National Space Exploration Campaign Report

Pursuant to Section 432(b) of the NASA Transition Authorization Act of 2017 (P.L. 115-10)

September 2018

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Section 1: Forward to the Moon, Mars, and Beyond

In December of 2017, President Donald J. Trump signed Space Policy Directive-1 (SPD-1). The President directed the NASA Administrator "to 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."

The National Space Exploration Campaign laid out herein is NASA's answer to that bold call. It also directly responds to the policy objectives in the National Aeronautics and Space Administration Transition Authorization Act of 2017 (P.L. 115-10), which calls upon the Agency to develop a Human Exploration Roadmap. This Roadmap will include a critical decision plan to expand human presence beyond low-Earth orbit (LEO), to the surfaces of the Moon and Mars, considering interim destinations such as cislunar space and the moons of Mars.

The National Space Exploration Campaign aims to revitalize and add direction to NASA's enduring purpose to carry out human and robotic exploration missions, expanding the frontiers of human experience and scientific discovery of the natural phenomena of Earth, other worlds, and the cosmos as a whole. NASA also advances new technologies in aeronautics and space systems that allow American industry to increase market shares and create new markets. The Campaign addresses five core national drivers:

- Scientific Knowledge
- Global Engagement
- Economic Development
- Societal Improvement
- Leadership and Inspiration

The call from the President and Congress for a National Space Exploration Campaign emerges at a critical point in America's space program and its relationship to strategic issues facing the nation in space. Challenges and opportunities exist that must be addressed over the next several years.

Close to Earth today, American leadership and commercial innovation, centered in part on the U.S.-led International Space Station, is starting to unleash a new economic arena. However, action is necessary to drive new commercial enterprises and provide a regulatory and security environment that enables and protects this emerging economy. Deeper into space, NASA's shift to focus on the creation of a sustainable presence on and around the Moon with international and commercial partners comes as more countries begin to establish a presence in this region with robotic missions.

China, India, Russia, Japan, South Korea, Israel and multiple European nations all have announced plans or initiated missions to send spacecraft into lunar orbit and to the surface of the Moon. In 2013, China demonstrated a successful lunar landing and rover mission and today is preparing a pioneering mission to the far side of the Moon.

Likewise, opportunities and challenges exist on our path to Mars. America has been the unsurpassed leader on the Red Planet. American robotic craft are the only ones in history to successfully land on Mars. Many nations, including China, now are planning their own missions to Mars's orbit and surface in the coming years.

Opening a New Era

The National Space Exploration Campaign strategy is ready. It includes direction from the White House and Congress, with input from industry, academia, international partners and, most importantly, the American public. It is not a repeat of efforts of the past 50 years. The National Space Exploration Campaign does not assume or require significant funding increases.

The National Space Exploration Campaign builds on 18 continuous years of Americans and international partners living and working together on the International Space Station. It leverages advances in robotics and other technologies, and accelerates in the next few years with the launch of the Orion spacecraft and Space Launch System (SLS) rocket. These two systems, Orion and SLS, provide America the capability to establish the first permanent American presence and infrastructure on and around the Moon. At the same time, NASA will leverage partnerships with the rapidly advancing commercial sector and international community to lay the foundation for a future of unlimited opportunity, discovery and growth.

The priorities set out in this report align to the White House's FY 2020 Administration Research and Development Budget Priorities. NASA seeks leadership in space science and exploration through excellence in long-duration spaceflight, in-space manufacturing, in-situ resource utilization (ISRU), long-term cryogenic fuel storage and management, and advanced spacecraft power and propulsion capabilities. Our priorities also include facilitating the economic development of new commercial space sectors, including microgravity-related research, commercial cargo and crew transportation, and commercial enterprise on the surface and in orbit around the Moon. The President's Space Policy Directives-2 and 3, related to space commerce regulation and orbital traffic management, will enhance and enable the primary goals of our missions.

As part of the National Space Exploration Campaign, NASA will expand its relationships and collaborations with other U.S. government agencies to take advantage of their expertise, create mutually beneficial synergies, and ensure ongoing coordination in the pursuit and achievement of the nation's space goals. To supplement our own creative power and technical expertise, NASA is looking for innovative ideas from any American citizen, student, company or institution ready to answer the call. We seek to engage and inspire the next generation, in particular, the vast community of science, technology, engineering and mathematics (STEM) professionals with the ideas and skills to enable our enduring purpose and missions.

The National Space Exploration Campaign has five strategic goals:

1. Transition U.S. human spaceflight in LEO to commercial operations that support NASA and the needs of an emerging commercial economy.

2. Lead the emplacement of capabilities that support lunar surface operations and facilitate missions beyond cislunar space.

3. Foster scientific discovery and characterization of lunar resources through a series of robotic missions.

4. Return U.S. astronauts to the surface of the Moon for a sustained campaign of exploration and utilization.

5. Demonstrate on the Moon the capabilities required for human missions to Mars and other destinations.

NASA has defined an open architecture that aligns with space policy directives and fulfills Agency strategic goals. It also enables partners, where appropriate, to contribute in meaningful ways. NASA's strategic implementation approach for the National Space Exploration Campaign follows.

