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RECOMMENDATIONS FOR THE NEW ADMINISTRATION

The Road Back to the Moon

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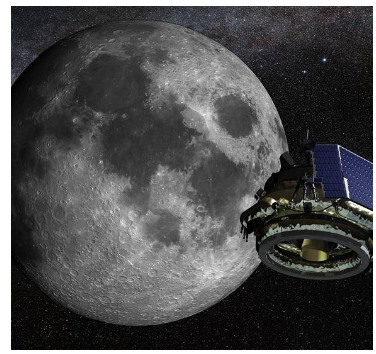
This brief is part of a series of policy recommendations for the administration of President Joe Biden. Focusing on a range of important issues facing the country, the briefs are intended to provide decision-makers with relevant and effective ideas for addressing domestic and foreign policy priorities. View the entire series at www.bakerinstitute.org/recommendations-2021.



INTRODUCTION

It has now been over fifty-one years since astronauts first walked on the moon and almost forty-eight years since Gene Cernan and Harrison (Jack) Schmidt became the last humans to visit the moon. During the administration of former President Donald Trump, NASA agreed to return to the moon by 2028. However, former Vice President Mike Pence, at a meeting of the National Space Council on March 26, 2019, ordered NASA to accelerate its plans for lunar return, and the new date was set for 2024. This expedited timeline requires additional modules and capabilities and an accelerated mission sequence. The program also lacks any realistic cost estimates (not to mention the program's excessive development times and the significant cost overruns that have already occurred). Therefore, as the administration of President Joe Biden now takes control, a systematic review of this accelerated plan is in order. It is crucial that officials at NASA and the White House review and adjust the current plans in order to ensure a successful return to the moon, even if that means it won't occur by 2024.

1969 MOON LANDING

When astronauts first flew to the moon a half century ago, they used the lunar-orbit-rendezvous concept. A Saturn V rocket launched two spacecraft—the Apollo command and service module and the lunar module. The command module was attached to the service module containing the propulsion system, expendables, and fuel cells, which were mounted atop the powerful Saturn V booster. The lunar module was mounted below the service module within the spacecraft lunar module adapter (SLA). Below the lunar module was the Saturn V instrument unit that controlled the Saturn V rocket. The instrument unit was atop the third stage of the Saturn V. The third stage of the Saturn V rocket was launched into Earth orbit, and the engine was shut down upon reaching orbit. It was subsequently re-started to perform the trans-lunar injection burn, sending the third stage, the command and service module, and the lunar module on a trajectory to the moon. The command and service module then separated from the SLA and performed a 180 degree turn to dock with the lunar module, separating the lunar module from the SLA and third stage of the Saturn V.

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When the two docked spacecraft reached the moon, the service module engine was utilized to place the two spacecraft in orbit around the moon. Two astronauts then entered the lunar module, separated from the command and service modules, which were left orbiting the moon with one astronaut, and, using the descent stage engine of the lunar module, landed on the moon. After completing their activities on the lunar service, they reentered the lunar module, which was a two-stage spacecraft, and lifted off from the moon in the ascent stage to rendezvous and dock with the orbiting command and service module. The service module engine was then utilized to perform the burn needed to depart from lunar orbit and place the command and service module on a trajectory to return to Earth. The lunar-orbit-rendezvous approach was the subject of much analysis and study before agreement was finally reached to use this method nearly a year after President Kennedy's announcement in May, 1961 to go to the moon. It proved to be a very straightforward and fundamental approach that helped to ensure the landing was successfully completed before the end of the decade.

NASA'S CURRENT PLAN: THE ARTEMIS PROGRAM

NASA's current plan for sending astronauts back to the moon is considerably more complex and challenging and will be much more costly. It is envisioned that rockets purchased commercially will be utilized to launch the components of a space station that will be assembled in high lunar orbit. Another rocket will launch an unmanned lunar lander to dock with the lunar orbiting space station. The Space Launch System (SLS) rocket will then launch an astronaut-manned Orion spacecraft to dock with the space station orbiting the moon, and astronauts will utilize the attached lander to descend to the lunar surface. After completing their activities on the moon, the crew will lift off from the moon to rendezvous and dock with the orbiting station. The Orion spacecraft, docked with the orbiting station, will be utilized by the astronauts to return to Earth. The lunar orbital space station, referred to as the Lunar Gateway (or simply the Gateway), is a collection of modules that include living quarters, an air lock, and a power and propulsion module.

