Lunar Rover
Virtual Industry Forum

12 February 2020

Agenda

Time (ET)	Topic	Speaker
11:00	Welcome and Logistics	**ERIN MAHONEY** Communications Manager, Advanced Exploration Systems
11:05	Artemis Overview	**MARSHALL SMITH** Director, Human Lunar Exploration Programs (NASA HQ)
11:15	Lunar Surface Science Mobility Systems (LSSMS) RFI	**JASON (JAY) JENKINS** Program Executive, Science Mission Directorate (NASA HQ)
11:35	Lunar Terrain Vehicle (LTV) RFI	**DOUGLAS CRAIG** Strategic Analysis and Planning Manager, Human Exploration and Operations Mission Directorate (NASA HQ)
11:55	Q&A	All

Forum Topics

- Ground Rules and Forum Logistics
- NASA Points-of-Contact
- Artemis Overview – Marshall Smith
- Lunar Surface Science Mobility Systems RFI Overview – Jay Jenkins
- Lunar Terrain Vehicle RFI Overview – Doug Craig
- Q&A

Forum Purpose

- Provide an overview of NASA's Artemis lunar exploration program and the two lunar surface mobility RFIs published last week
  - Lunar Terrain Vehicle (LTV)
  - Lunar Surface Science Mobility Systems (LSSMS)
- Address questions from potential RFI respondents
- Summary and links to RFIs is available here:
  - https://www.nasa.gov/feature/nasa-to-industry-send-ideas-for-lunar-rovers

Forum Ground Rules

- **This forum is being recorded for purposes of capturing questions and answers.**
- **NASA will address questions during this forum to clarify the content of the RFIs.**
- **Participants may submit questions by:**
  - Pressing *1 on the phone, to be entered into a question queue
  - Submitting via text to WebEx Chat (to “Host,” NASA HQ)
  - NASA will not provide the identities of anyone asking questions
- Media should direct all questions in writing to Gina Anderson, and Grey Hautaluoma, NASA HQ Public Affairs Officers, gina.n.anderson@nasa.gov and grey.hautaluoma-1@nasa.gov
- **NASA will not provide evaluations, opinions, or recommendations regarding any suggested approaches or concepts**
- **Following this forum, NASA will post briefing slides and an industry attendance list for partnering purposes.**
  - Send an email to **hq-lunarexploration@mail.nasa.gov** by Thursday, Feb. 13 if you do not want to be included on the participant list. NASA will post the attendance list on Friday, Feb. 14.

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NASA POCs

- Lunar Surface Science Mobility System (LSSMS-1)
  - Science Mission Directorate Program Executives
    - Jay Jenkins: jason.e.jenkins@nasa.gov
    - Angela Melito: angela.m.melito@nasa.gov
- Lunar Terrain Vehicle (LTV)
  - Human Exploration & Operations Mission Directorate Program Executive
    - Doug Craig: douglas.a.craig-1@nasa.gov

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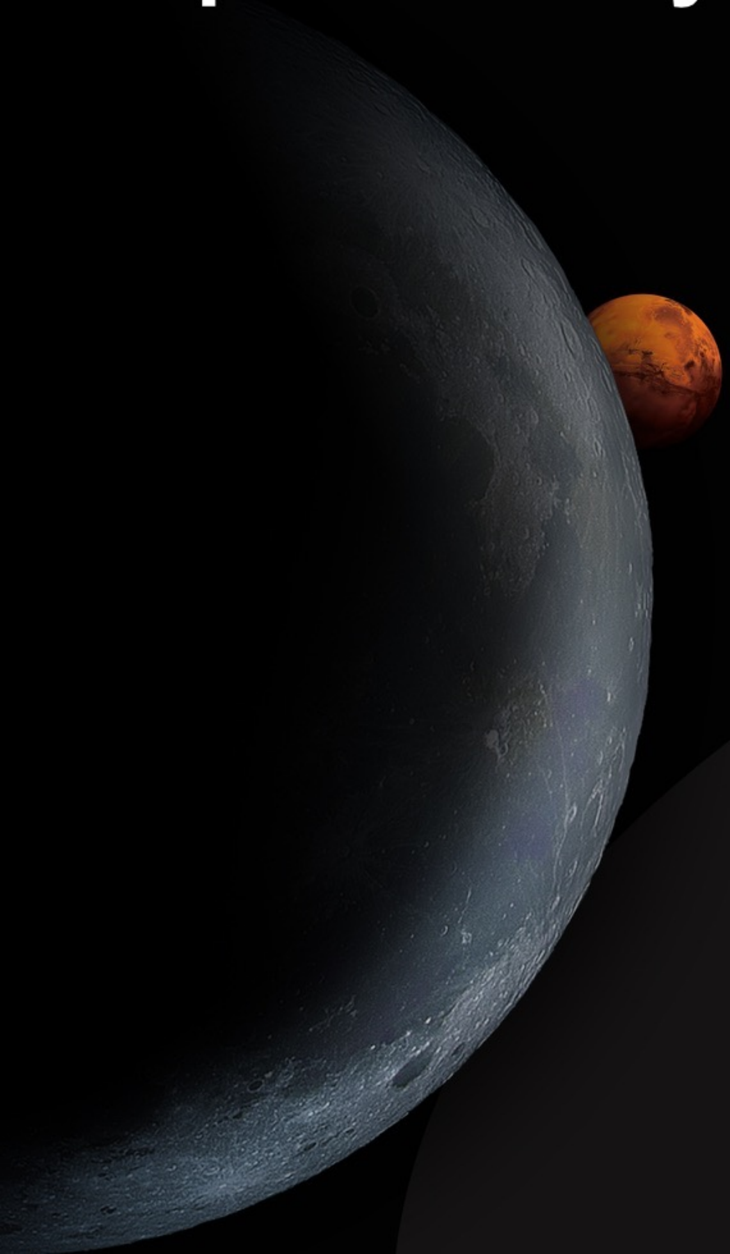
Artemis Overview

Marshall Smith
Director, Human Lunar Exploration Programs
NASA Headquarters

Space Policy Directive 1: To The Moon, Then Mars



"Lead an innovative and sustainable program of exploration with commercial and international partners to enable human expansion across the solar system and to bring back to Earth new knowledge and opportunities. Beginning with missions beyond low-Earth orbit, the United States will lead the return of humans to the Moon for long-term exploration and utilization, followed by human missions to Mars and other destinations…"

Why go to The Moon?