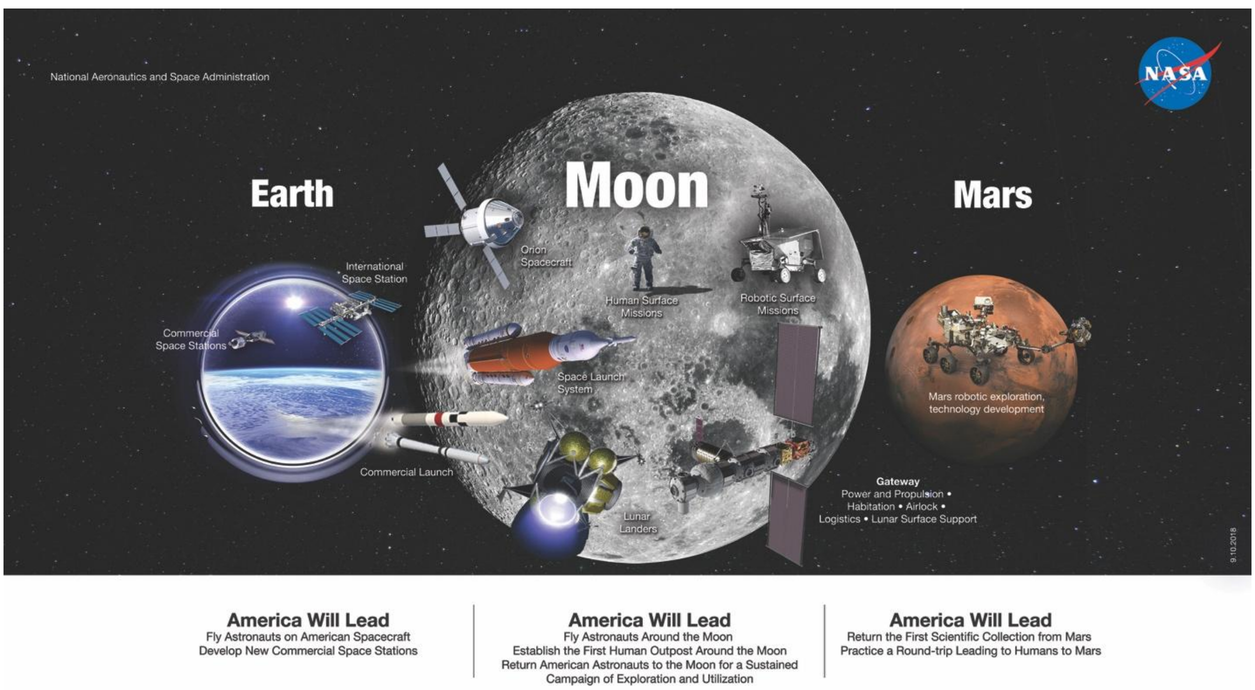

Figure 1: Platforms - From Earth to the Moon to Mars

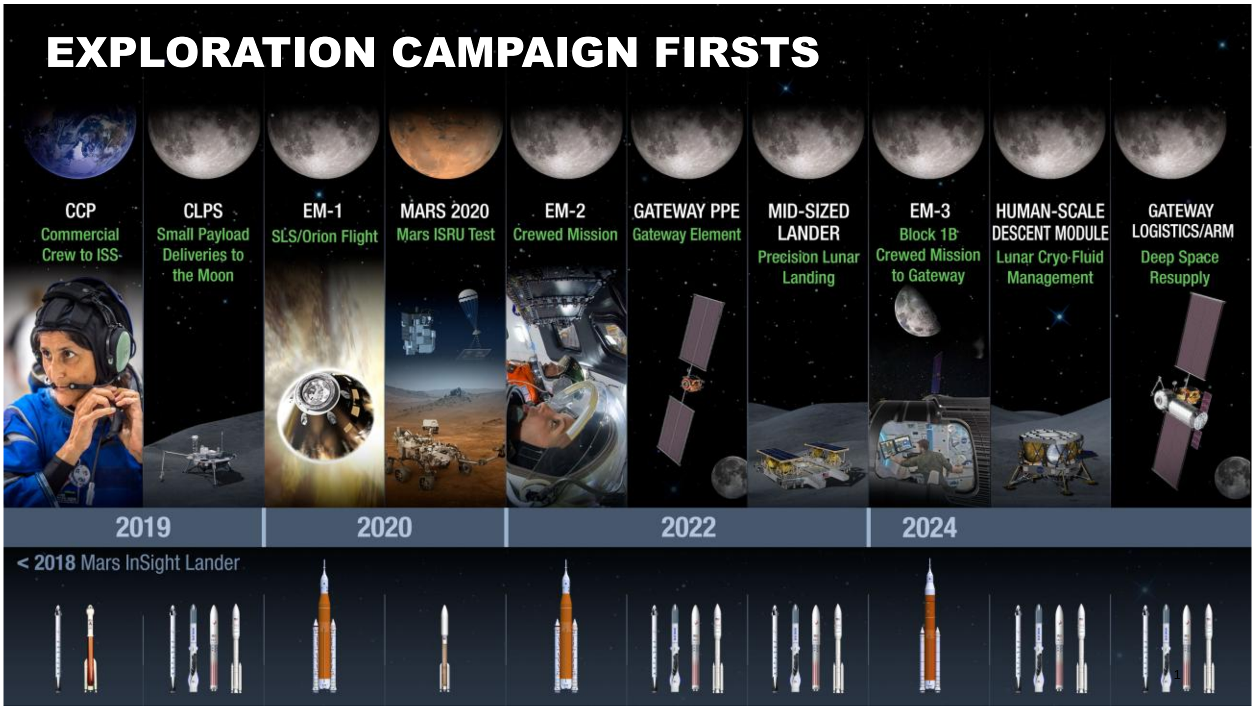

Figure 2: Moon to Mars Timeline

Section 2: Americans in Lunar Orbit and on the Lunar Surface

The Moon is a fundamental part of our planet's past and future. Although Americans first walked on its surface almost 50 years ago, our explorers left only fleeting footprints at a few sites, over a total of 16 days on the surface. The next wave of lunar exploration will be fundamentally different. NASA is building a plan for Americans to orbit the Moon, starting in 2023, and land astronauts on the surface no later than the late 2020s. This will be the first chance for the majority of people alive today to witness a U.S. lunar encounter and landing – a moment when, in awe and wonder, the world holds its breath. But, America will not stop there. A core focus of this Campaign is to extend the nation's geo-strategic and economic sphere to encompass the Moon with international partners and private industry.

