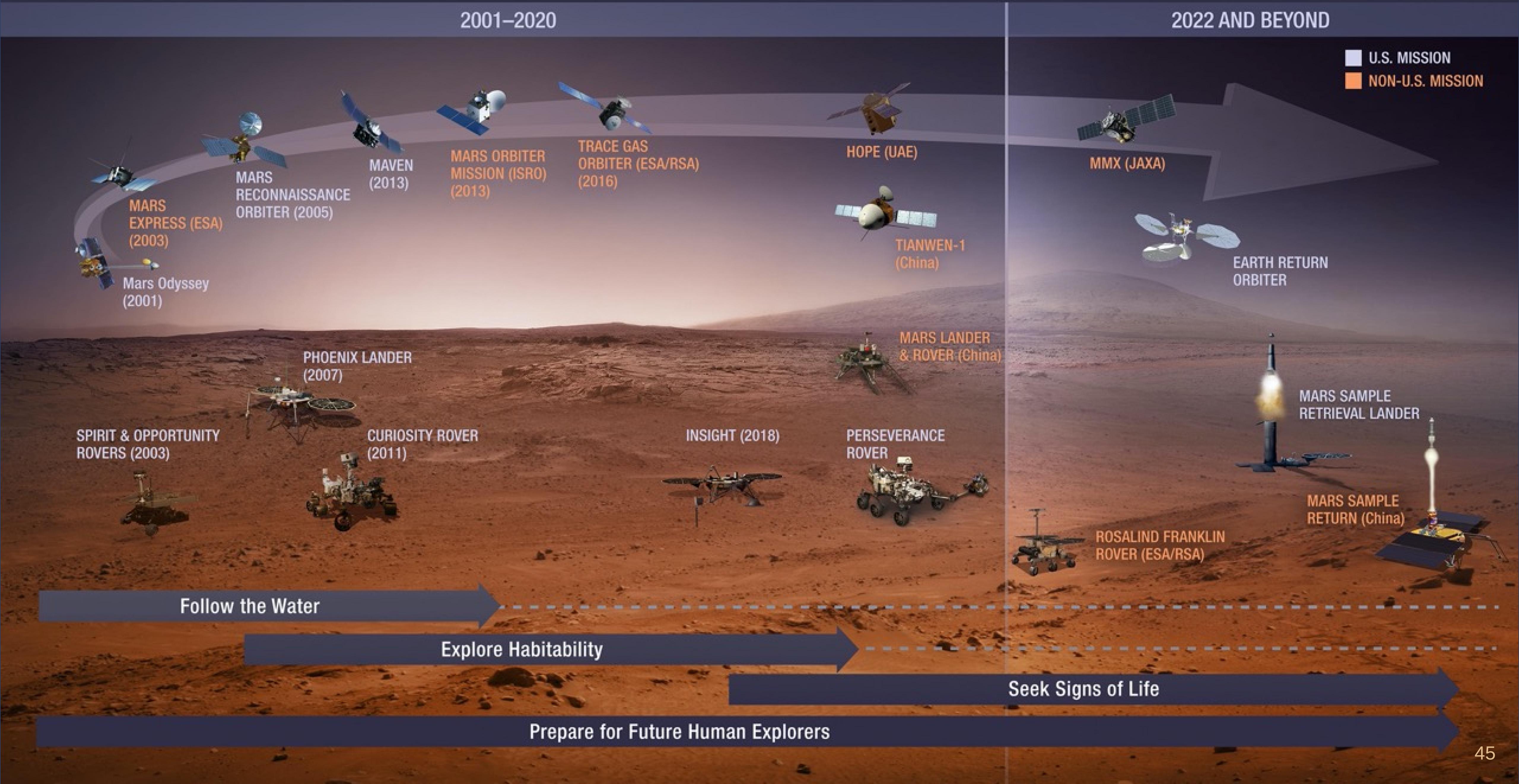
OH/H_2O absorption (blue) at 3-µm from M^3 (Pieters et al., 2009)



NASA's Mars Exploration Program is a science-driven, technology-enabled study of Mars as a planetary system, to understand:

- The formation and early evolution of Mars as a planet
- The history of geological and climate processes that have shaped Mars through time
- The potential for Mars to have hosted life, either in the ancient past or present day
- The future exploration of Mars by humans
- How Mars compares to and contrasts with Earth

