NASA's Human Landing System: The Strategy for the 2024 Mission and Future Sustainability

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Abstract—**In response to the 2018 White House Space Policy Directive-1, to lead an innovative and sustainable lunar exploration, and to the Vice President's March 2019 direction to do so by 2024, NASA is working to establish humanity's presence on and around the Moon by: 1) sending payloads to its surface, 2) assembling the Gateway outpost in orbit and 3) demonstrating the first human lunar landings since 1972. NASA's Artemis program is implementing a multi-faceted and coordinated agency-wide approach with a focus on the lunar South Pole. The Artemis missions will demonstrate new technologies, capabilities and business approaches needed for future exploration, including Mars. Assessing options to accelerate development of required systems, NASA is utilizing public-private engagements through the Human Exploration and Operations (HEO) Mission Directorate's NextSTEP Broad Agency Announcements. The design, development and demonstration of the Human Landing System (HLS) is expected to be led by commercial partners. Utilizing efforts across mission directorates, the Artemis effort will benefit from programs from the Science Mission Directorate (SMD) and Space Technology Mission Directorate (STMD). SMD's Commercial Lunar Payload Services (CLPS) initiative will procure commercial robotic lunar delivery services and the development of science instruments and technology demonstration payloads. The Space Technology Mission Directorate (STMD) portfolio of technology advancements relative to HLS include lunar lander components and technologies for pointing, navigation and tracking, fuel storage and transfer, autonomy and mobility, communications, propulsion and power. In addition to describing the objectives and requirements of the 2024 Artemis mission, this paper will present NASA's approach to accessing the lunar surface with an affordable human-rated landing system, current status and the role of U.S. industry in 2024 and for a sustainable lunar presence.**

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1. INTRODUCTION

President Trump unveiled his administration's National Space Strategy in March 2018, which "builds on America's pioneering, spacefaring tradition, laying the groundwork for the next generation of American exploration in space" [1] and included the first Space Policy Directive, SPD-1. SPD-1 provides the direction to work more effectively with industry and develop commercially available services to enable a sustainable presence on the Moon. One year later, at the fifth meeting of the National Space Council, Vice President Pence further charged NASA to land U.S. astronauts on the lunar South Pole by 2024.

In order to meet this ambitious goal, NASA's human lunar exploration plans are based on a two-phase approach. The first is focused on speed of execution—landing the first