Proves technologies and capabilities for sending humans to Mars

Establishes American leadership and strategic presence

Inspires a new generation and encourages careers in STEM

Leads civilization changing science and technology

Expands the U.S. global economic impact

Broadens U.S. industry and international partnerships in deep space

Moon Before Mars

On the Moon, we can take reasonable risks while astronauts are just three days away from home.

There we will prove technologies and mature systems necessary to live and work on another world before embarking on what could be a 2-3 year mission to Mars.

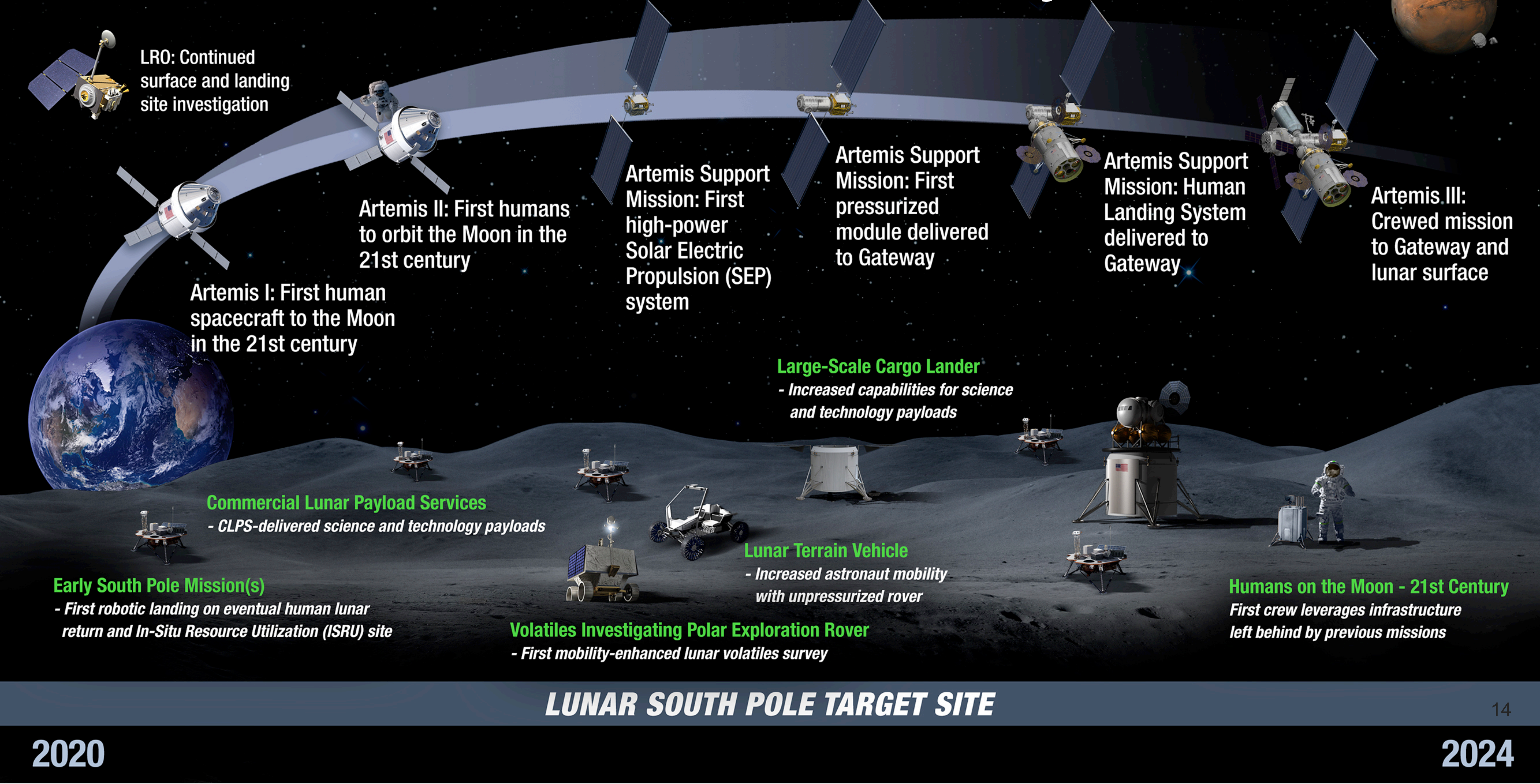
The Artemis Program

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 by 2024.

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 Phase 1: To the Lunar Surface by 2024