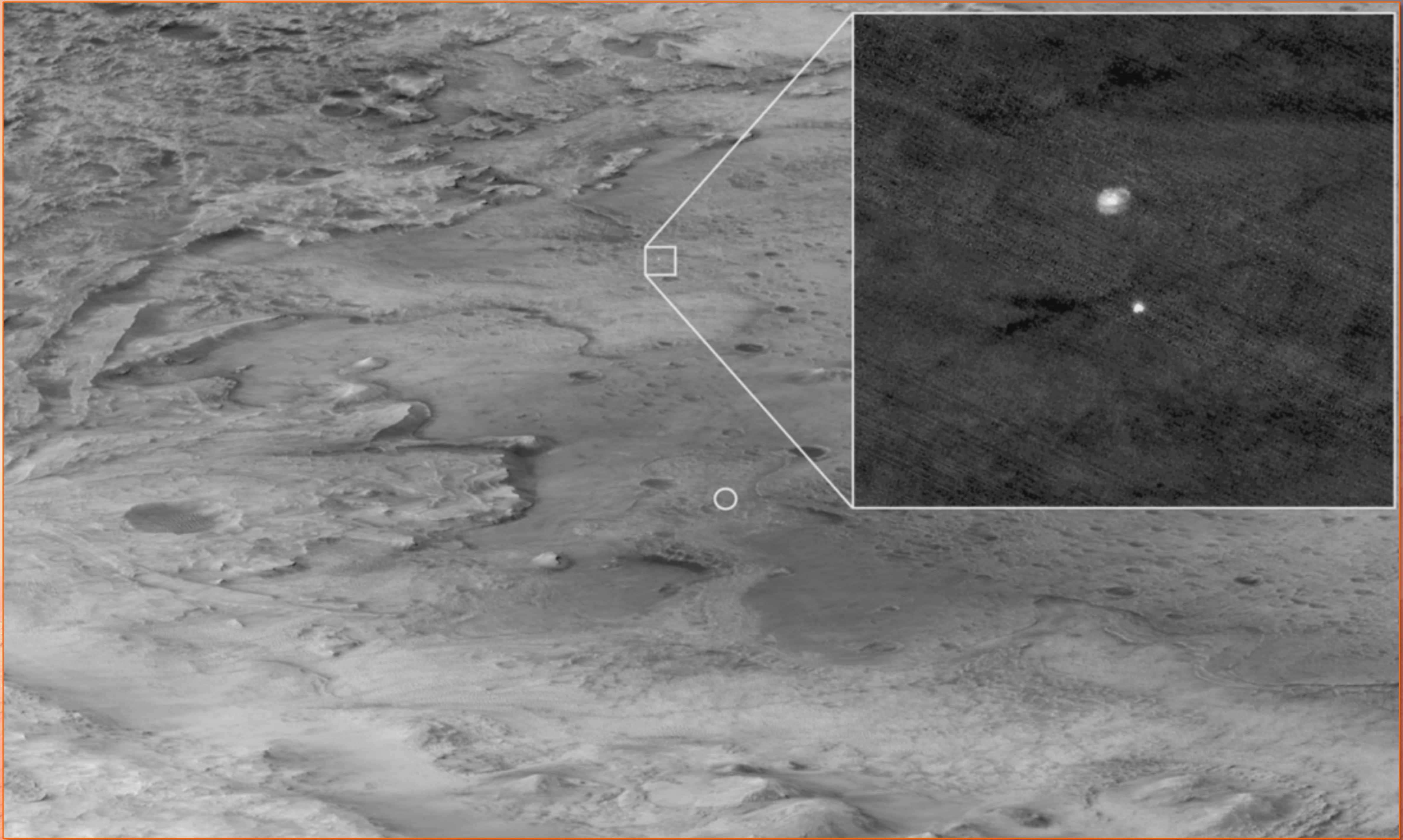
Mars Missions

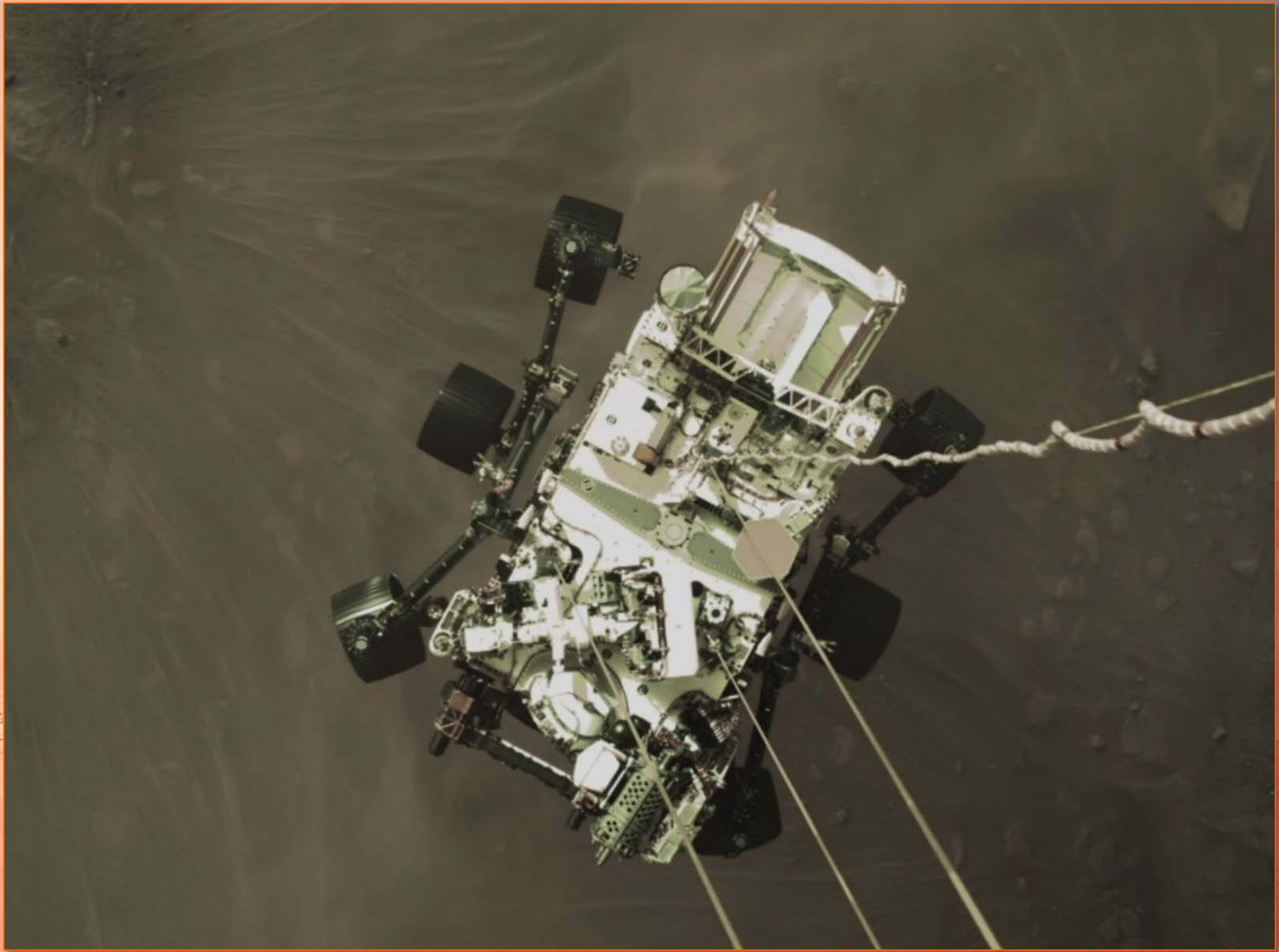