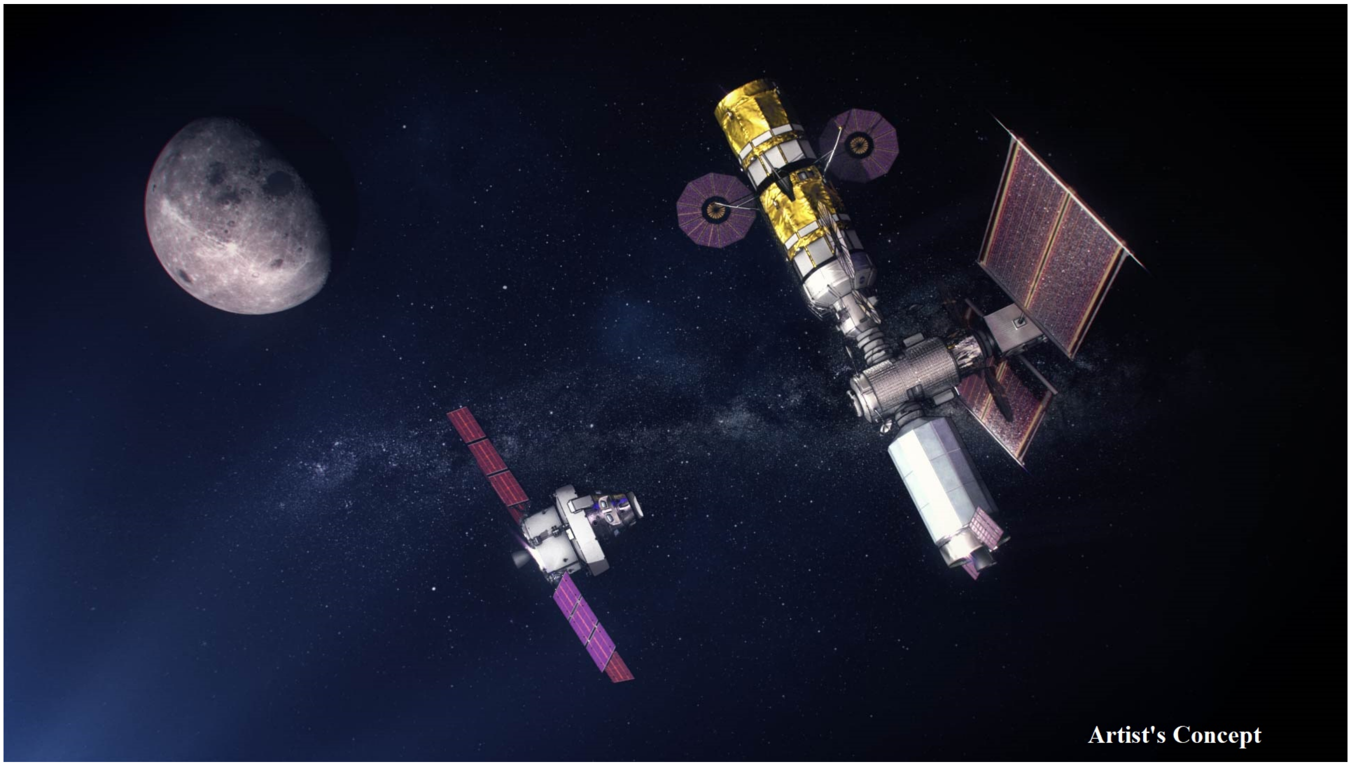

Figure 1. Artist concept of Orion approaching the Gateway with the docked Human Landing System

woman and the next man on the Moon by 2024. The second phase involves establishing a sustained human presence on and around the Moon by 2028. A natural steppingstone to Mars, these efforts will help demonstrate technologies and expand business approaches and commercial opportunities needed for deeper space exploration.

This paper will lay out the primary architecture of the 2024 Artemis mission and NASA's procurement strategy for industry partner design, development and demonstration of the Human Lunar Landing in 2024 as well as the support from SMD and STMD to ensure a robust landscape for sustainable future missions.

2. NASA'S ARTEMIS PROGRAM

The Artemis program is NASA's next step in human exploration, returning astronauts to the Moon by 2024 and establishing a sustainable human presence by 2028 with the goal of sending humans to Mars [2].

Artemis I is an uncrewed test flight of the Space Launch System (SLS) and the Orion crew vehicle as an integrated system. This will be followed by Artemis II, a mission that will launch a crewed Orion around the Moon aboard SLS. The Artemis III mission in 2024 will have SLS send the crew on Orion to the Gateway outpost in lunar orbit. Astronauts will dock Orion at the Gateway. A two-person crew will board the pre-emplaced Human Landing System for a lunar surface sortie of 4-6 days during which they will conduct extravehicular activities (EVAs) and science activities. The crew will return to the orbital outpost before boarding Orion for the return to Earth. [3]. See Figure 2.

The Human Landing System will demonstrate the delivery of a crew from lunar orbit to the lunar surface, provide capabilities for surface extra-vehicular activities and then return the crew to lunar orbit to enable their journey back to Earth. In order to meet these goals and directives, NASA seeks to develop the HLS utilizing fixed-price contracts with NASA-industry collaboration to reduce the cost of development, reduce the time required for the development cycle and enhance U.S. competitiveness in the global space industry [4].

3. THE 2024 MANDATE AND THE NEXTSTEP PROGRAM

In accepting the challenge of the March 2019 mandate by Vice President Pence to land humans on the lunar South Pole by 2024, NASA assessed options to accelerate development of systems required to ensure success.

To achieve long-term sustainability of the enterprise, NASA has focused on reducing costs and incentivizing innovation through different acquisition models to increase competition and partnerships, planning the exploration architecture to utilize advances in the commercial marketplace and refocusing investment toward technologies that will reduce costs and increase capabilities. Each of these aspects is an integral element in NASA's plans for a sustainable exploration architecture [3].