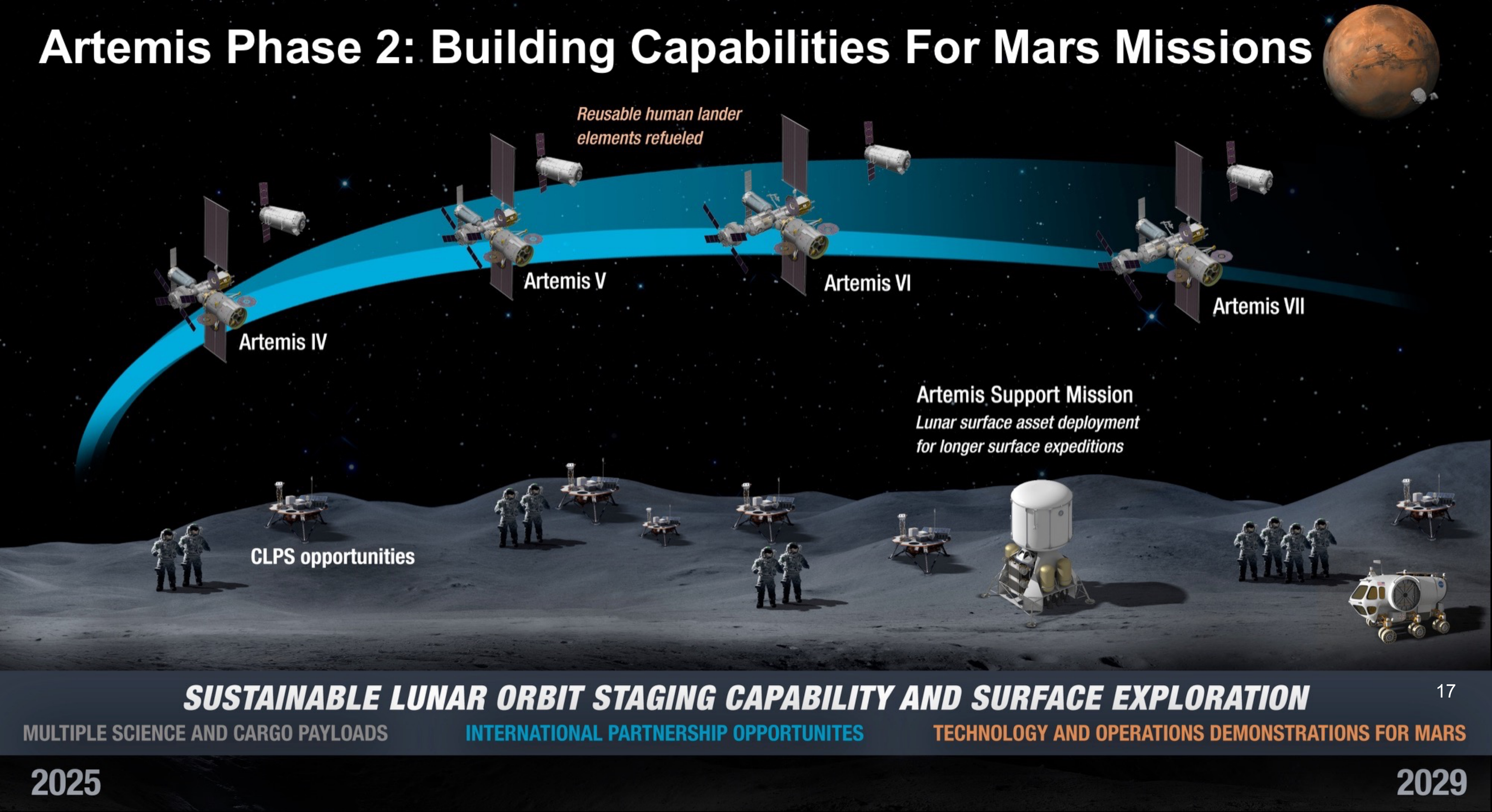
Commercial Lunar Payload Services (CLPS)

- CLPS is an innovative, service-based, competitive acquisition approach that enables rapid, affordable, and frequent access to the Lunar surface via a growing market of American commercial providers.
  - End-to-end delivery service from payload hand-over through deployment/operation.
  - Inclusive of all related services (e.g., integration, launch, communications)
- 14 CLPS Providers on contract to date; 2 active service Task Orders on track for lunar surface deliveries in 2021
- Future LTVs and/or LSSMSs may likely be delivered via a CLPS service task
  – It is also possible that lunar surface mobility may become another CLPS or CLPS-type service.

Commercial Lunar Payload Services (CLPS)

Working with industry to deliver science and technology payloads to the lunar surface

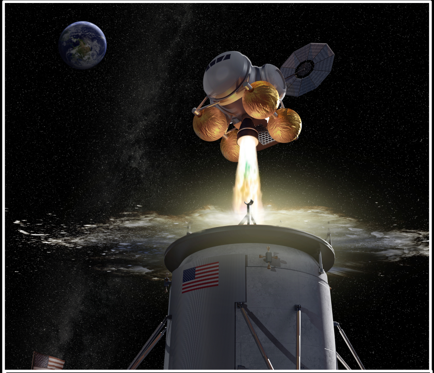
Artemis Phase 2: Building Capabilities For Mars Missions



Common Moon/Mars Systems and Operations

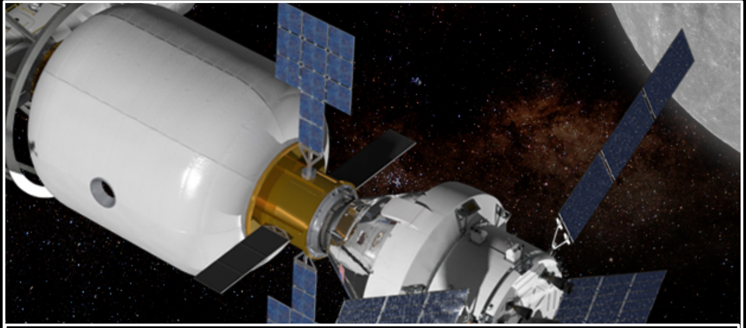
MOBILITY

SUITS



ASCENT SYSTEMS

PROPULSION



HABITATION SYSTEMS

DEEP SPACE AGGREGATION

OPERATIONS:

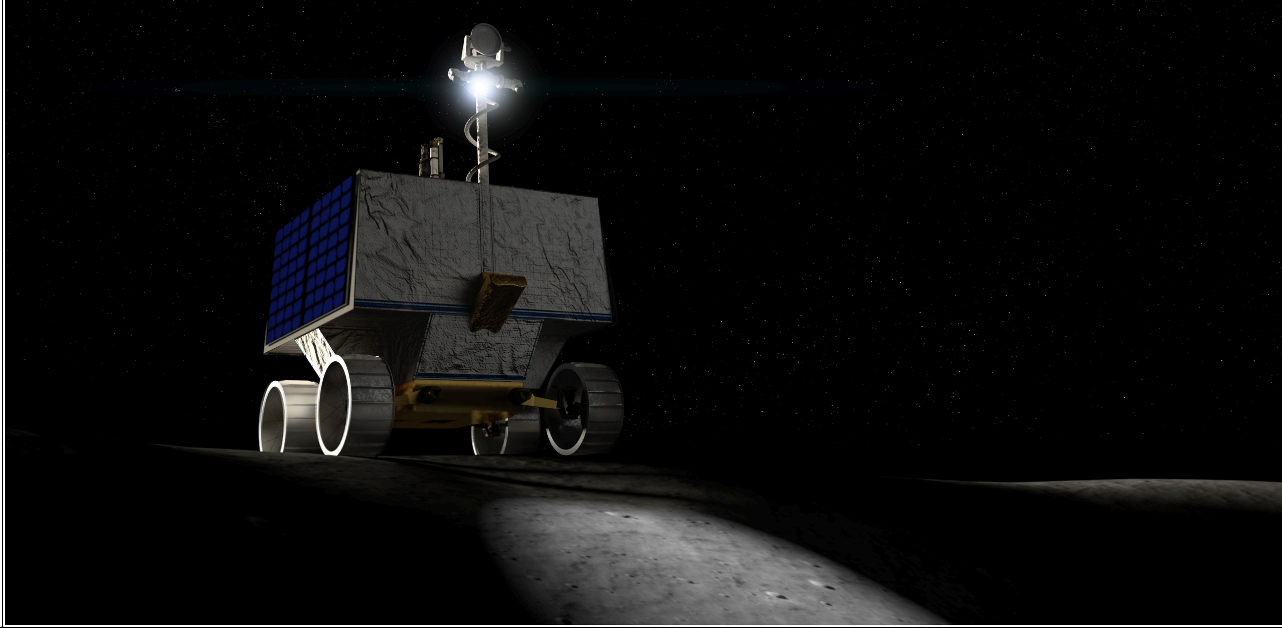
- Orbiting outpost with landing system
- Scientific exploration of a planetary surface
- Automation and robotics to assist/maximize human-led science
- End-to-end dust mitigation
- Physical and behavioral health operations
- Communications & Navigation
- Power systems

Distinction Between the Two RFIs

Lunar Terrain Vehicle (LTV)

Human-rated, for the purpose of moving two suited astronauts across the lunar surface

Lunar Surface Science Mobility Systems (LSSMS)



Robotic vehicles to transport instruments across the lunar surface

NEITHER IS MEANT FOR LARGE-SCALE EXCAVATION OR TRANSPORTATION OF ELEMENTS OR BULK COMMODITIES.

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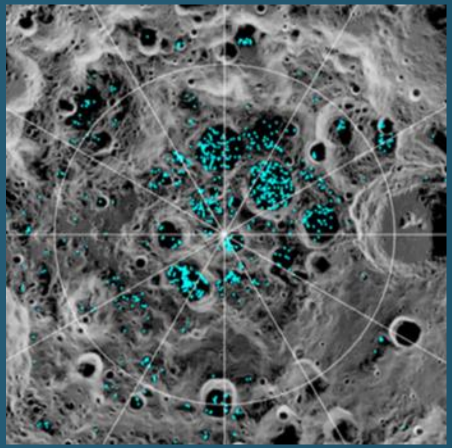
National Aeronautics and Space Administration

EXPLORE SCIENCE

Lunar Surface Science Mobility System RFI

Jay Jenkins & Angela Melito
Program Executives
Science Mission Directorate, NASA

Lunar Discovery & Exploration Program




- Foundational to Artemis missions, leads the Nation's return to the lunar surface in 2021, leveraging an innovative and rapid acquisition approach to commercial lunar delivery services, building to a cadence of 2 deliveries per year
- Implements an integrated science strategy of the Moon through robotic and human exploration collaboration, and interagency and international participation
- Leverages future platforms including SmallSats, the Gateway, and Human Landing System to enable interdisciplinary science and technology development opportunities
- Develops and delivers the first lunar south pole rover to investigate water ice in advance of of Artemis Mission III, landing the first woman and next man to the lunar surface

Lunar Surface Science Mobility Background

- The Deputy Associate Administrator of Exploration in the Science Mission Directorate (SMD) is developing strategies to:
    - Use science to inform and support exploration
    - Maximize scientific return from the Artemis campaign of exploration
- This includes planning a lunar surface science mobility to extend the range of science and robotically enhance crewed exploration
- Seeking innovation and unique leverage possibilities, while accepting some risk
    - It is “OK” to lack aerospace experience; if you have a viable terrestrial concept that you can imagine being used on the Moon, we want to hear about it
    - Of course, mobility systems designed for space are wanted as well
- Inform a broader lunar mobility strategy that may include several parallel approaches
    - This RFI is not a procurement action

Lunar Surface Science Mobility Strategy

- Candidate Parallel Options for Mobility Development:
  - Technology development partnerships toward maturation/adaptation of innovations.
  - Traditional procurement options to buy a system to meet specific needs.
  - Evolution of the Commercial Lunar Payload Services (CLPS) to procure mobility service without having a stake in the design.
  - NASA in-house development and maturation/adaptation of existing designs.
  - International contributions and collaborations.
- This RFI is to see what may be available from U.S. commercial, and commercializable, communities that could flow into the strategy.

Lunar Surface Science Mobility System (LSSMS) Scope

- Carry, and possibly operate or emplace, NASA science, technology, and exploration payloads across the surface of the Moon
- Intentionally open-ended to cast wide net across non-traditional companies and mobility products
  - System scope described by a set of loose functional descriptions rather than firm requirements or even specific missions
  - Attributes that are "generally valuable" to us, but not intended to constrain unique approaches or niche applications
- Not "entirely open" though:
  - Emphasize science & technology demo use while providing collateral benefit for exploration (i.e. enhancements)
  - LSSMS is not about human-centric mobility needs;
  - LSSMS seeks to stay off the critical path or and not be part of critical architecture for crewed exploration
  - Responses should be grounded in viable concepts which may include terrestrial applications
- Does include development, production, integration of any payloads, integration support into a separate launch/lander system, and operation on the lunar surface
  - Any launch and lander system are not part of this RFI except to the extent that they may form a part of the LSSMS.