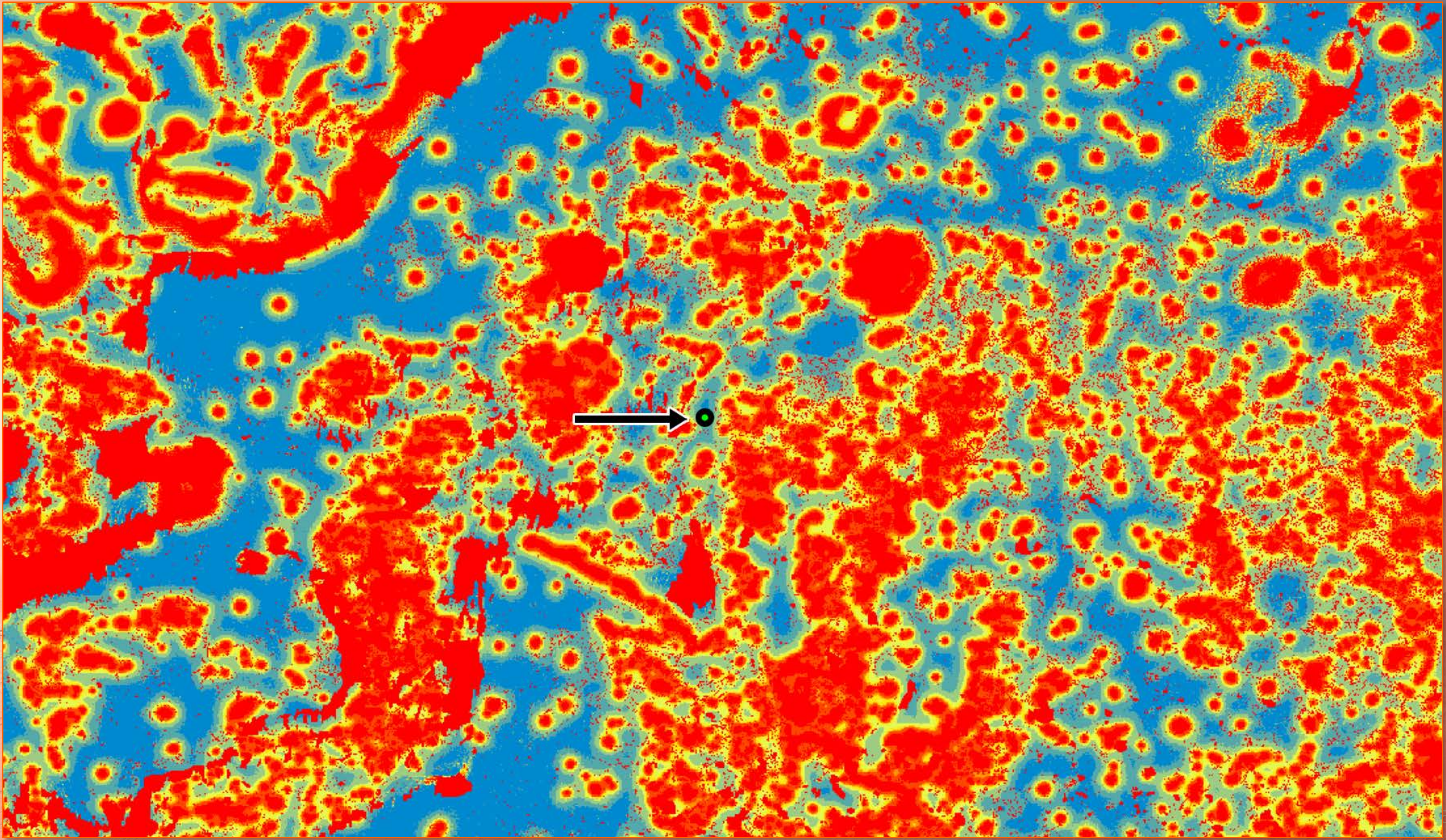
National Aeronautics and
Space Administration