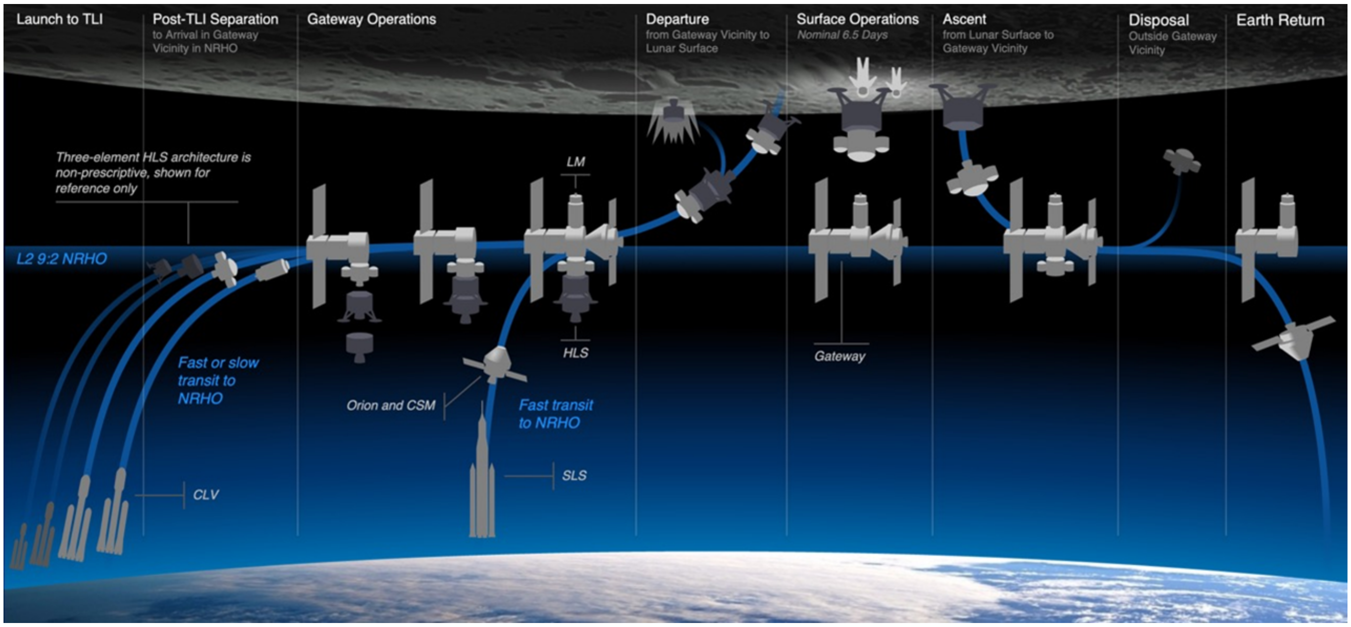

Figure 2. A generic concept of operations for initial mission capability outlining various waypoints in the HLS mission

Through the Advanced Exploration Systems Division (AESD) within HEO, NASA's Next Space Technologies for Exploration Partnerships (NextSTEP) seeks commercial development of deep space exploration capabilities to support more extensive human spaceflight missions in and beyond cislunar space.

NextSTEP issued the first Broad Agency Announcement (BAA) to U.S. industry in late 2014 and the second NextSTEP BAA in April 2016 soliciting concept studies, basic and applied research and technology development and demonstrations. This approach provides an opportunity for NASA and industry to develop capabilities that meet NASA human space exploration objectives while also supporting industry commercialization plans.

4. Human Landing System and Industry Partnerships

In February 2019, NASA released NextSTEP-2 Appendix E: Human Landing System Studies, Risk Reduction, Development and Demonstration, a solicitation seeking proposals from industry in support of design analysis, technology maturation and development of HLS elements. Eleven companies were selected to conduct studies of HLS architecture and design, inform requirements and produce prototypes, with multiple companies building multiple elements of an HLS that could be integrated by NASA for long-term deep space exploration. These six-month studies will conclude in 2020.

After programmatic assessment of options to expedite the work of the Vice President's 2024 charge, NASA determined having contractors deliver a fully integrated HLS to be the most schedule-efficient approach. NASA issued a new solicitation, NextSTEP-2 Appendix H, for integrated Human Landing System development and crewed flight demonstration.

On September 30, 2019, NASA released the final version of the NextSTEP-2 Appendix H BAA seeking firm fixed-price, milestone-based proposals to enable rapid development and 2024 crewed flight demonstration of a Human Landing System.