The LSSMS Desired Functionality Examples

- The RFI seeks systems that are more apt to:
  - Transport scientific samples to a collection point (1's to 100's of kg)
  - Transport and operate a suite of scientific instruments (10's to 100's of kg)
  - Enable a unique investigation otherwise not accessible (1's to 100's of kg)
  - Transport and operate technology demonstrations (100's to low-1000's of kg)
  - Transport exploration tools that are enhancing or otherwise non-critical, or crew-deployed science experiments (10's to low-1000's of kg)
  - As a secondary benefit, transport of any exploration commodity, material or equipment that is supplemental, enhancing, or otherwise non-critical to a crewed mission. (10's to low-1000's of kg)

List should not be considered exhaustive nor universally applicable; it is important to not discount a unique approach that has possible niche value!

Scope outside this LSSMS RFI

This LSSMS RFI is not seeking mobility systems that would be more appropriate to:

- Transport large exploration elements such as habitats or outposts
- Perform excavation, mining, and construction activities
- Transport large quantities of bulk materials or resources
- Transport crew or crewed elements
- Transport any item or element that itself is critical to crewed mission success or to the health and safety of crew

LSSMS attributes that are “generally valuable”

- Payload accommodation
- Survivability and/or operation during lunar night and in permanently shadowed regions.
- Traverse varied terrains, obstacles, slopes, pits, soft regolith, etc., and to do so over long distances (i.e., 10’s to 100’s of kilometers).
- Deployable and useable globally
    - Polar and non-polar; near-side and far-side
- Autonomous operation (local, Gateway, or earth teleoperation of value as well)
- Availability and affordability

List should not be considered exhaustive nor universally applicable; it is important to not discount a unique approach that has possible niche value!

Information Sought

- Seeking information to inform and help shape a lunar surface mobility strategy to enable science and to enhance exploration
  - Information needs to convey the nature and value of the system, and give some reasonable sense of cost, schedule, and feasibility
- Ideally:
  - Detailed technical descriptions, credible schedules identifying major milestones and critical paths, justified cost estimates, risk assessments
- Realistically:
  - Do what you can to provide useful information about what you know.
  - It is OK to lack aerospace experience:
    - Try to provide information that you do know that would convey a sense of the design, its complexity and feasibility, the steps you think need to be taken, development time, and cost
    - Describing your efforts and investments to date can help give a sense of what more is needed to be used on the Moon
    - You may wish to form partnerships in the aerospace community to better inform estimates and understand feasibility

Information Sought: Technical Descriptions

- What would it look like? What would it do? What would you need to do to make it happen?
- Design
    - Overall description, subsystem basics, notable features, capabilities, sensitivities, technical challenges, environments
- Operations
    - Applications, concept of operations, powering/charging, communication, autonomy, control, resilience, survivability, limitations, modes of operation
- Maturity
    - What exists? Terrestrial prototype? Commercial product for terrestrial use? Space-qualified?
- Analogs
    - Does it leverage terrestrial capabilities? Do you think the design would be easy to convert to space use? Difficult? What challenges would you imagine?

Guidance should not be considered exhaustive, nor universally applicable; it is intended only to convey the types of information that are useful to inform NASA's strategy.

Information Sought: Schedule

When would you imagine this could be ready to go to the Moon? What are the steps? Why are your estimates realistic?

- Development
  - Maturation, design, proofs of concept, demonstrations, qualification
- Production
  - Production time / volume
- History
  - How long has it been in development? How long between block improvements? How long to make prototypes? What is the current production time / volume for any current capability?
- Challenges
  - What would be the biggest challenges to schedules? How confident are you in the estimates?

Guidance should not be considered exhaustive, nor universally applicable; it is intended only to convey the types of information that are useful to inform NASA's strategy.

Information Sought: Cost

How much would it cost to develop first unit ready for the Moon, including all test units and activities leading up to it? What would production costs be for additional units? Are there any noteworthy operational costs? Why are your estimates realistic?

- Development
  - Maturation, design, proofs of concept, demonstrations, qualification
  - Contract type, partnerships, cost sharing, infrastructure
- Production
  - Unit costs, economy of scale
  - Contract type, infrastructure
- History
  - About how much has it cost to get where you are? What have your prototype costs been? What is your current catalog price for the capability you have now?
- Challenges
  - What would be the biggest challenges and uncertainties in your cost estimates? How confident are you in the estimates?

Guidance should not be considered exhaustive, nor universally applicable; it is intended only to convey the types of information that are useful to inform NASA's strategy.

Questions about the RFI

NASA is accepting questions about this RFI by email through Feb 19, 2020

- Do not send proprietary, ITAR/EAR, Classified, or other sensitive information in your questions
- Title question emails as: SMD LSSMS-1 RFI Question
- Send questions to: jason.e.jenkins@nasa.gov and angela.m.melito@nasa.gov
- Do not submit your RFI responses to these email addresses

NASA intends to reply to questions by Feb 24, 2020

- May respond individually by email if the question applies to specific ideas or to the asker.
- May respond via redacted publicly posted FAQ if the question would be of general interest or clarifying the RFI process

LSSMS RFI Submissions

Responses due: March 6, 2020 at 11:59pm

10 pages and 1 page summary in PDF

May submit via email to:

hq-lunarmobilityrfi@mail.nasa.gov

or via upload to NSPIRES per the directions in the RFI.

All responses that contain proprietary, ITAR, EAR, or other sensitive information must be marked as such and must be uploaded via NSPIRES or must be encrypted if emailed.

Do not send Classified information.