Bombarded by solar and cosmic radiation for billions of years and left largely undisturbed, the Moon is a historic archive of our Sun and solar system. Scientific discoveries are locked in its regolith that could lead to improved understanding of our own planet and its evolution. It also harbors resources, such as water, that are among the rarest and most precious commodities in space, offering potential sustenance and fuel for future explorers.

The Gateway – Living and Working Around the Moon

As part of the Campaign, NASA is developing the Gateway, a lunar orbiting platform to host astronauts farther from Earth than ever before and forge U.S. leadership and presence in the region between the Moon and Earth. An advancement in space technology and human life support systems, the platform will offer astronauts longer stays on the lunar surface, easier crew returns, safe haven in the event of an emergency, and the ability to navigate to different orbits around the Moon. NASA's leadership is shifting from LEO and its international partnerships on the ISS, to the Moon and the creation of new opportunities that enable the National Space Exploration Campaign.

On the Gateway, America and her partners will prepare to transit deep space, validating new technologies and systems as we build the infrastructure to support missions to the surface of the Moon and prepare for the epochal journey to Mars. NASA also will study the effects of the deep space environment of the Gateway. We will learn how living organisms react to the radiation and microgravity environment beyond LEO. The Gateway will serve as a critical laboratory to expand our knowledge in this area by hosting biological and biomedical studies in the deep-space environment over longer periods than previously possible.

The Gateway also will be assessed as a platform for the assembly of payloads and systems, by robots or humans, for human and scientific exploration that leverages its unique vantage point in deep space. The Gateway will serve as a reusable command module for lunar vicinity and surface exploration. It will evolve to serve as a way station for the development of refueling depots, servicing platforms, and a sample return facility from the surface of the Moon and other bodies in support of science and commerce. At its fullest, the Gateway will take up 20 percent of the habitable volume of the ISS.

From a strategic perspective, the Gateway transitions ISS partnerships within the commercial space sector and international community from low-Earth orbit to the Moon. Some elements of the Gateway already are under construction at NASA centers across the United States, including facilities in Ohio, Texas and Alabama, and at commercial partner facilities. The first element, providing power and propulsion, will launch from Florida in 2022. The development of this first strategic element will incorporate innovative procurement and partnering strategies, capitalize on U.S. commercial communication satellite capabilities, demonstrate high-power solar electric propulsion technology, and provide critical functionality for the rest of the space vehicle (such as the SEP and Habitation module).

The Gateway will be constructed in place, incrementally, using the American-built Orion spacecraft and SLS, as well as commercial launch vehicles.

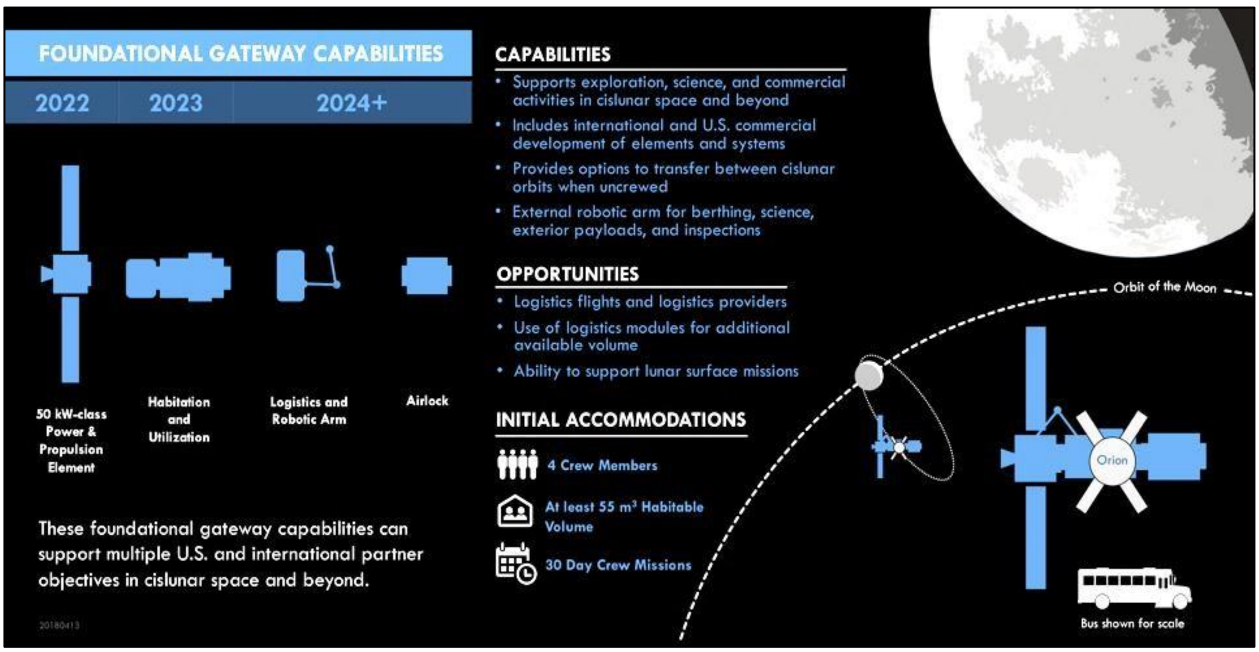

Figure 3: Foundational Gateway Capabilities

Humans and Robots – Exploring and Developing the Moon

The surface of the Moon is an offshore continent that may hold valuable resources to support space activity, as well as scientific treasures that may tell us more about our own planet. The lunar surface will serve as a crucial training ground and technology demonstration test site where we will prepare for future human missions to Mars and other destinations. Through an innovative combination of missions involving commercial and international partners, robotic lunar surface missions will begin as early as 2020, focus on scientific exploration of resources, and prepare the lunar surface for a sustained human presence.