The origin of the lunar gateway concept goes back several years. It was conceived by NASA during a previous administration that envisioned a robotic spacecraft grabbing a small, near-Earth asteroid and bringing it into an orbit around the moon, where it would be visited by astronauts. There was concern about the feasibility and costs of such a mission, and it was never approved.

NASA maintained, however, that human space exploration should utilize a presence in cislunar space—the area between the Earth and the moon—to test technologies for future missions to Mars and beyond. This evolved into a concept called the Deep Space Gateway, a collection of modules in a distant retrograde orbit around the moon. By the late 2020s, astronauts operating from the Gateway could begin assembling a separate spacecraft, the Deep Space Transport, for long-duration missions to Mars.

The administration of President Donald Trump, in a December, 2017 space policy directive, refocused the U.S. space program on human exploration and returning American astronauts to the moon.[1] It called for the use of commercial and international partnerships. It did not, however, specify an architecture for returning to the moon. NASA proposed the Gateway, formally renaming it the Lunar Orbital Platform-Gateway, and presenting it as a staging area for lunar missions. The Gateway would be assembled in a different orbit, a highly elliptical one over the poles of the moon, called a near-rectilinear halo orbit. Using the Lunar Orbital Platform-Gateway approach, NASA planned a lunar landing in 2028.

NASA also approached international partners involved in the International Space Station (ISS). The Canadian Space Agency (CSA), the European Space Agency (ESA), the Japanese Aerospace Exploration Agency (JAXA), and Roscosmos, the Russian Space Agency, were all considering participating with NASA in the Gateway by early 2019.

The vision changed dramatically when former Vice President Mike Pence, at a meeting of the National Space Council on March 26, 2019, ordered NASA to accelerate its plans for lunar return. "At the direction of the president of the United States, it is the stated policy of this administration and the United States of America to return American astronauts to the moon within the next five years."[2]

The program to land astronauts on the moon was named the Artemis Program, and NASA announced it would be landing both a man and a woman on the moon by the 2024 date. To achieve a lunar landing by this earlier date, NASA modified its plans relative to using the Gateway. The accelerated return to the moon required the agency to minimize the number of systems involved with landing humans on the surface. While future lunar landings will still use the Gateway as a staging point in lunar orbit for missions to the surface, NASA, in procuring a commercially provided Human Landing System (HLS), has considered proposals that don't use the Gateway on early Artemis missions.

The Gateway, a key element of NASA's long-term lunar operations, basically represents the first two components of a space station orbiting the moon. NASA is proposing to launch the first two elements of the Gateway—the Power and Propulsion Element (PPE) and the Habitation and Logistics Outpost (HALO)—together in 2023. They then propose to have commercial launches provide logistic support to the two modules.

Maxar Technologies is developing the PPE.[3] The spacecraft's solar electric propulsion system provides the Gateway with electrical power, control, thrust, and communication capabilities. The PPE also provides accommodations for science and technology demonstration payloads.

Northrop Grumman is developing the HALO, which will be the initial crew cabin for astronauts visiting the Gateway.[4] Its primary purpose is to provide basic life-support needs for the visiting astronauts after they arrive in the Orion spacecraft and as they prepare for their trip to the lunar surface. It will provide command, control, data-handling capabilities, energy storage, power distribution, thermal control, communications, and tracking capabilities. It will have environmental control and life-support systems to augment the Orion spacecraft and support crew members. It will also have several docking ports for visiting vehicles and future modules as well as room for science projects and stowage. Cargo deliveries, initially provided by SpaceX, will service the Gateway with pressurized and unpressurized cargo, including food and water for crew, science instruments, and supplies for the Gateway and lunar surface expeditions.

ISS partners are all considering providing support to the Gateway. The CSA is proposing to provide robotics, and the ESA and JAXA have plans to provide support to the Gateway as well. Roscosmos has also expressed interest in cooperating on the Gateway.[5]

NASA has selected three companies to begin the development of the HLS that will land astronauts on the moon and then safely return them to lunar orbit before their return to Earth during the Artemis missions. Blue Origin, Dynetics, and SpaceX offer distinct lander and mission designs. All three will be designed to dock with Orion or the Gateway to receive crews in lunar orbit. In early 2021, NASA expects to determine which commercial concepts are the most mature to land astronauts on the moon for the early Artemis surface expeditions.[6]

Two flights of the Orion spacecraft and the SLS are planned leading up to the projected 2024 lunar landing: Artemis I and Artemis II.