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Lunar Terrain Vehicle RFI

Doug Craig
Strategic Analysis and Program Planning
Human Exploration and Operations, NASA HQ

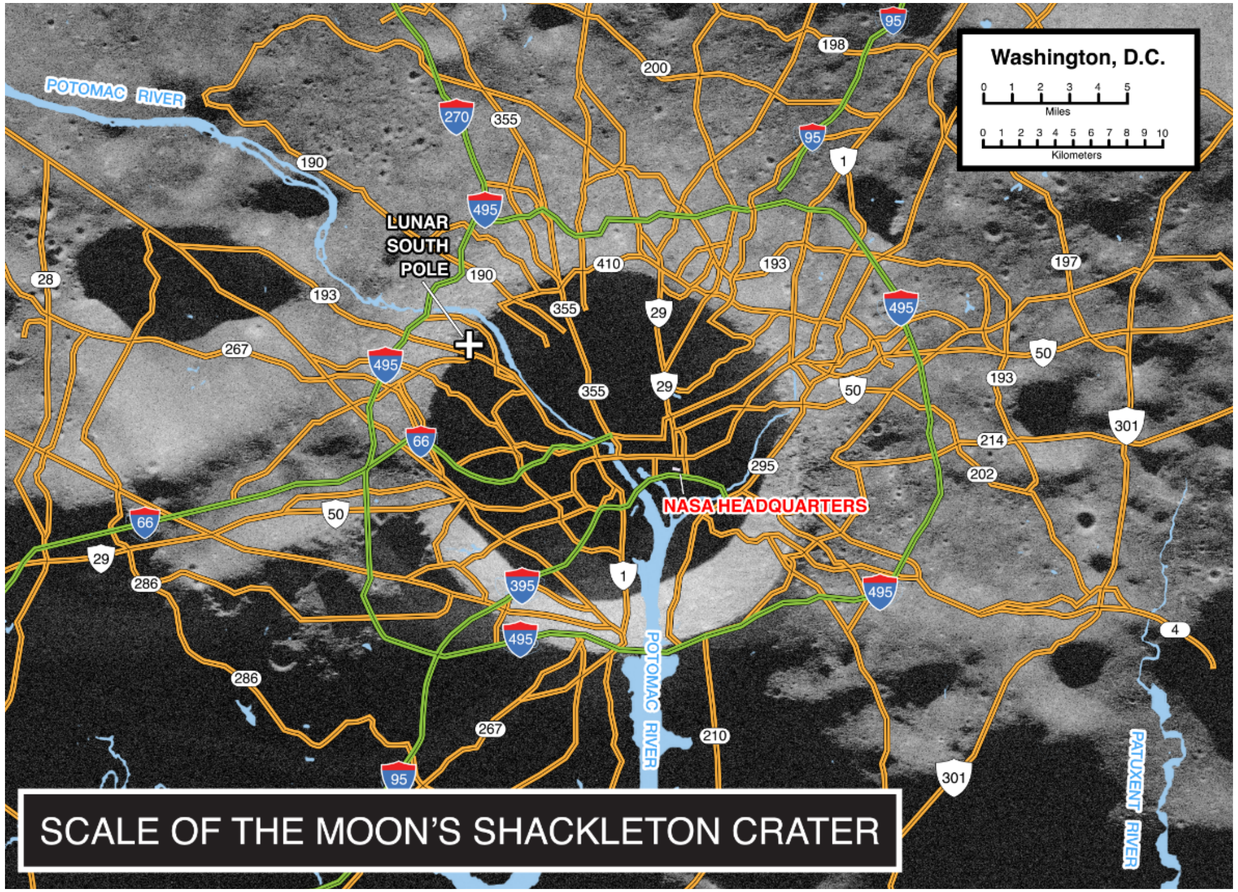
LTV Scope

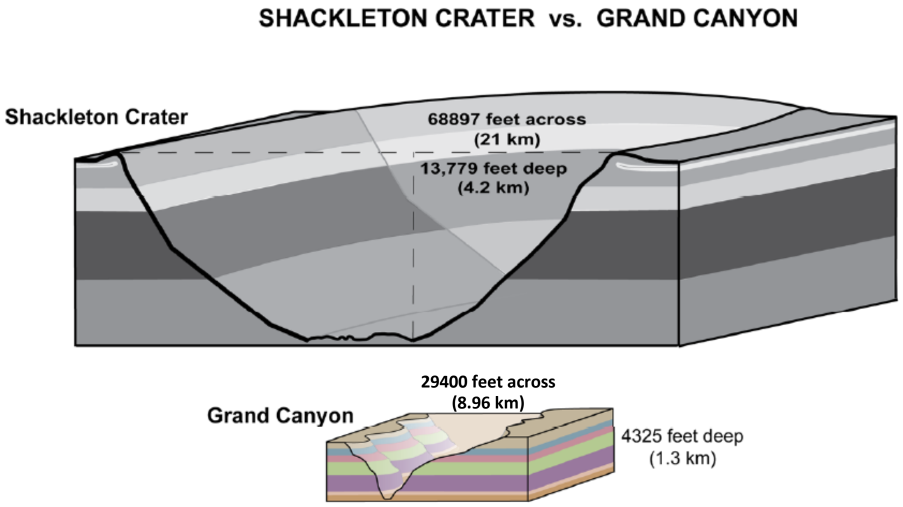
- NASA/HEOMD is seeking information industry on how to approach the development of a human-class, unpressurized mobility system that will extend the exploration range of Extravehicular Activity (EVA) - suited crew on the lunar surface, with the goal of launching the first LTV potentially as early as 2024.
- NASA has identified key LTV-required capabilities that may also have potential commercial applications, including
  - Electric vehicle systems (e.g., energy storage, energy management and distribution, recharging)
  - Autonomous driving in high contrast lighting conditions and hazardous terrain, and extreme environment tires and possibly many others.
- While the need to extend crewed exploration drives the LTV mission, any collateral, non-intrusive benefits to science investigations and technology demonstrations should not be precluded (e.g. sharing of power, data, or communication resources, instrument-mounting footprints)

Potentially Relevant Industries

- There are several U.S. Industries that are investing millions of dollars in LTV-relevant capabilities that NASA can leverage
  - Commercial Automotive Industry
  - Heavy Equipment Manufacturers
  - Military Vehicle Manufacturers
  - Autonomous Systems Developers
  - Aerospace System Developers
- Responses are sought from U.S. corporate entities, or teams led by a U.S. corporate entity; foreign participation as a teammate in this RFI is not precluded