By the late 2020s, a lunar lander capable of transporting crews and cargo will begin sortie missions to the surface of the Moon. Lunar surface activities enabled by these efforts, in tandem with the Gateway, will expand and diversify over time, taking advantage of the Moon and cislunar space for scientific exploration in the broadest sense. NASA will immediately use its current exploration missions, Lunar Reconnaissance Orbiter (LRO) and Acceleration, Reconnection, Turbulence and Electrodynamics of the Moon's Interaction with the Sun (ARTEMIS), to support this increase in scientific discovery objectives.

In the near-term, NASA's Science Mission Directorate (SMD) Lunar Discovery and Exploration Program (LDEP) will provide delivery of lunar payloads using emerging commercial landers through the Commercial Lunar Payload Services (CLPS) procurement – the defining values being speed and commercial partnership. NASA will focus on continued growth of emerging commercial capabilities to enhance lunar lander capabilities and utilization of the Moon (including potential lunar communications networks). In every aspect, technology and commercial sector capabilities will feed forward and integrate with human exploration approaches.

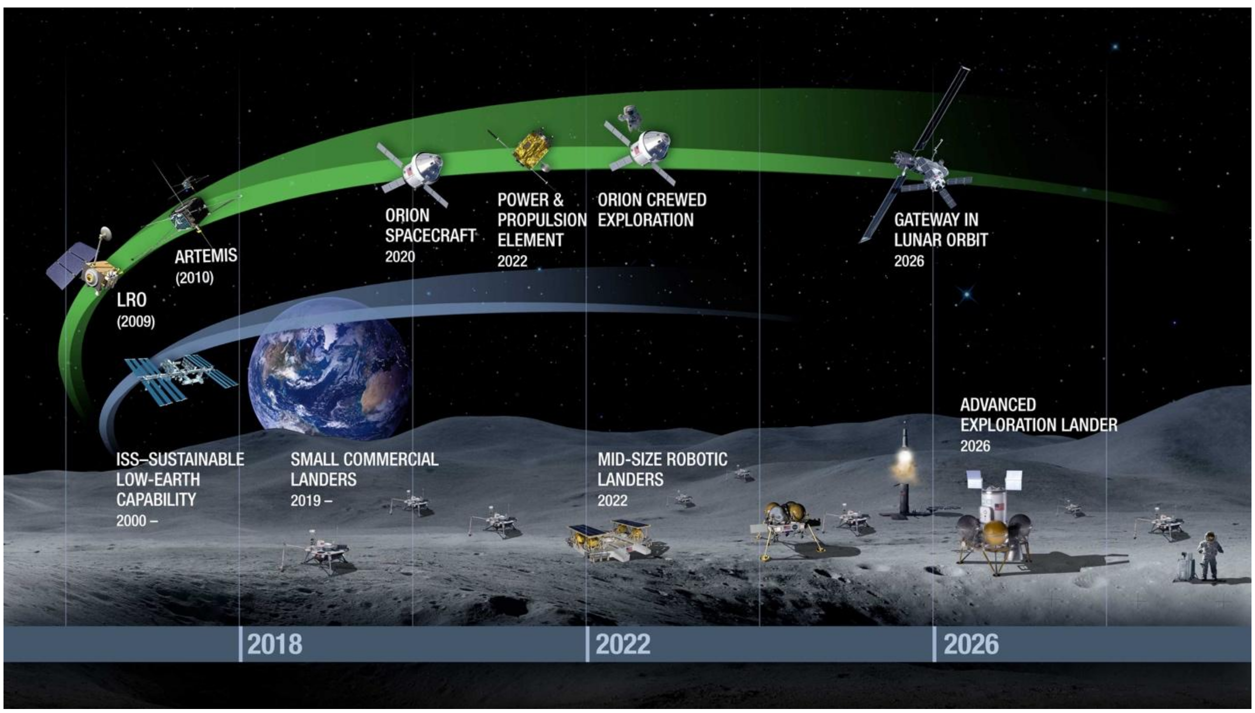

Figure 4: Key elements of the lunar strategy

While orbital missions have provided extensive information about the lunar surface and its potential resources, robotic lunar scouts are essential to validate these observations and prepare for human habitation and utilization of the Moon's rich array of resources. Planned landers and rovers provide excellent platforms to demonstrate technologies that will enable greater lunar surface mission capabilities and have applications that extend beyond the Moon to Mars. Multiple landers will provide a global view of the Moon and its resources. Landers, outfitted with sensor packages, also will be used to conduct critical risk-reduction activities, including those that aid in the development of technologies that will enable precise and soft landings on the lunar surface. Rovers will be used to explore the surface more extensively; carrying instruments such as ISRU experiments that will provide detailed information on the availability and extraction of usable resources, including oxygen and water.

NASA is reviewing longer-term, higher-power capabilities needed to survive lunar nights and operations in shaded portions of the surface by considering surface fission power, which will fuel in-situ resource utilization demonstrations and other needs. NASA also is studying requirements for the next-generation spacesuits needed for lunar exploration.