NASA has expedited the procurement process to meet the 2024 target. While preserving all of the agency's human safety measures, NASA has removed requirements that industry perceived as potential barriers to meeting the schedule.

For example, industry members expressed that delivery of a high number of formal technical reports would require a company to spend considerable resources and incur undue schedule risk. Taking this into consideration, NASA has designed a less formal insight model that will be used for accessing critical contractor data while minimizing administrative overhead. As a result, NASA reduced the number of required contract deliverables by more than 30 percent.

NASA also minimized the number of functional and performance requirements, establishing minimum thresholds for the requirements such as total return mass and number of EVAs.

The agency's baseline approach to a lunar landing involves the crew in the Orion spacecraft and the uncrewed HLS launching separately and connecting in lunar orbit at the Gateway. NASA intends to explore all options to achieve the 2024 mission and remains open to alternative, innovative approaches [5].

After a deliberate, iterative process of solicitation drafts, NASA incorporated extensive industry feedback into the final Appendix H BAA. The agency is prepared to award multiple contracts to safely deliver humans to the lunar surface annually, beginning in 2024. NASA hopes to make the award announcement in early 2020. Down-selection will occur through continuation reviews, with the goal of securing at least two offerors to demonstrate taking designs to flight. The first will launch in 2024, the other will launch in 2025.

5. DETAILS OF THE HUMAN MISSION

The crew will be taken to the Gateway by SLS in an Orion spacecraft, where the Gateway will be used to support the transfer of crew and supplies into the pre-emplaced HLS. The nominal HLS mission will collect the crew and mission materials at the Gateway, transport them to the lunar surface, provide surface and EVA support, then return the crew and surface samples to the Gateway.

For the initial capability phase missions, two crew members will transfer to the HLS for transport to and from the surface, while two will remain with Gateway/Orion. Later missions in a sustainable program are expected to have four crew members traveling to and from the surface [4].

The list below contains the objectives for the initial HLS, reflecting a typical reference mission from lunar orbit to the lunar surface and back.

1. Support a minimum of two crew as a sortie mission without pre-deployed assets.
2. Provide a habitable environment for eight Earth days without pre-deployed assets.
3. Accommodate the transfer of crew and cargo between HLS and a crewed staging vehicle for lunar surface missions.
4. Provide automated rendezvous and docking.
5. Support a sustainable presence on the Moon beyond the initial HLS by providing a regular cadence of reliable transportation services for humans and cargo.
6. Provide crew transfers between lunar orbit and a landing site, located between 84°S and 90°S, and from the landing site to lunar orbit.
7. Provide the capability of operating in continuous daylight conditions on the lunar surface.
8. Provide the capability to perform automated transfers between lunar orbit and the lunar surface, and from the lunar surface to lunar orbit.
9. Accommodate at least 100 kg of science experiments and technology demonstrations, including at least 35 kg of return mass to lunar orbit.
10. Provide the capability for EVA excursions on the lunar surface.
11. Provide vehicle design and capabilities to enable effective and efficient crew performance throughout the mission.

Table 1 lists the Initial HLS Functional and Performance Requirements of the 2024 Mission. These requirements are derived from the initial objectives listed above.

In future sustained missions, the objectives will be shifted such that the HLS will support a minimum of four crew as a sortie mission, provide global lunar surface access for round trip crew and cargo transfers from the Gateway, and survive eclipse periods with pre-emplaced surface infrastructure [4]. Table 2 contains lander system requirements expected for sustainability. Requirements of the designation “sustained,” apply to the demonstration of the HLS sustainable capabilities (2026) after the demonstration of HLS initial capabilities (2024).

Table 1. Initial HLS Functional & Performance Requirements, 2024 Mission

#	Area	Requirement
HLS-R-0070	Daylight Operations	The initial HLS shall be capable of operating in continuous daylight conditions on the lunar surface. The initial mission will be designed to avoid lunar night, eclipse and occulation, such that the HLS will not need to survive periods of darkness on the surface.
HLS-R-0048	EVA Excursion Duration	The initial HLS shall be capable of supporting EVA excursions lasting a minimum of 4 hours. EVA excursion includes two suited crew, begins when crew switch from HLS power to suit power and ends when cabin repress is initiated upon return of crew. Nominal EVA excursion is 6 +/- 2 hours; lower end of that duration is the requirement for initial configuration. HLS repress time must be compatible with GFE EVA resources in order to fully comply with requirement to support EVA excursions.