The Artemis I flight, scheduled to be launched in 2021, will be an unmanned launch of the Orion spacecraft atop the SLS into Earth orbit, placing it on a path toward a lunar distant retrograde orbit. It will then travel 40,000 miles beyond the moon (a total of about 280,000 miles from Earth) before returning home. This mission is planned as a demonstration of both the performance of the SLS booster on its maiden flight and a major test of the Orion spacecraft's heat shield as it reenters the Earth's atmosphere at 24,500 miles per hour.

Artemis II, scheduled to be launched no later than 2023, will be the first manned launch of the Orion and the SLS. Orion and four astronauts will make two orbits around Earth before committing to the trip to the moon. Orion will first reach an initial insertion orbit at an altitude of 115 by 1,800 miles, and the elliptical orbit will last approximately 90 minutes with the perigee adjusted via the rocket's first firing of the interim cryogenic propulsion stage (ICPS). After the first orbit, the rocket's ICPS will again provide the thrust to raise Orion into a high Earth orbit (HEO), flying in an ellipse for approximately 42 hours between 200 and 59,000 miles above Earth.

After completing checkout procedures in HEO, the Orion will perform the translunar injection maneuver (TLI). The Orion's service module will send the spacecraft on a path toward the moon with a lunar, free-return trajectory. The TLI will send the crew on an outbound trip of about four days around the far side of the moon, where they will ultimately create a figure eight extending more than 230,000 miles from Earth as the Orion returns on another four-day journey back home.

Artemis III, the third planned flight of NASA's Orion spacecraft on the SLS, is scheduled for launch in October, 2024. Artemis III will take the Orion and its crew of four to the moon for a lunar landing. In order to attempt to return to the moon by the directed 2024 date, NASA has tried to minimize the number of systems involved with landing humans on the surface. So, while future lunar landings will use the Gateway as a staging point in lunar orbit for missions to the surface, NASA has allowed commercially provided HLS bidders an option that does not use the Gateway on early Artemis missions. However, for long-term lunar operations, NASA is planning to use the Gateway as a staging point for human and robotic lunar missions.

COST ESTIMATES AND DEVELOPMENT PROBLEMS

NASA's approach to return to the moon by 2024 will undoubtedly be a very costly one. They are, in essence, planning to build a space station to orbit the moon, the so-called Lunar Gateway. This is an approach based upon a number of separate modules that are being developed by different contractors, and it all must come together if they are to successfully achieve their objective. The management of the program and its various critical elements have also been assigned to all the various NASA centers. Experience in the management of complex programs has clearly demonstrated that success requires a strong and knowledgeable program management and effective program integration with clear lines of technical and budget authority. That does not appear to be apparent in the Artemis Program as presently defined. The concept of building a space station to orbit the moon (a God-given space station that already orbits Earth), is also very costly and potentially less safe than going directly to the moon and investing our resources in a lunar outpost, the ultimate objective.

A realistic cost estimate for the Artemis Program has yet to be made. NASA, in their Artemis plan—NASA's Lunar Exploration Program Overview of September, 2020—shows a total cost for Phase I of the Artemis Program amounting to $27.971 billion.[7] In the 1960's the Apollo Program, flying two missions in Earth orbit and nine missions to the moon, landing six times, came to $25 billion. That amount would equate to over $219 billion in today's dollars—a far cry from the $27 plus billion estimated by NASA for Phase I of the Artemis Program.

The lack of realism in NASA cost estimation for the Artemis Program has already been demonstrated by the costs being incurred by the SLS—a major element of the Artemis Program that was not included in NASA's $27 billion quote.

The launch vehicle planning to be used, the SLS, has already suffered significant cost overruns and schedule delays. According to a 2020 Office of Inspector General (OIG) report, the cost of the booster had already grown by nearly 30% (or about $2 billion), and the first launch of the rocket, originally planned for late 2017, would be delayed to June 2021 or later.[8] The OIG report also estimated that NASA would spend $17 billion on the SLS through the end of fiscal year 2020, of which $5.9 billion was not included in its baseline commitment.[9, 10]