Human exploration of both the Moon's surface and its environment requires the capability to transport crews and large masses of cargo beyond LEO. To accomplish this, NASA is building a launch and crew system – the Orion spacecraft, heavy-lift SLS launch vehicle, and supporting ground systems – and will rely on commercial launch providers to support robotic lunar surface and orbit operations. The Orion spacecraft will carry up to four humans into deep space for up to 21 days. It is the only vehicle, at this point in the development of the National Space Exploration Campaign that is able to provide crew return and reentry from the vicinity of the Moon. The SLS Block 1 cargo variant will be capable of delivering Orion beyond LEO (called trans-lunar injection, or TLI) in the early 2020s, and the Block 1B SLS will be capable of delivering 9-10 metric tons to TLI, co-manifested with Orion, in the mid- to late-2020s. The first SLS/Orion mission will be the uncrewed Exploration Mission-1 (EM-1), currently scheduled to launch to lunar orbit in FY2020, followed by the first crewed SLS/Orion mission, EM-2, no later than 2023. These SLS/Orion missions will demonstrate the capability to operate safely and productively around the Moon.

Overall, the National Space Exploration Campaign is different from past endeavors that were unsustainable or never matured. With an open architecture approach, the National Space Exploration Campaign provides the flexibility to incorporate new systems and capabilities as they develop, thereby taking advantage of newly acquired knowledge and the technological and economic capabilities of all exploration partners. For example, commercial launch capabilities are increasing with multiple new heavy-lift systems expected to be operational by the early- to mid-2020s. It is in the national interest to have reliable, lower-cost launch capabilities and the National Space Exploration Campaign will take advantage of those capabilities as they emerge. NASA has led the development of standards in key operations and interfaces that will ensure that, as new capabilities are developed by the U.S. commercial space sector and international partners, the National Space Exploration Campaign can leverage and incorporate them as appropriate.

With our National Space Exploration Campaign approach, NASA will allow, as warranted, its concept of operations for human lunar surface and orbital activities to evolve and mature. Specifically, reusability and the evolution of other architectures will be incorporated as activities increase in orbit and on the surface of the Moon. An open architecture provides on-ramp opportunities for new and broadened commercial and international engagement as the National Space Exploration Campaign continues to innovate and adapt.

As we move beyond low-Earth Orbit, America and its strategic partners will begin to answer critical questions, such as:

Can the Moon become a center for commercial enterprise? Are there significant deposits of water that can support human settlement or fuel a human journey to deep space? When the explorers Meriwether Lewis and William Clark first set out to traverse the western territories of the United States, they were tasked to survey scientific and commercial opportunities, and they did not know what they might find. Today, the people of the United States of America owe an impossible debt of gratitude to their exploration and the knowledge they provided a young nation. In the long-term scale of human endeavors, understanding what is possible on the Moon, and being the first to realize its potential, could be transformational.

How can the Campaign engage a broader range of U.S. industrial sectors? American companies will help lead this effort. Establishing new methods for collaborating with non-aerospace industries will be critical to the Campaign's success. Unlike the Apollo era of 60 years ago, the U.S. commercial sector includes maturing industries specializing in highly advanced microelectronics, materials, advanced manufacturing and design processes, power generation and storage, autonomy and software, data analytics, and others. NASA seeks new ways to leverage and incorporate these capabilities into the space sector. NASA will continue to encourage increased competition and efficiency for current technologies, as well as non-traditional partnerships that support a range of needed capabilities, from landers to lunar surface mining technologies. If a company has experience drilling into the Earth's crust, several miles under the ocean, such research and development (R&D) created through trial and error in the harshest of terrestrial and marine environments may be useful to America's space program. Only by harnessing the knowledge and advancement of U.S. R&D across sectors and pairing it with NASA's vision, mission and expertise can we achieve sustainable and lasting success in space.

How can we translate the incredible developments from this Campaign into benefits for American and global society? Just as the ISS spurred broader applications and innovations on Earth, America goes to the Moon to extend humanity's presence in the solar system and to improve the lives of people on Earth. The ultra-efficient use of scarce resources in orbit, the production of tools and systems from extant resources off the Earth, or the extraction of water from frozen lunar regolith are challenges that, once mastered, will help address societal challenges and spur economic growth on Earth. The development of autonomous systems that can operate on the lunar and Martian surfaces and in orbit will push the technological frontier and support current trends in autonomous vehicles – with exceptional quality control and robust engineering needed to design vehicles to operate in the most difficult environments known to humanity. By learning to live and work in alien environments, we will learn skills and develop technologies that would otherwise be unattainable. Space exploration is the ultimate classroom.

How will advanced propulsion play a role in opening the ocean of space for American voyagers well beyond today's limitations? **For example, what roles will chemical propulsion, solar electric propulsion, and nuclear propulsion for space transportation play?** Whether to use nuclear propulsion for future exploration missions in the 2030s and beyond will need to be determined, as this will affect the design of many future systems.

Critical Decisions and Milestones:

Lunar Orbit

<u>2018</u>

- Decision to develop the Gateway, commercial and international partnerships, and final configuration. The Gateway also will provide broad science research and technology demonstration opportunities from cislunar space, in areas including lunar surface (e.g., lunar sample return, tele-robotics, etc.), astrophysics, heliophysics and Earth science.

<u>2019</u>

- Determine appropriate Gateway requirements and then, based on those, orbital parameters. A key consideration will be affordability (i.e., Gateway can be visited by multiple launch vehicles).

<u>2020</u>

- SLS/Orion EM-1, uncrewed, to the lunar vicinity.
- Initiate scientific payload development for Gateway by competitively assessing the most suitable and impactful scientific analysis.
- Science and industry missions flown on EM-1 using 13 co-manifested CubeSats launched as secondary payloads.
- Decision on acquisition approach for remaining elements of Gateway (complete by 2021).
- Based on status of launch vehicle development, decide on future Gateway logistic resupply missions.