HLS-R-0318	HLS Operations Mass Delivery from Lunar Orbit	The HLS shall deliver 865 kg (threshold) and 965 kg (goal) from Lunar Orbit to the lunar surface, based on the delivery of two crew and government-furnished equipment for high-level surface operations.
HLS-R-0319	HLS Operations Mass Delivery Return to Lunar Orbit	The HLS shall return at least 525 kg from the lunar surface to Lunar Orbit, based on nominal surface mission and return of two crew and government-furnished equipment for current, high-level surface operations approach. 500 kg assumes the xPLSS (205 kg) is discarded before ascent though it is agency preference that the xPLSS be returned, if possible, for a total ascent mass of 705 kg.
HLS-R-0324	HLS Habitation Capability	The initial HLS shall provide a habitable environment for two crew for an eight Earth-day lunar sortie without pre-emplaced surface infrastructure at the landing site. The HLS will provide all habitability functionality throughout the sortie, driving consumables requirements as well.
HLS-R-0306	Surface Access	The HLS shall provide crew transfers to and from Lunar Orbit and a lunar landing site on the South Pole of the Moon, between 84°S and 90°S. Communications coverage from Gateway will be crucial for providing adequate AOS communication time for the EVA crew due to multi-path issues and blockages to DTE communications at lunar polar locations, which require line-of-site from the HLS landed element to Earth.
HLS-R-0001	HLS Reliability	The HLS shall have a minimum system hardware reliability of 0.975 for an eight Earth-day sortie mission to the lunar surface, including at least two (threshold) and five (goal) lunar surface EVAs, without corrective repair for the entire sortie.
HLS-R-0004	Failure Tolerance to Catastrophic Events	The HLS shall provide at least single failure tolerance for the control of catastrophic hazards, with the specific level of failure tolerance and implementation derived from an analysis of hazards, failure modes and risk associated with the system. Failure tolerance capability is without the use of aborts, emergency equipment and systems, or corrective maintenance. The overall objective is to provide the safest design that can accomplish the mission, given the constraints imposed on the Program.
HLS-R-0021	HLS Landing Accuracy	The HLS shall be capable of landing within 100m (3-sigma) of target landing site in order to optimize EVA resources, scientific objectives, fuel consumption, vehicle navigation capabilities and crew schedule.
HLS-R-0322	Quiescent Lunar Orbit Operations	The HLS shall be capable of maintaining quiescent (inactive) operations for no less than 60 days (threshold) and 90 days (goal) at Lunar Orbit. The HLS may need to remain in Lunar Orbit after the HLS is confirmed operational while awaiting crew and cargo delivery, including potential launch scrubs and mission delays.
HLS-R-0042	Surface Operations	The HLS shall be capable of operating on the lunar surface for a minimum of 6.5 Earth days.
HLS-R-0050	EVA Excursions Per Sortie	The HLS shall be capable of supporting at least two (threshold) and five (goal) surface EVA excursions per sortie, inclusive of one contingency EVA.
HLS-R-0055	HLS Lunar Orbit Insertion	The HLS shall be capable of autonomous lunar orbit insertion upon completion of TLI and upon ascent from the lunar surface.
HLS-R-0056	Scientific Payload Return to Lunar Orbit	The HLS shall be capable of returning scientific payload of at least 35 kg and 0.07 m^3 volume (threshold) and 100 kg and 0.16 m^3 volume (goal), inclusive of tare, from the South Pole to Lunar Orbit.