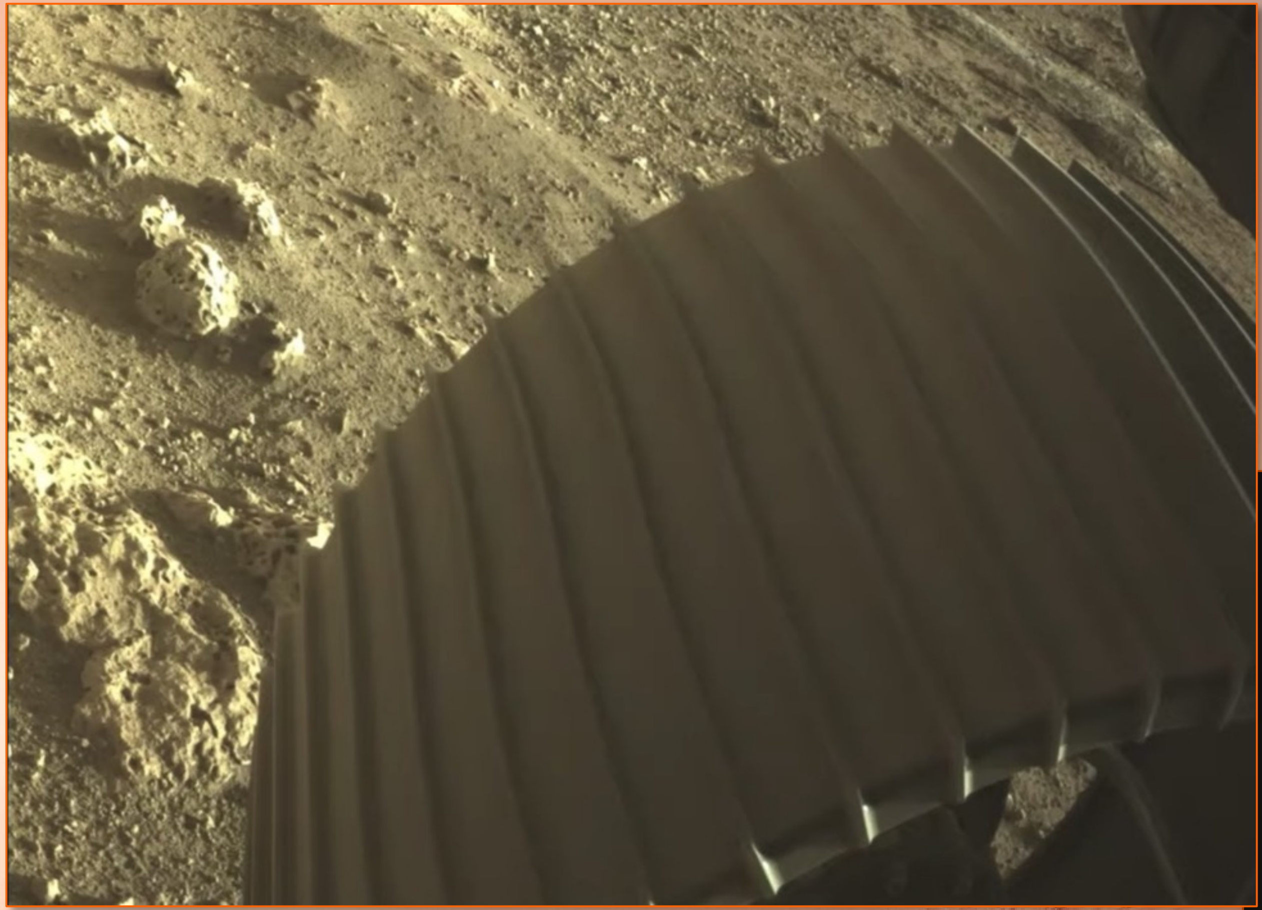
MARS 2020
PERSEVERANCE


NASA
MARS 2020
JPL
Ground Data System
Telecom









Understanding the Possibilities for Life on Mars