Another critical element in the Artemis Program is the Orion spacecraft. NASA has been developing the Orion spacecraft for over 14 years since 2006.The Orion is one of three capsules being developed by NASA. Space X'S Dragon capsule and Boeing's CST-100 Starship capsule are also both being funded by NASA. They are to be used to carry astronauts to the International Space Station. SpaceX has already successfully flown the Dragon, but Boeing has yet to fly their spacecraft. One might ask, why develop three capsules when one would suffice for flying astronauts to the ISS and for flights to the moon? Unfortunately, none of the three capsules can accomplish spacewalks, also known as extravehicular activities. They also cannot be used to construct large structures in space, a capability that was given up when the Space Shuttle Program ended. At present, another international space station could not be built in Earth orbit as was accomplished by the Space Shuttle Program, and building a space station in lunar orbit, as is presently planned, will be a very challenging task. NASA hopes to accomplish the construction automatically.

The Orion and the SLS are scheduled to fly together for the first time in late 2021 on the Artemis I mission that will send an unmanned Orion around the moon. NASA's OIG report determined report determined that the Orion, under development for over a decade, has continued to experience cost increases and schedule delays.[11] Since a cost and schedule baseline was set in 2015, the program has experienced over $900 million in cost growth through 2019, a figure expected to rise to at least $1.4 billion through 2023, the report concluded.[12] The OIG report also found that NASA's exclusion of more than $17 billion in Orion-related costs has hindered the overall transparency of the vehicle's complete costs.[13]

A recent problem experienced with the Orion as it progresses through processing at the Kennedy Space Center in Florida could further impact those costs. Although NASA announced on December 17, 2020 that it will not repair a faulty electronics unit on the Orion spacecraft, if they were to proceed with repairs, it would require months of work to replace and fix.[14] The failed component is within one of the spacecraft's eight power and data units, or PDUs. The PDUs are the main power/data boxes for the Orion and are responsible for activating key flight systems.

Replacing the PDU isn't easy. The component is difficult to replace as it's located inside an adapter that connects the Orion to the service module that provides support, propulsion, and power for the spacecraft. To get to the PDU, the Orion crew capsule would have to be removed from its service module. This is a lengthy process that would take up to a year. As many as nine months would be needed to take the vehicle apart and put it back together again, in addition to having to undergo three months of subsequent testing.

Engineers have considered other possible ways to replace the failed unit. One would involve tunneling through the adapter's exterior by removing some of the outer panels of the adapter to get to the PDU. The panels weren't designed to be removed in this way. This approach would still take up to four months to complete if it even proves to be possible.

The PDU failed in such a way that it lost redundancy within the unit, but it can still function. Although NASA concluded that there was sufficient redundancy in the overall system, flying without the designed redundancy is not exactly a prudent approach. Far more important is understanding the reason for the failure and determining if the other PDU's are susceptible to the same failure.

In any event, the problems faced by both the Orion and the SLS raise concerns about a combined Orion-SLS flight even occurring in 2021.

CONCLUSION

If one were to look back at the Apollo Program, every capability needed to perform the mission to the moon, except for the actual landing, was proven in Earth orbit. The first manned flight, Apollo VII, was an Earth orbital flight of almost 11 days. The objectives of the mission were to demonstrate the performance of the command and service module, the crew, the mission support facilities, and the command and service module's rendezvous capability. A flight out of Earth orbit was not considered until those objectives were all satisfactorily met. A far more prudent approach, an extended Earth orbital flight of similar duration, should also be considered for Artemis II, the first manned flight of an Orion spacecraft.

Two commercial companies, Space X and Blue Origin, have plans to fly to the moon, and China just successfully landed on the moon on December 1, 2020 on a lunar sample return mission.[15] Neither company plans to use a complex architecture with an orbiting space station to fly to the moon, and the Chinese chose a straightforward approach to accomplish their landing. Rather than spend money on space stations to orbit the moon, a more forthright approach, such as Apollo's lunar-orbit-rendezvous concept, should be considered for achieving a successful lunar landing, and the emphasis should be on building a permanent research station on the moon.

When considering the planned architecture, the Lunar Gateway concept, the launch vehicle and spacecraft, the additional modules and capabilities required with all their complexity, the presently planned mission sequence, the absence of any realistic cost estimates for the program (as well as excessive development times and significant cost overruns that have already occurred), an overall review of the program and the presently planned approach to return to the moon is very much in order. The present plan of trying to meet a dictated landing date of 2024 rather than proceeding on an orderly planned sequence of missions leading up to a successful landing should also be a part of that review.

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