HLS-R-0058	Abort to Crewed Staging Vehicle (CSV)	The HLS shall be capable of conducting a safe return and dock to the crewed staging vehicle within Lunar Orbit in the event of an abort.
HLS-R-0061	Automated Missions	The HLS shall be capable of conducting an automated landing on the lunar surface and return to Lunar Orbit in order to reduce crew workload during critical operations.
HLS-R-0314	Operational Cabin Pressure Range	The HLS shall be capable operating with a cabin pressure that ranges from the vacuum of space to a maximum of 15.2 psi max design pressure. EVAs will require open hatch HLS operations on the lunar surface.
HLS-R-0090	High Resolution Imagery Capability	The HLS shall have the capability to provide interior and exterior still and motion imagery with associated audio and metadata, to the crew and to Mission Systems, during all mission phases.
HLS-R-0356	Scientific Payload Delivery from Lunar Orbit	The HLS shall be capable of delivery of scientific payload of 100 kg and 1.42 m^3 volume, inclusive of tare, from Lunar Orbit to the South Pole.
HLS-R-0029	Concurrent RF Communication	The HLS shall be capable of concurrent RF communications with lunar-orbiting crew, Mission Systems, and Suits. HLS operations may require the capability to communicate with an EVA excursion, Mission Systems and the orbiting crew at the same time.
HLS-R-0304	HLS Automated RPODU	The HLS shall be capable of automated rendezvous, proximity operations, docking and undocking with a crewed staging vehicle (threshold) and both crewed staging vehicles (goal). Threshold: the HLS must dock with at least one of the crewed staging vehicles (Orion with an active docking mechanism or Gateway with a passive docking mechanism). Goal is both.
HLS-R-0108	Manual Control	The HLS shall provide the capability for the crew to manually control the flight path and attitude. The capability for the crew to control the spacecraft's flight path is a fundamental element of crew survival and mission success.
HLS-R-0109	Remote Operations	The HLS shall provide the capability for the crewed staging vehicle and Mission Systems to monitor, operate and control the HLS elements and subsystems remotely when: it is necessary to execute the mission, it would prevent a catastrophic event, or it would prevent an abort.
HLS-R-0110	Fault Isolation and Control	In order to meet agency human rating requirements for space vehicles, the HLS shall provide the capability to isolate and recover from faults identified during system development or mission operations that would result in a catastrophic event.
HLS-R-0071	Landing Site Vertical Orientation	The HLS shall provide vertical orientation of 0 to 8 (threshold) and 0 to 5 (goal) from local vertical for surface operations. It is expected that the slope tolerance of the HLS will exceed the acceptable lander tilt angles for the safe and effective execution of critical crew functions during the lunar surface mission.
HLS-R-0073	Window(s) for Crew Tasks	The HLS shall provide one or more window(s) for crew use through all phases of flight that provides direct, non-electronic, through-the-hull viewing and the unobstructed field-of-view necessary to perform critical crew viewing tasks.

Table 2. Sustained HLS Functional & Performance Requirements, 2026 Missions and Beyond

#	Area	Requirement – Sustainability Phase
HLS-R-0304a	HLS Automated RPODU - Sustained	The HLS shall be capable of automated rendezvous, proximity operations, docking and undocking with Gateway (threshold) and both crewed staging vehicles (goal).
HLS-R-0002	HLS Reliability (cumulative) - Sustained	The HLS shall have a minimum system hardware reliability of 0.87 over the life of the program with corrective maintenance of reusable elements for sustaining missions. Reusability is not required for the 2024 mission, however by 2028, at minimum the ascent module should be reusable. The HLS reusable elements are expected to support at least five designed mission uses over a 10-year period.
HLS-R-0027	HLS Reliability (per mission) - Sustained	Each of the lunar sorties shall have a minimum per mission reliability of .98 from Gateway separation to Gateway return.
HLS-R-0070a	Daylight Operations - Sustained	The HLS shall be capable of surface operations during 50 hours (threshold) and 191 hours (goal) of continuous darkness.
HLS-R-0048a	EVA Excursion Duration - Sustained	The HLS shall be capable of supporting EVA excursions lasting a minimum of 8 hours. EVA excursion includes two suited crew, begins when crew switch from HLS power to suit power and ends when cabin repress is initiated upon return of crew. Nominal EVA excursion is 6 ± 2 hours; upper end of that duration is the requirement for sustained configuration.
HLS-R-0318a	HLS Mass Delivery from Gateway – Sustained	The HLS shall deliver at least 1,595 kg from the Gateway to the lunar surface.
HLS-R-0319a	HLS Operations Mass Delivery Return Gateway - Sustained	The HLS shall return at least 1,070 kg from the lunar surface to Gateway.
HLS-R-0324a	HLS Habitation Capability – Sustained	The HLS shall provide a habitable environment for a four-crew lunar sortie with pre-emplaced surface infrastructure but is still expected to provide EVA excursions (two suited crew per excursion) as specified in HLS-R-0050 EVA Excursions Per Sortie.
HLS-R-0306a	Surface Access - Sustained	The HLS shall provide global lunar surface access for round-trip crew and cargo transfers from the Gateway.