<u>2022</u>

- By June, conduct crewed flight, EM-2, sending Americans around the Moon.
- First element of Gateway, the power-propulsion (including communications) element (PPE), placed in lunar orbit.

<u>2024</u>

- Based on status of crew capsule development and operations, decide on need for further investments to increase options for return to Earth from lunar orbit

<u>Post-2024 Decisions</u>

- Based on human lunar surface return plans and scope, and decision on human Mars orbital mission architecture for the 2030s, determine need for, and viability of, developing and placing propellant depots in lunar orbit. Assess and make appropriate decisions on Gateway evolution requirements.

Lunar Surface

2018
- Decision to procure commercial lunar payload services for NASA starting as early as 2019
- Establish the Lunar Discovery and Exploration Program in SMD. This initiative will feature several programs, including Commercial Lunar Payload Services (funding for end-to-end delivery of payloads to the lunar surface starting in 2020).
- Decision on potential missions to focus on lunar resources and other scientific discoveries, including mobility and sample return capabilities.

2019
- Make early decisions on architecture of lunar exploration program.
- Decision on a date for a demonstration mission for human-class lunar lander capability.
- Decision to begin human lunar surface architecture and mission analyses to support Americans on the lunar surface no later than 2029.

2020
- Based on early results of human-class lunar lander development and human lunar surface architecture analyses, begin capability stimulation, development and/or procurement of other elements required for human lunar surface return (e.g., human cabin and ascent vehicle, retro-braking stage, extended Orion service module).

2021
- Based on results of commercial services for NASA lunar payloads, plan to either procure commercial launch services for a second resource and science rover mission or conduct mission development and operations in-house.

2022
- Based on results of 2022 NASA lunar resource and science rover mission, plan to either accelerate development of ISRU systems and partnerships, or maintain baseline R&D effort.

2024
- Based on results of human-class lunar lander capability demonstration missions, status of other human systems, other possible mission enhancements (e.g., retro-braking stage, launch vehicle availability) make decision on date and method of human lunar surface return and the mission objectives.

Post-2024 Decisions

- Based on the cost of lunar surface access, viability of higher-power systems and ISRU, as revealed by exploration and science missions and technology investments, and on private-sector and international demand for lunar surface access, determine the nature of a sustainable American human presence on the lunar surface and associated infrastructure development projects.

Section 3: Living in Space Prepared Us for this Moment – A Key Inflection Point

With the ISS program, NASA has led an unprecedented global partnership of humans living and working in space for the past 18 years – a milestone achievement for humanity. As the Agency shifts its focus beyond low-Earth orbit, this hard won experience and mastery of specialized capabilities will be instrumental in enabling us to continue to live and work in space for the millennia to come. The American-led Gateway orbiting the Moon, combined with continued U.S. access to commercial platform(s) in LEO, will ensure we advance American leadership in opening up the heavens to further human and scientific development well into the future.

In order to prepare for sustained human expeditions and eventual settlement beyond LEO, America and her partners first must conduct breakthrough research and tests on the advanced technologies necessary for long voyages in deep space. Long-duration human missions that cannot easily return to Earth introduce new and increased concerns for human safety, health and performance. On the ISS, NASA is conducting scientific research needed to supply the evidence base for both technological and operational countermeasures to address these risks. An on-orbit platform like the ISS is necessary to mitigate 22 of the 33 human health risks identified by NASA's Human Research Program in support of current and future deep space missions. NASA also is using the ISS as a testbed to fill critical gaps in technologies that will be needed for long-duration missions. For example, elements of ISS life support and other habitation systems will be evolved into the systems for deep space missions and undergo long-duration testing. It is NASA's plan to first develop and demonstrate many critical technology capabilities using the ISS (and, potentially, other future platforms) as a permanently-crewed testbed prior to deploying these capabilities beyond LEO.

Low-Earth Orbit – Time to Transition

Unlike the temporary and limited focus of the Apollo effort, NASA is building forward from the ISS in a manner to inform and feed a sustainable lunar surface and orbit architecture. The ISS is an experiential testing ground enabling the research and development of advanced robotics, communications, medicine, agriculture and environmental science. The Station's unique infrastructure also has provided a platform for several Earth and space science instruments that conduct important investigations supported by the global science community.

Ongoing operations and research on the ISS encourage development of a robust LEO economy in which U.S. private industry matures the ability to provide goods and services – such as commercial crew and cargo transportation systems – for customers beyond NASA and other government users. By 2025, NASA intends to shift its resources from operating the ISS to purchasing services from commercial providers and providing resources to the National Space Exploration Campaign.

In pursuit of a timely development and transition of commercial capabilities in LEO, where NASA envisions being one of many customers in the mid-2020s, the Administration is requesting $150 million in FY2019 (with increasing investments in subsequent years) for a new Commercial LEO Development program. These funds will stimulate the development and maturation of private sector entities and capabilities that will ensure commercial successors to the ISS – potentially including elements of the ISS – are operational by 2025. This stimulation seeks to strengthen overall demand and interest in utilization of commercial platform(s) in LEO. It is vitally important that a broad customer base emerges in the next few years to supplant NASA's historically central role in the LEO economy. Private sector platform operators will be best able to identify potential customers for their platforms, including activities that NASA might may not have the capability or authority to support using a government-owned and operated platform.