ANCIENT MICROBIAL LIFE

OBJECTIVE A
Geology

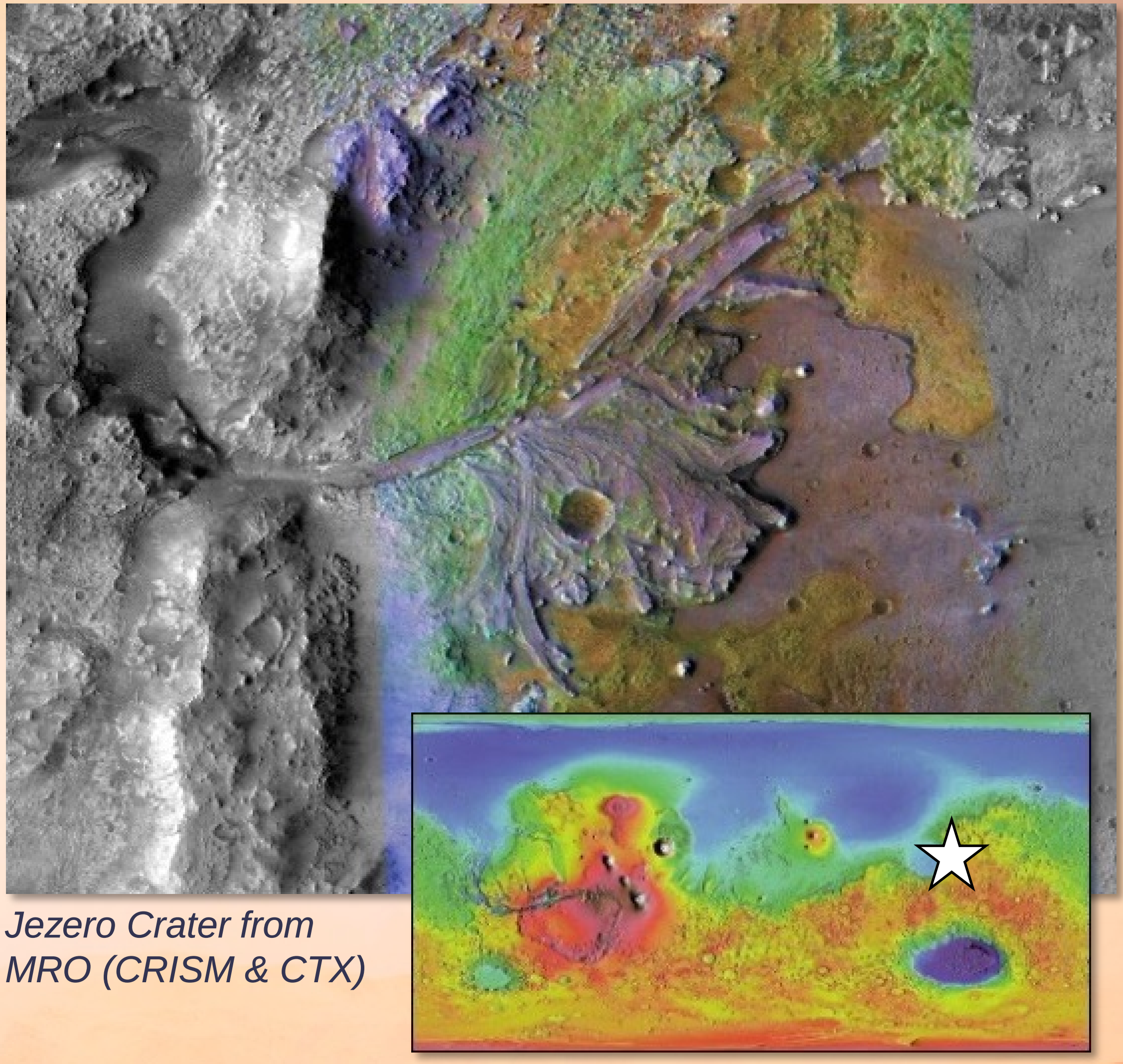
OBJECTIVE B
Astrobiology

OBJECTIVE C
Sample Caching

HUMAN LIFE

OBJECTIVE D