6. Commercial Lunar Payload Services

Ahead of the 2024 human mission, NASA will utilize industry advancements in small robotic lander technology by sending science instruments and technology demonstrations to the lunar surface. Through the Science Mission Directorate's Lunar Discovery and Exploration Program (LDEP), NASA will solicit lunar surface payloads to enhance our knowledge of the Moon and its resources via commercial delivery. The SMD Commercial Lunar Payload Services (CLPS) initiative will procure commercial robotic lunar delivery services and the development of science instruments and technology demonstration payloads, building on the work of HEO's former Morpheus, Mighty Eagle, and Lunar Cargo Transportation and Landing by Soft Touchdown (CATALYST) activities.

Payloads from worldwide governments, academia and private sectors will be considered to fly aboard robotic lunar landers developed by U.S. industry and contracted through SMD's CLPS effort.

The payloads are initially expected to be smaller instruments and investigations (less than 500 kg), but NASA will also use the deliveries for risk-reduction demonstrations to help evolve lander capabilities and capacities, and inform larger, human-class lander development. These robotic lander services, beginning as early as 2021, may be leveraged to validate precision landing technologies, cryogenic propulsion systems and in-situ resource utilization technologies that are critical for a sustained human presence on the Moon

NASA anticipates the need for both small and mid-size lunar landers to enable a variety of science investigations and larger technology demonstration payloads that will meet science objectives and human exploration goals. Future payloads could include rovers, power sources, science experiments and technology to be infused into the Artemis program. These services will be procured through indefinite delivery, indefinite quantity (IDIQ) contracts with a combined value of $2.6 billion. [5].

7. TECHNOLOGY DEVELOPMENT

The Space Technology Mission Directorate portfolio includes technology advancements relative to HLS, such as components and technologies for pointing, navigation and tracking, fuel storage and transfer, autonomy and mobility, communications, propulsion and power. NASA's Tipping Point program is designed to provide the extra push a company needs to significantly mature a capability. These U.S. industry partnerships occur through competitive solicitations that develop, demonstrate and infuse revolutionary, high-payoff technologies. STMD selected fourteen companies in September 2019 with a combined total award value of about $43.2 million. These Tipping Point selections address technology areas that will prepare NASA for the next phase of lunar exploration.

The strategic focus areas are cryogenic propellant production and management, sustainable energy generation, storage and distribution, efficient and affordable propulsion systems, autonomous operations, rover mobility and advanced avionics [8].

8. SUMMARY

With the release of the final NextSTEP-2 BAA Appendix H in September 2019, NASA has streamlined the partnering approach, combining new innovative ideas and empowering industry to meet the functional requirements of sending the first woman and the next man to the lunar surface by 2024. NASA is expected to make multiple awards for the HLS. Through a down-selection process, the final two offerors will fly in 2024 and 2025. Supported across mission directorates with SMD's CLPS program and STMD's technology development programs such as Tipping Point, the Human Landing System for 2024 will demonstrate capabilities for future sustainable lunar surface exploration.

REFERENCES

[1] President Donald J. Trump is Unveiling an America First National Space Strategy: https://www.whitehouse.gov/briefingsstatements/president-donald-j-trump-unveiling-americafirst-national-space-strategy/ March 23, 2018

[2] What is Artemis?: https://www.nasa.gov/what-is-artemis (accessed 03.10.2019)

[3] Developing Core Capabilities for Deep Space Exploration: An Update on NASA's SLS, Orion, and Exploration Ground Systems: Hearings before the Subcommittee on Space and Aeronautics, Committee on Science, Space, and Technology, House, 116th Cong. (2019) (Testimony of Kenneth Bowersox)

[4] Appendix H: Human Landing System, Solicitation Number: NNH19ZCQ001K_APPENDIX-H-HLS: https://www.fbo.gov/index?s=opportunity&mode=form&tab=core&id=d5460a204ab23cc0035c088dcc580d17 September 30, 2019

[5] NASA Announces Call for Next Phase of Commercial Lunar Payload Services https://www.nasa.gov/press-release/nasa-announces-call-for-next-phase-of-commercial-lunar-payload-services July 30, 2019