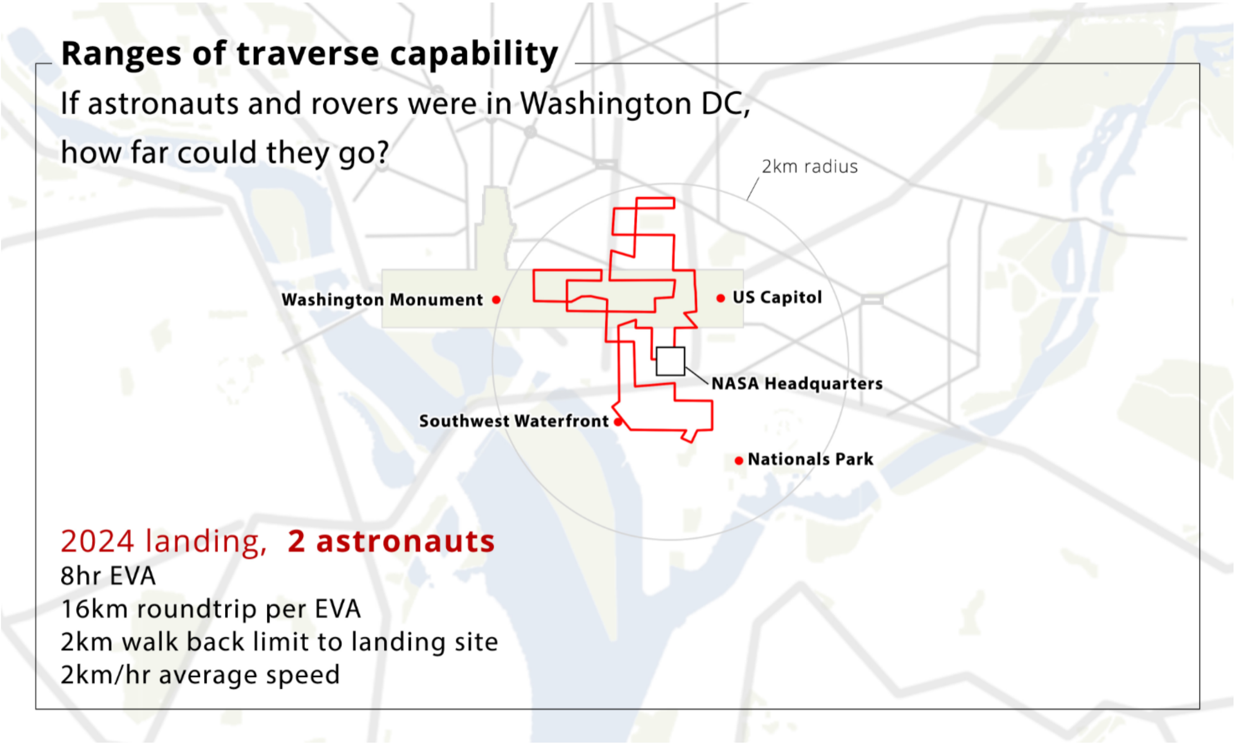
Potential Lunar Landing Site

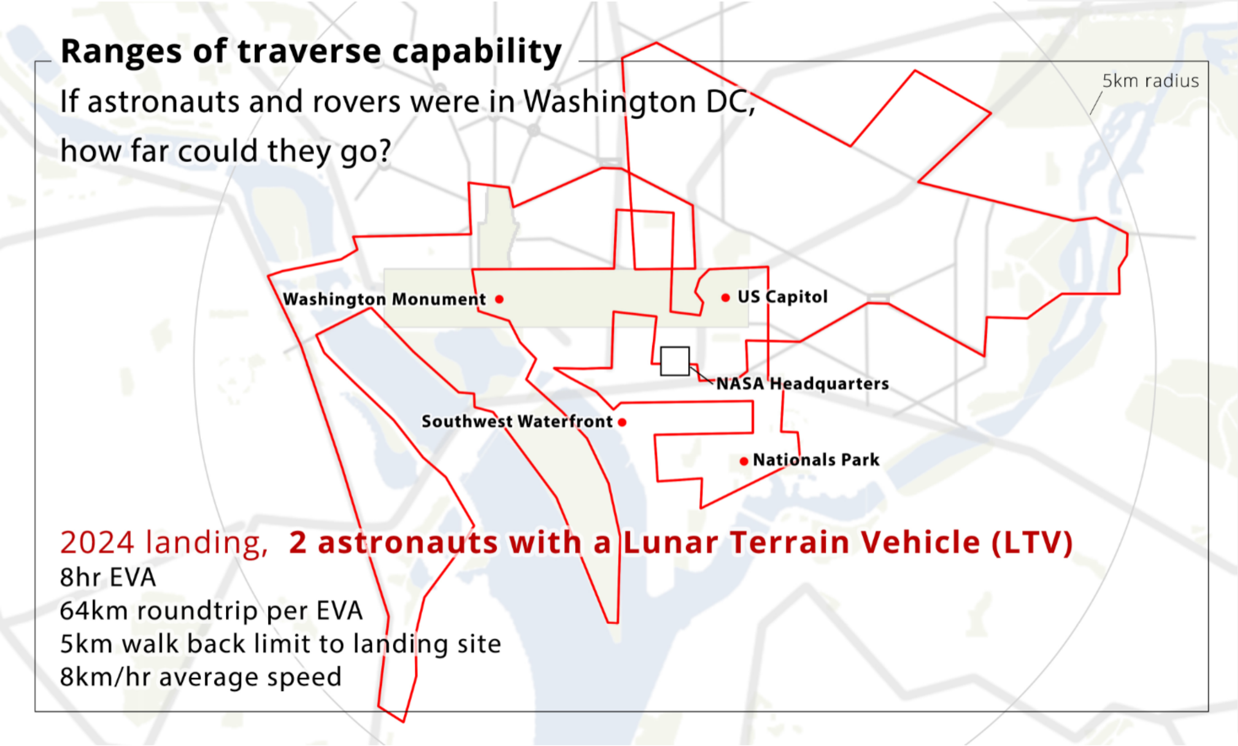




- Shackleton Crater
  - ~20 km in diameter, ~4 km deep and ~3x deeper and wider than the Grand Canyon at Enfilade Point
  - Located at lunar South Pole and is primary target for future lunar landings