Prepare for Humans

Jezero Crater

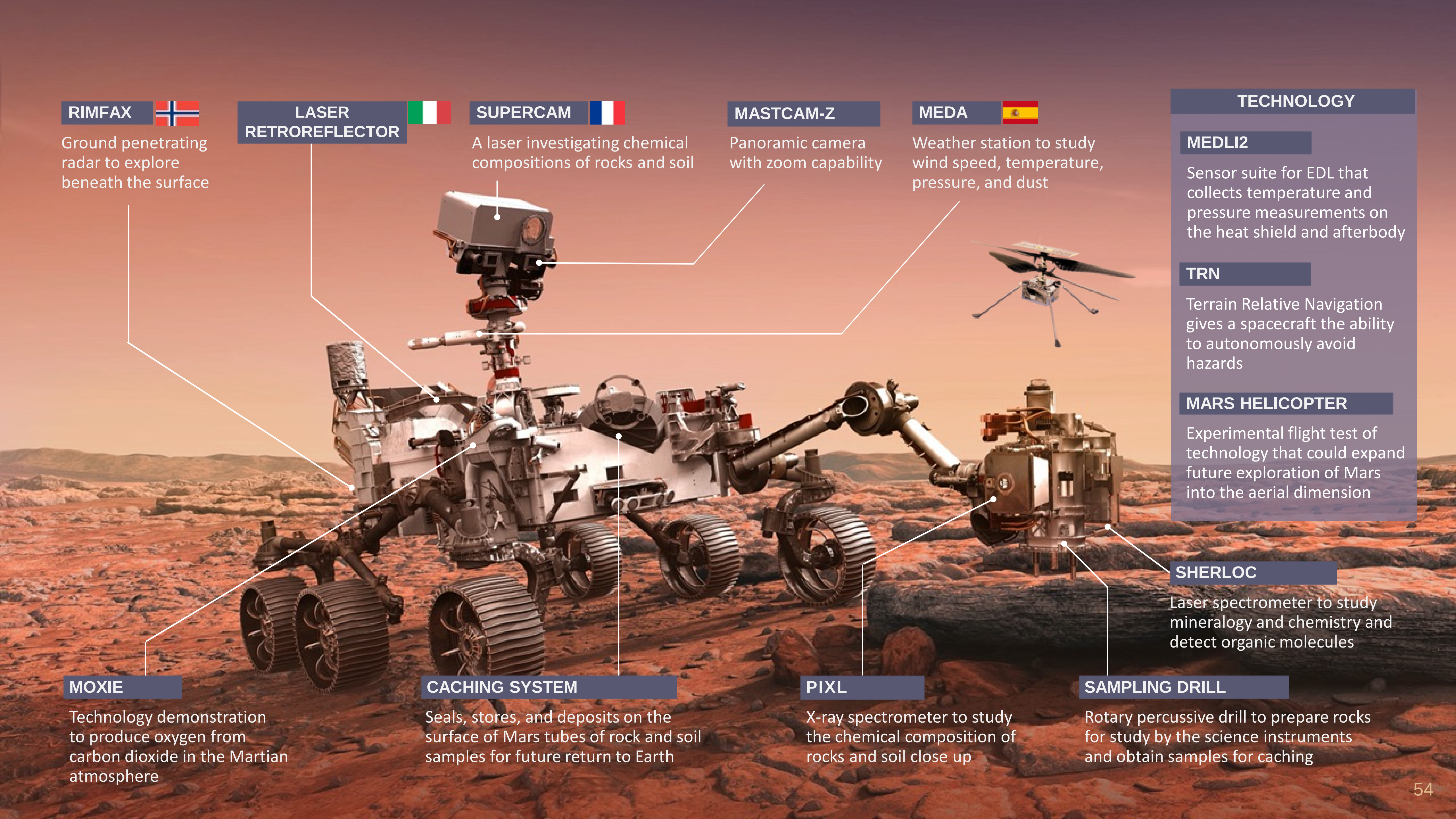


Jezero Crater from MRO (CRISM & CTX)

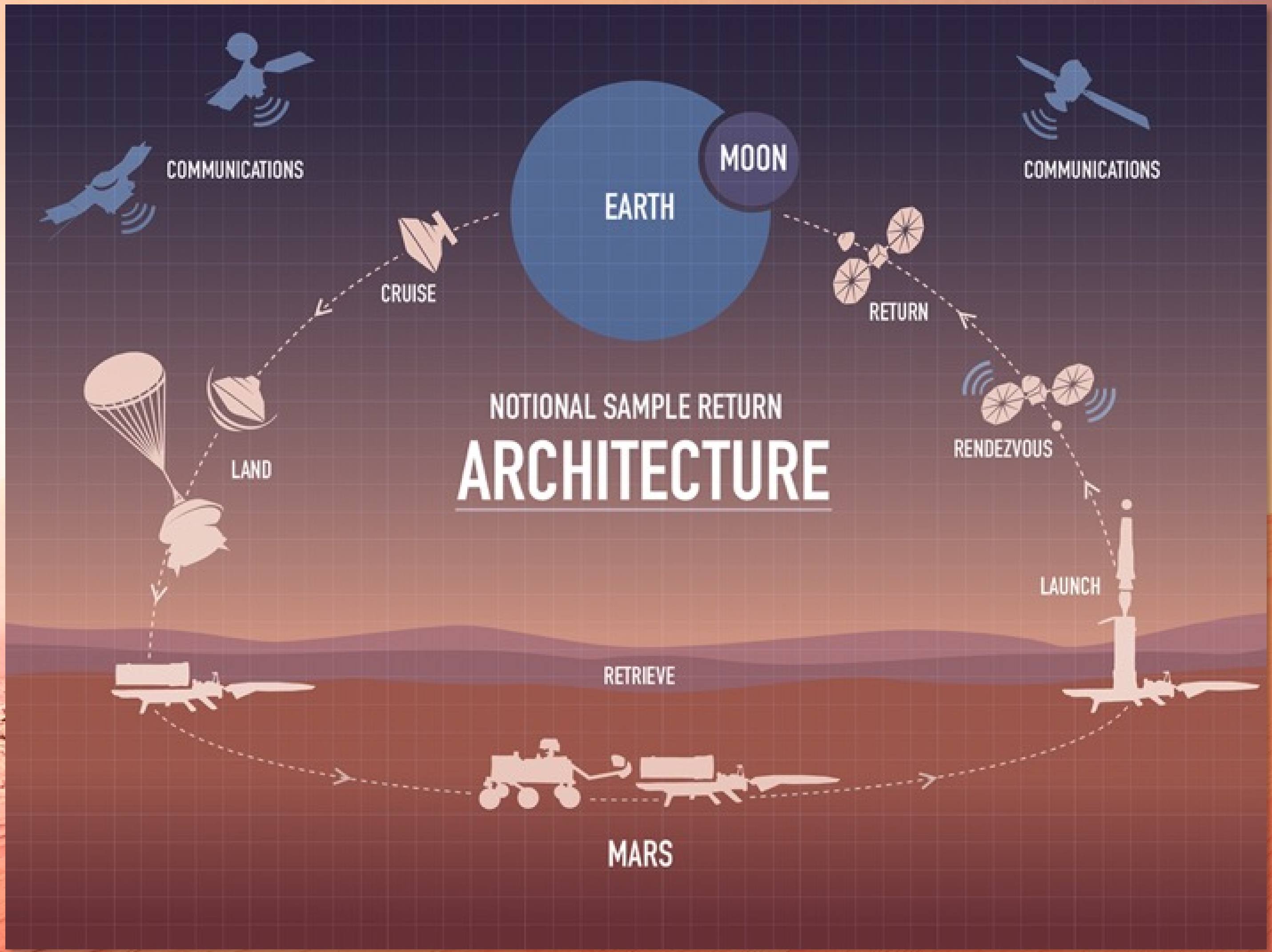
Why Jezero?