[6] NASA Announces New Partnerships to Develop Space Exploration Technologies: https://www.nasa.gov/pressrelease/ nasa-announces-new-partnerships-to-developspace-exploration-technologies August 8, 2018

BIOGRAPHY

Dr. Greg Chavers *is Acting Deputy Project Manager for NASA's Human Landing System Program Office. He served for two years as the Acting Formulation Manager for Lander Development. Prior to the formulation roles at NASA Headquarters, Greg was the Project Manager of the HEOMD/AES Landers Technology project, which included the Lunar Cargo Transportation and Landing by Soft Touchdown (Lunar CATALYST). Dr. Chavers was engineering lead for the Robotic Lunar Lander Development Project from 2011 to 2012. From 2008 to 2010, Dr. Chavers was the lead systems engineer for the International Lunar Network (ILN) lander where he led the development of the Mighty Eagle terrestrial demonstrator. Greg Chavers holds a M.S. and Ph.D. in Physics from the University of Alabama in Huntsville and a B.S in Aerospace Engineering from Auburn University.*

Dr. Lisa Watson-Morgan *is the Human Landing System program manager at NASA's Marshall Spaceflight Center. In her previous roles as Deputy Director of Marshall's Engineering Directorate, she was jointly responsible for the Center's largest organization, comprised of more than 2,000 civil service and contractor personnel, leading the design, testing, evaluation, and operation of flight hardware and software associated with space transportation, spacecraft systems, science instruments, and payloads in development. Since her appointment to* *the Senior Executive Service in 2013, she has served as Manager, MSFC Chief Engineer's Office; Director, Spacecraft and Vehicle Systems Department; and Associate Director of Operations for the Engineering Directorate. Dr. Watson-Morgan graduated from the University of Alabama in 1991 with a bachelor's degree in Industrial Engineering. She received a master's degree in Industrial and Systems Engineering in 1994 and a doctorate in Engineering Management in 2008, both from the University of Alabama in Huntsville.*

– ***Marshall Smith*** *directs the formulation and execution of NASA's human lunar exploration activities—primarily the Gateway, Human Landing System, and space suits that will establish a sustainable, 21st century human presence on the Moon. Most recently, Smith served as the Director of Cross-program System Integration (CSI) for the Exploration Systems Development (ESD) Division at NASA Headquarters. In this role, he was responsible for Systems Engineering and Integration (SE&I) of NASA's next deep-space transportation system—the agency's crew vehicle, next generation heavy-lift rocket, and supporting ground systems and operations. In parallel, Smith also served as SE&I lead for the Gateway, ensuring that the Gateway systems work seamlessly with the ESD systems while meeting agency objectives to foster both a sustainable presence on, and broad access to, the lunar vicinity through commercial and international partnerships. Smith received his Bachelor of Science in Electrical and Computer Engineering from the University of Tennessee with a Master of Science in Electrical and Computer Engineering from Virginia Polytechnic Institute and State University.*

Nantel Suzuki *is the Program Executive for the Human Landing System in the Human Exploration and Operations Mission Directorate at NASA Headquarters in Washington, DC. Mr. Suzuki led NASA's Lunar CATALYST partnerships that couple the agency's expertise with the speed, innovation, and private capital of entrepreneurial firms to accelerate the development of robotic lunar landers and to lower the cost of delivering payloads to the lunar surface. He has also managed technology projects to enable insitu resource utilization.*
Mr. Suzuki has spent three decades working on spacecraft engineering, operations, project management, policy development, and international coordination. This includes 29 Space Shuttle missions as a propulsion systems engineer and flight controller at NASA's Johnson Space Center in Houston, and serving for 3 years in Tsukuba, Japan as an International Space Station technical consultant to the Japanese space agency.

Tara Polsgrove *is the Lead System Engineer with the Human Landing System Program Office at NASA's Marshall Space Flight Center. She is currently focused on the vehicle designs, system engineering, and programmatic assessments for the future human missions to the Moon and Mars, particularly the lander and ascent vehicle for human missions. She has been with NASA since 2000 and has a background in interplanetary trajectory optimization and mission analysis. Ms. Polsgrove has a Bachelor of Science in Aerospace Engineering from the Georgia Institute of Technology and a Master of Science in Engineering with a Systems Engineering focus form the University of Alabama in Huntsville.*