Enabled by NASA's support for commercial cargo and crew providers, U.S. companies will, by no later than 2020, transport astronauts to low-Earth orbit and rendezvous with the ISS. Once this capability is demonstrated, it will open significant new opportunities for commercial space flight. U.S. companies will begin to provide commercial access to space for paying customers from the U.S. and around the world. The commercial possibilities are endless – from tourism to training for deep space missions. For example, biotechnology, materials and manufacturing companies require equipment to produce the breakthrough pharmaceuticals, the highest-quality optical fiber or 3D-printed tools for space travel, and any platform will need to support highly trained, discipline-specific scientists and engineers to live and work in the unique microgravity environment.

Specific transition activities include*:*

- Expand partnerships in LEO to include new companies and nations, including working with commercial partners to support new international astronaut visits.
- Expand public-private partnerships to develop and demonstrate technologies and capabilities to enable new commercial space products and services, including those that continue scientific exploration in LEO.
- Pursue other efforts to enable the shift away from direct government-funded support of the ISS. For a full assessment on the transition of LEO, please refer to the recently published NASA ISS Transition Report at: https://www.nasa.gov/sites/default/files/atoms/files/iss_transition_report_180330.pdf

Critical Decisions and Milestones

2018

- Complete 13 selected LEO commercialization studies
- Decision on Commercial LEO Development (FY2019 funding request)
- Decision on ISS Commercial and Private Astronaut Use Policy

2019

- Based on results of completed LEO commercialization studies, competitive selection of funding/logistical support for commercial module and/or free-flyer space station development.
- Work with the U.S. Departments of Commerce, State and other agencies to spur greater use of ISS and overall interest in LEO development.
- Identify and eliminate regulatory barriers to enable increased commercial activity.
- Identify and implement incentives for LEO efforts. Examine funding models, such as the Aviation Trust Fund, that may aid the development of ongoing non-ISS commercial space activities and platforms.

2022

- Based on status of commercial module and/or free-flyer space station development and emerging commercial activities on ISS, fine-tune plans to end direct Federal funding of ISS by 2025 to ensure continuous access to a LEO space platform.

Post-2024 Decisions

- Based on the status of commercial module and/or free-flyer space station development and emerging commercial human spaceflight activities in LEO, decide on appropriate NASA and overall governmental support to ensure ongoing NASA requirements and permanent U.S. presence in LEO.

Section 4: Vistas of Opportunity and Discovery - Mars and Beyond

The first human landing on Mars – audacious in its complexity – will be an achievement recalled with awe far into humanity's future. Key components of the National Space Exploration Campaign already are underway and include long-duration human spaceflight on the ISS, advanced life support systems in cislunar orbit, and continuing to lead and advance the world in science missions beyond LEO. The latter includes the return of samples from asteroid Bennu in 2023, humanity's first roundtrip sample-return mission to Mars, and the launch of an orbiter around Jupiter's moon Europa.

Overall, the National Space Exploration Campaign focuses on a transformative approach that includes the development of technologies and systems that enable a series of human and robotic lunar missions and are extensible to destinations beyond the Moon, including Mars. NASA continues to maintain leadership in robotic exploration on and around Mars. NASA's InSight mission now is on its way to Mars and will land in November 2018 to study the interior of the Red Planet. The Mars 2020 rover continues to make excellent progress and is scheduled to launch in July 2020. In addition, as previously stated, planning for a mission to return samples from the Martian surface is well underway. Research on Mars is paving the way for human exploration and utilization of the Red Planet.

Mars robotic missions have: enabled the United States to master the incredibly complex task of entry, descent and landing of one-metric-ton payloads (similar to the size of a compact car); gathered data about radiation in transit to and on the surface of Mars; investigated the Martian atmosphere and weather; and shown the existence of significant water reserves. In the near-term, NASA's Mars 2020 mission will measure atmospheric entry conditions and surface dust, and demonstrate the production of oxygen from atmospheric carbon dioxide while also selecting and encapsulating samples for potential return to Earth. Future robotic pathfinders will investigate and map destinations prior to human missions, collect surface samples, characterize potential landing sites, and test technologies necessary for future robotic and human systems.

Expand American Leadership at Mars

The National Space Exploration Campaign will build upon NASA's Mars Exploration Program (MEP) missions, which were built on the priorities recommended by the science community and the National Academy of Sciences over the past two decades. The discoveries made by each mission's unique instrument package complement each other and, collectively, build the world's knowledge base for Mars exploration. These missions have revealed that Mars has a diverse mineralogy indicative of an environment that has water; could have supported life in its past; experienced a massive loss of atmosphere over time; has thick deposits of ice beneath its surface; holds methane and other organics; and is a dynamic planet today.

An important part of the National Space Exploration Campaign's goals for Mars and beyond include maintaining and growing U.S. leadership at Mars with a rover in 2020 as the first step of a sample-return strategy. We will search for past life and demonstrate the production of fuel and other resources that enable human exploration. We also will use this mission as a building block for a subsequent roundtrip robotic mission with the historic first rocket launch off another planet and a sample return. This mission will serve as a critical precursor to an eventual series of crewed Mars missions planned to start in the 2030's and culminating in a surface landing.

Critical Decisions and Milestones

2019

- Decision on Mars robotic roundtrip mission (Mars Sample Return) implementation and architecture and target launch date.
- Decision on Mars-forward technology R&D investment portfolio in Exploration Research and Technology (ER&T).
- Prioritize and guide investments and partnerships in "long-pole" technology areas and resource characterization needed for the exploration of Mars and other deep space destinations (ongoing).
- Develop standards for human long-duration deep space transportation vehicles (ongoing).

2021

- Based on results of Mars 2020, the Mars Oxygen ISRU Experiment (MOXIE) payload, and helicopter performance, modify Mars-forward technology R&D investment portfolio in ER&T.

2024

- Based on results of investment in Mars-forward technology R&D investment portfolio, Gateway development and operations, launch vehicle and crew vehicle development and operations, decide on architecture of human Mars orbital mission and begin associated systems development.