- From orbit, this crater shows promising signs of a place that was likely friendly to life in the distant past
- Ancient delta deposits in the crater could have collected and preserved organic molecules and other potential signs of microbial life
- Orbital spectral data show that some of the crater's sediments have minerals indicative of chemical alteration by water such as clays and carbonates

Location:	Northern hemisphere of Mars, in the Isidis Planitia region (18.4°N, 77.5°E)
Diameter:	28 miles (45 km)


RIMFAX
Ground penetrating radar to explore beneath the surface
LASER RETROREFLECTOR
SUPERCAM
A laser investigating chemical compositions of rocks and soil
MASTCAM-Z
Panoramic camera with zoom capability
MEDA
Weather station to study wind speed, temperature, pressure, and dust
TECHNOLOGY
MEDLI2
Sensor suite for EDL that collects temperature and pressure measurements on the heat shield and afterbody
TRN
Terrain Relative Navigation gives a spacecraft the ability to autonomously avoid hazards
MARS HELICOPTER
Experimental flight test of technology that could expand future exploration of Mars into the aerial dimension
SHERLOC
Laser spectrometer to study mineralogy and chemistry and detect organic molecules
MOXIE
Technology demonstration to produce oxygen from carbon dioxide in the Martian atmosphere
CACHING SYSTEM
Seals, stores, and deposits on the surface of Mars tubes of rock and soil samples for future return to Earth
PIXL
X-ray spectrometer to study the chemical composition of rocks and soil close up
SAMPLING DRILL
Rotary percussive drill to prepare rocks for study by the science instruments and obtain samples for caching

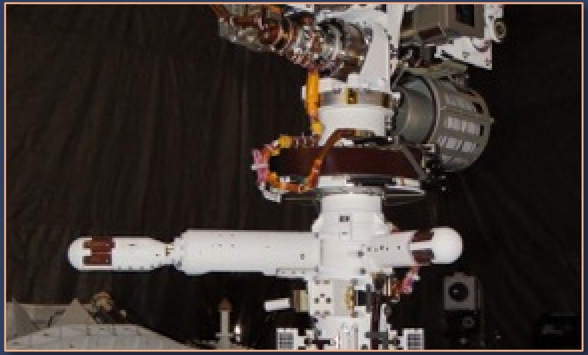
First Leg in Mars Sample Return



Preparing for humans

- **MOXIE:** Testing ISRU technologies to enable propellant and consumable oxygen production from the Mars atmosphere for future exploration
- **MEDA:** Surface weather measurements to validate global atmospheric models and develop weather forecasting & atmospheric dust measurements to help understand effects on surface operations and human health
- **SHERLOC:** space suite material calibration targets to test how they resist the harsh Mars environment
- **Terrain Relative Navigation:** testing autonomous hazard-avoidance landing systems

MOXIE



MEDA

SHERLOC

Mars Ice Mapper

- Near-surface ice (top 10 m) is a critical element of the human exploration of Mars
    - Rich in science potential
    - In situ resource for human exploration
    - Potential driver for human landing site selection
- Planning for human exploration requires knowledge about the location, character, and extent of accessible

- Emerging multilateral partnership is beginning to plan for the mission (launch as early as 2026), and studying next-gen communications needs that could provide robustness for Mars Sample Return and critical infrastructure for all future Mars missions
    - NASA, ASI, CSA, JAXA recently signed Statement of Intent


THE EVOLUTION OF A MARTIAN

Masten

The Moon: Get It

The accessibility of the Moon has changed.

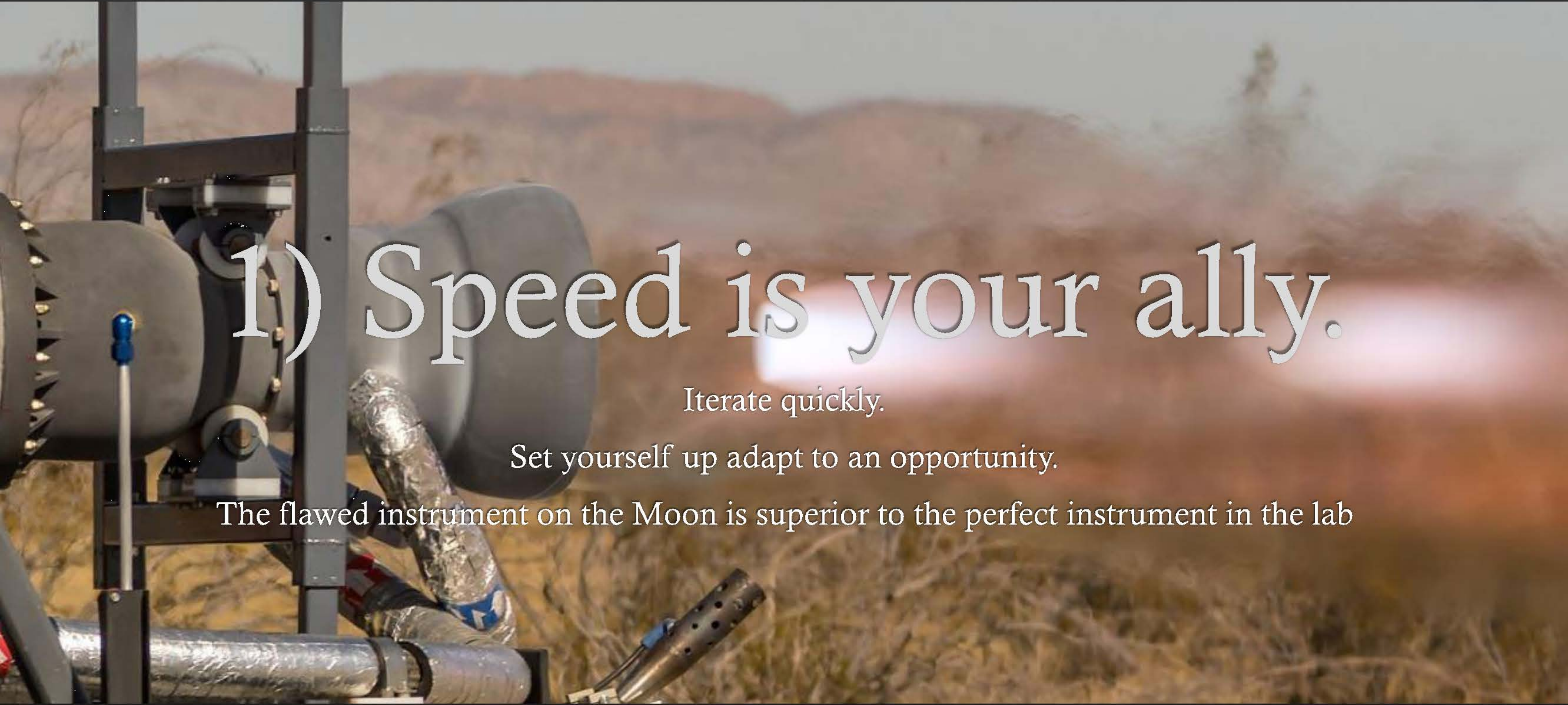
You need to change as well to be part of this opportunity.