The Case for Surface Mobility Systems





LTV RFI Goals and Objectives

- RFI Goal
  - Market research to inform the acquisition of a Lunar Terrain Vehicle
  - This is not an acquisition; this activity is to inform architectural strategy
- RFI Objectives
  - Identify innovative mission and vehicle design ideas
  - Novel development and operations approaches
  - Relevant state-of-the-art (SoA) technologies
  - Opportunities for commercialization and public-private partnerships
- Characterize Industrial Base
  - Current and potential industry interest and capacity (including non-traditional sources)
  - Industry capabilities and relevant NASA capabilities
  - Acquisition and partnering strategies
  - Feasibility of requested NASA LTV concept
    - Technologies
    - Schedule

LTV Minimal Capability Descriptions

Capability Title	Reference Capability Description	Capability Supporting Comments
1. Launch Constraints	The LTV total mass and size will allow it to be launched on a CLPS-sized lander.	CLPS landers are launched on commercial launch vehicles and will have a 3.2 meter deck and be able to land ~up to 500kgs.
2. Range	The LTV can carry 500kgs on a single charge around the Lunar South Pole Region for distances in excess of 2km.	The LTV will be able to carry 2 EVA suited astronauts beyond walking distances and over reasonable lunar surface conditions. NASA assumes ~500kg for two EVA-suited crewmembers, associated science and exploration equipment and collected/curated samples.
3. Surface Conditions	The LTV must be capable of traversing across lunar highland terrain, meeting or exceeding conditions experienced by the Apollo Lunar Roving Vehicle (LRV).	The south polar region of the Moon is composed of heavily cratered highlands terrain. Apollo 16 also operated within highland terrain. The LRV was used to carry crew over slopes as high as 15 degrees, which should serve as a baseline for LTV capabilities.
3. Recharging Capability	The LTV can be recharged from internal power generation sources and from other lunar surface assets.	The LTV could be recharged in the nominal lunar surface environment by a variety of power sources, to include (but not limited to) a HLS descent lander, an on-board solar array, or future lunar surface infrastructure.
4. Lunar Environment Survivability	The LTV should survive the extreme temperatures on the lunar surface to include a lunar night south pole to allow for reuse across lunar nights and between human missions.	The lunar surface temperatures vary from 260 degrees Fahrenheit (127 degrees Celsius) to minus 280 F during a 100-hour lunar night at the lunar south pole.
5. Autonomous Operations	Autonomous operations of the LTV can aid surface exploration and enhance operational uses. Possible autonomous ops could include the ability to deploy from CLPS lander, the ability to drive paths programmed and uploaded by users on the surface, from the Gateway, or from Earth. Teleoperation of the rover on the lunar surface by astronauts or other sources may allow for increased science investigations and exploration when astronauts are not present or between missions.	Mobility systems could transport cargo or science packages between locations with masses or distances that exceed crew capabilities. Dual systems might enable improved overall transportation risks and allow for return of crew from extended distances (e.g. 10km-20km). In addition to cargo, the LTV should provide opportunities for integration of instruments that can be tele-operated during crew activities and between crewed missions. The LTV will also be expected to transport cargo/tools/instruments between landing sites in order to negate delivery of similar hardware in future missions. Mobility systems should accommodate the ability to autonomously load and unload cargo or science packages including excavation rovers carrying regolith.

NASA HEOMD's Requests

- Partnerships
  - How should NASA work with Industry (e.g., co-located teams, exchange of technologies, involvement of NASA SMEs) to develop the mobility platform capability?
  - What is the current or potential commercialization value of the required mobility capabilities development? (e.g., electric vehicle systems, autonomous driving, and extreme environment tires)
  - What potential partners would the respondent consider? (e.g., U.S. industry, International, Academia)
- Feasibility of Development
  - What are the critical technologies to be developed and their current Technology Readiness Level?
  - What NASA capabilities will assist you in developing LTV capabilities? (e.g., integration & test facilities, technical expertise, Government Furnished Equipment)
  - Is the 2024 development timeline achievable? If not, why not and what is an achievable timeframe?
  - What capabilities or requirements would incur the most schedule risk or drive schedule/cost disproportionately?
  - What is the feasibility and relative state of the art for meeting each of the capabilities in Table 1.2.1?
- Contract Mechanisms
  - How should NASA partner with industry (e.g., cost-shared contracts, NextSTEP BAA, Funded Space Act Agreements, Other Transactional Authority (OTA), Service contract) to develop this capability?
  - What approach should be taken toward intellectual property (IP) and data rights?

LTV RFI Schedule Targets

Milestone	Completion Date
Publish RFI	2/5/2020
Virtual Industry Forum	2/12/2020
Inquiry Deadline	2/17/2020
Publish Q&A Log (amend as needed)	2/21/2020
RFI Responses Due	2/26/2020

Response Submission Guidance

- Responses should not exceed 15 pages
  - Should address all requests for information included in Section 1.3 of the RFI
  - Any proprietary information should be properly identified and marked as such
  - Additional information security measures for the submission of proprietary information is described in the RFI
  - **No** classified information will be allowed
- Additionally, a single-page abstract that includes information identified in Section 1.3, paragraph 2, as well as a summary of the response, is requested
- RFI responses are due no later than 12:00pm 26 FEB 2020

hq-lunarexploration@mail.nasa.gov

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Questions and Answers

- Open Q&A session
  - Press *1 to ask over the phone, or send question to the Host on WebEx chat
  - NASA intends to answer questions in real time when able, however some questions might require consideration and follow-up. The written/posted questions are considered the final answer.
  - Interested parties may now ask questions or via email, according to the RFI.
- A Q&A log will be posted to the LTV site on beta.SAM.gov
  - Answers provided in the log will be considered the official answer and will supersede any information provided today
  - All questions will be non-attributed
- Interested parties are encouraged to monitor the LTV beta.SAM.gov website for program updates