Post-2024 Decisions

- Based on results of robotic roundtrip mission, cislunar operations, and progress of Mars-forward technology R&D investment portfolio, determine set of technology investments and timeline required to achieve human landing on the surface of Mars.

Section 5: Corporate Reform - Enabling Initiatives

The National Space Exploration Campaign will include streamlining the NASA corporate organization and mission management to become even more efficient and effective. NASA already has initiated a federated core team for the lunar portion of the National Space Exploration Campaign that reports directly to the NASA Administrator.

NASA is aligning lunar exploration integration between the Science and Human Exploration and Operations Mission Directorates. The Science Mission Directorate will continue the MEP missions, the CLPS missions, and lunar science. In support of this effort, a Deputy Associate Administrator for Exploration in the Science Mission Directorate was established in June 2018. The Space Technology Mission Directorate also has added a Deputy for Exploration. The Administrator also has empowered a small cross-mission directorate team to develop the Campaign at this point, in coordination with the Administrator and his staff.

ER&T is undergoing significant organizational change to support the Campaign. The Agency is working to mature exploration technologies and systems in preparation for deep space missions to the Gateway. ER&T is developing advanced power and propulsion technology – including 13-kilowatt solar electric propulsion Hall thrusters, power processing units, and associated hardware – to support Gateway power and propulsion needs and, potentially, extend to meet the needs of deep space architectures. ER&T also is advancing promising transformative technologies, including: next-generation environmental control and life support systems; ISRU; cryogenic fluid management and long-term storage; fission power systems (perhaps leading to nuclear propulsion systems for Mars); advanced communications, navigation and avionics; in-space manufacturing and on-orbit assembly; advanced materials; entry, descent and landing; autonomous operations; and research to enable humans to safely and effectively operate in various space environments. High readiness-level technologies will be applied to near-term missions, while the Agency invests in low readiness-level technologies to address challenges of future exploration missions. Wherever possible, these technologies are infused into science missions.

NASA has mapped the capabilities necessary to explore the Mars system, along with current and planned missions and technology investments by the agency's mission directorates. A high-level summary of this mapping appears in Figure 5 (below) and is used to identify and guide budget planning activities, as well as Agency architecture strategies.

As NASA continues to develop an acquisition strategy for the National Space Exploration Campaign, we will identify new sources for critical technologies in the U.S. private sector and government, and international partners. We are fortunate that many of the critical technologies pioneered by the Apollo missions – microelectronics, power storage, propulsion technology, advanced materials, and others – have become major industrial sectors backed by decades of innovation and improvement. From this advantageous starting position, we intend to rapidly integrate advanced capabilities with our own new technology and take one giant leap toward the sustainable and long-term human and robotic space exploration of the solar system.

Exploration Capability Evolution

= Current HEOMD Activities
= Current ER&T Activities
= Current SMD Activities
= Needs analysis underway; to be funded in future years

	Mission / Demand Areas	ISS	Cis-Mars Robotic	Cislunar Short Stay	Cislunar Shakedown	Lunar Surface	Mars Orbit	Mars Surface
Working in Space and On Mars	In Situ Resource Utilization		Exploratory ISRU & Atmosphere	Exploratory ISRU Regolith	Exploratory ISRU	ISRU Propellant Production	Exploratory ISRU	Operational ISRU & High Power
	Surface Power					Kilopower		Kilopower & High Density Energy Storage
	Habitation & Mobility	Long Duration with Resupply		Initial Short Duration	Deep Space Transport Habitat	Surface Habitat	Deep Space Transport Habitat	Rover & Habitat/Lab
	Human/Robotic & Autonomous Ops	System Testing	Earth Monitored	Crew-tended	Earth Monitored Robotics & R&D	Human/Robotic Exploration	Autonomous Rendezvous & Dock	Autonomous Rendezvous & Dock
	Crew Productivity	Science Experiments	Science Experiments	Science Experiments	Science Experiments	Science Experiments	Science Experiments	Science Experiments
	Exploration EVA	System Testing		Limited Duration	Limited Duration	Surface EVA	Full Duration	Frequent EVA
	Reconnaissance		Landing Site			Prospecting Sample Returns	Landing Site	Sample Return
Staying Healthy	Crew Health	Long Duration	Dust Toxicity	Short Duration	Long Duration	Long Duration	Long Duration	Long Duration
	Environmental Control & Life Support	Long Duration		Short Duration	Long Duration	Long Duration	Long Duration	Long Duration
	Radiation Safety	Increased Understanding	Surface Radiation Environment	Forecasting	Forecasting Shelter	Forecasting Shelter	Forecasting Shelter	Forecasting & Surface Enhanced
Transportation	Ascent from Planetary Surfaces		Sub-Scale MAV			Lunar Ascent Stage	Sub-Scale MAV	Human Scale MAV
	Aggregation, Refueling, and Resupply Capability	Resupply		Refueling	Resupply	Refueling		
	Entry, Descent & Landing		Sub-Scale/Aero Capture			Auto. Precision Landing	Sub-Scale/Aero Capture	Human Scale EDL
	In-space Power & Prop		High Power	Medium Power	High Power		High Power	Very High Power
	Beyond LEO: SLS & Orion			Initial Capability	Initial Capability	Initial Capability	Initial Capability	Full Capability
	Commercial Cargo & Crew	Cargo/Crew	Opportunity	Opportunity	Opportunity	Opportunity	Opportunity	Opportunity
	Communication & Navigation	RF	Deep Space Optical	RF & Initial Optical	Optical	Optical	Deep Space Optical	Deep Space Optical

Figure 5: Exploration Capability Evolution