Cubesat paradigm shift changed the art of the possible for LEO.

A new paradigm is emerging for the Moon.

Ridiculously oversimplified guidance:

1) Speed is your ally.
2) Risk is your friend.
3) Testing is truth.



1) Speed is your ally.

Iterate quickly.

Set yourself up adapt to an opportunity.

The flawed instrument on the Moon is superior to the perfect instrument in the lab


2) Risk is your friend.
Risk will keep most people on the couch.
Humans are poor evaluators of statistics and risk.
Shed your aversion to learning
Sacrilege!

3) Testing is truth.

"No plan survives first contact with the enemy." - Moltke the Elder

Simulation is great at simulating the things it simulates.

The Moon is real. You need more real getting to the Moon.

Headed to Moon

Landed on Mars


Headed
to Moon
EOS DIGITAL
Canon

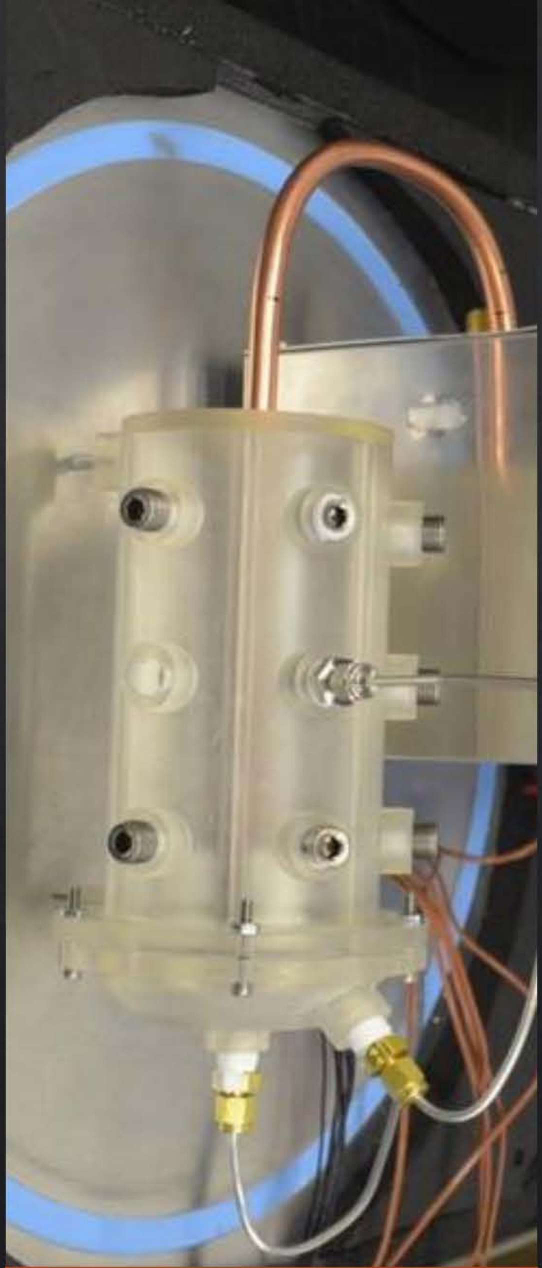
Oh… Yeah.

When you are ready to get the Moon,
Masten will make it happen.

Tech Dev

Terrestrial Test

Lunar Delivery



Product Labs

Masten

Sean Mahoney
Moon@Masten.aero

Thank you for joining the panel

nasa.gov/artemis

@NASAArtemis

@NASAArtemis

@NASAArtemis

blogs.nasa.gov/artemis

Sign up for updates at nasa.gov/subscribe