NASA Advisory Council Recommendation

Use of Decadal Surveys and Exploration Objectives to Set Priorities for the Gateway
2018-02-01 (HEOC/SC-01)

Recommendation:
The Council recommends:

- *For the NASA Science Mission Directorate (SMD) Associate Administrator*: That the science initiatives implemented at the Gateway should be prioritized to align with the National Academies' decadal surveys.
- *For the NASA Human Exploration and Operations Mission Directorate (HEOMD) Associate Administrator*: That the objectives for exploration initiatives enabled by the Gateway approach should be clearly articulated by HEOMD to set expectations for all stakeholders.

Major Reasons for the Recommendation:
The Council applauds the leadership of HEOMD and SMD for fostering a balance between exploration and discovery in the Gateway concept. When communicating about the Gateway concept both science and exploration should indeed be emphasized. Clearly articulated exploration objectives for the Gateway and reference to science decadal surveys will be critical as requirements for the Gateway are developed in order to set expectations for all Gateway stakeholders and prioritize future Gateway science activity.

Consequences of No Action on This Recommendation:
Failure to articulate exploration objectives and science priorities for the Gateway could result in confusion amongst stakeholders and unnecessarily decrease the effectiveness of a major NASA initiative.

NASA Response:

NASA concurs with the NAC recommendation.

Gateway Science Priorities

Transformational science from, near or of the Moon only can occur if initiatives at the Gateway align with the astrophysics, Earth science, heliophysics and planetary science decadal surveys (DSs) produced by the National Academies of Science, Engineering and Medicine (NASEM). Once each decade, NASA and its partners ask the NASEM to look out 10 or more years into the future and prioritize research areas and observations. NASA then conducts a detailed evaluation of the technical and scientific maturities attendant to the DS priorities, as well as the near-, mid-, and long-term costs and benefits to the nation.

Set timetables of the DSs do not limit discourse and decision-making by the Agency, as NASEM and NASA Science Mission Directorate (SMD) closely coordinate and engage in iterative discussions. NASEM will issue the planetary science and astrophysics DSs in the early 2020s. For the planetary science DS, discussions are underway between SMD and the NASEM to ensure that key science of the Moon advanced studies could be performed in areas that the community identifies. The Earth science DS was received by NASA in December 2017, and the Agency is examining and implementing those priorities with broad stakeholder involvement. The heliophysics mid-term review (mid-way between DSs) currently is in work by NASEM.

NASA SMD has begun integrating a cross-discipline approach to science from, near or of the Moon with consideration of science opportunities in cis- lunar space, low lunar orbit, and surface operations. Looking across disciplines, a number of science activities could be considered transformational: 1) establish the period of giant planet migration in the Solar System, 2) provide an absolute chronology for Solar System events, 3) use the lunar far side to view the universe, 4) discover and understand the sources of lunar water and the water cycle, 5) characterize the nature of the lunar interior, and 6) evaluate plasma interactions with the lunar surface. A white paper on these scientific areas has been provided by the Solar System Exploration Research Virtual Institute (SSERVI) at NASA's request. Other foundational works to inform this effort include (1) the Scientific Context for the Exploration of the Moon (SCEM) (2007) by the National Research Council, and (2) Lunar Exploration Analysis Group (LEAG) Specific Action Teams (SATs) reports from teams focused on Advancing Science of the Moon (ASM-SAT) and Next Steps on the Moon (NEXT-SAT), found at https://www.lpi.usra.edu/leag/reports.shtml.

NASA also has convened and engaged in numerous fora to allow scientific community-driven priorities for transformational science to emerge:

- NASA Ames Research Center in Mountain View, CA held the Lunar Science for Landed Missions Workshop January 10-12, co-chaired by the LEAG and SSERVI. The talks and resulting reports detailing excellent science to be done at every step are archived here: https://lunar-landing.arc.nasa.gov/. Landed lunar science priorities and proposed destinations are invaluable inputs for Gateway development as it is to be a versatile outpost supporting both human and robotic scientific missions on and around the Moon. It is envisioned that the Gateway could support small landers, and in addition maintain position or move between lunar orbits over its lifetime to maximize science operations. Robotically collecting lunar samples for investigation aboard the Gateway for safekeeping until they can be returned to Earth could be another capability.

- NASA, the Lunar and Planetary Institute (LPI) and Universities Space Research Association (USRA) held the Deep Space Gateway Concept Science Workshop on February 27 - March 1 in Denver, CO, with approximately 300 attendees and 180 talks presented. Discussions focused on cross-discipline science priorities and the infrastructure and instruments the Gateway would need to provide to facilitate different types of investigations.

- European, Japanese, and Canadian space agencies have held science meetings regarding the Gateway, and NASA is sharing data with these partners. These agencies, and others, are participating in the Gateway design and development process.

Gateway Exploration Objectives

NASA agrees the exploration objectives enabled by the Gateway should be clearly defined and documented to provide stakeholders with a common set of Gateway expectations for science and exploration of the cislunar environment.

The HEOMD has created a single document with the goal of capturing exploration objectives and tracing the Gateway objectives directly from the NASA Strategic Plan to facilitate communication and define expectations for the exploration architecture.

The tracing to the Gateway exploration objectives starts at the 2018 NASA Strategic Plan's Stategic Goal #2 which states to: Extend Human Presence Deeper into Space and to the Moon for sustainable long-term exploration and utilization.

The Strategic Plan identifies two supporting Objectives assigned to HEOMD in support of this goal:

Strategic Objective 2.1: Lay the foundation for America to maintain a constant human presence in low Earth orbit enabled by a commercial market.

Strategic Objective 2.2: Conduct human exploration in deep space, including to the surface of the moon.

These two NASA objectives were assessed against the NASA Exploration Campaign by the HEOMD engineering and science teams and were then broken down into 60 HEOMD Exploration Objectives specifying unique spaceflight systems tests, demonstrations and capabilities. and further grouped between the exploration Phase 0 (ISS testing), Phase 1 (Cislunar Demonstration of Exploration Systems) and Phase 2 (Cislunar Validation of Exploration Systems). The 60 objectives are found in HEOMD-001 *Human Exploration and Operations Exploration Objectives*, with the Tables 6.3, 6.4 and 6.5 reproduced below. HEOMD-001 is undergoing a review and will be updated to include lunar exploration goals.

NASA has defined the National Exploration Campaign to include the following 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.

The Gateway addresses goals 2-5. The Gateway will be used as a platform to accommodate robotic cargo landers to and from the surface of the Moon with the ability to configure payloads, control and relay communications for surface missions, and potentially handle samples returned from the surface as well as refurbishing of robotic landers. Gateway will serve as a hub for lunar transportation of crew to the surface of the Moon and serve as a deep space port for refurbishing, refueling, and reusing those surface systems. These activities at the Gateway are of the same type that will be used to support future Mars missions as those vehicles will be aggregated and refueled at the Gateway.

In addition, the following Gateway objectives have been established. These objectives can be traced back to the HEOMD-001 Exploration Objectives and the National Exploration Campaign strategic goals.

- The Gateway shall be utilized to enable human crewed missions to cislunar space including capabilities that enable surface missions. (Crewed Missions)
- The Gateway shall provide capabilities to assist in meeting scientific requirements for lunar discovery and exploration, as well as other science objectives. (Science Requirements)
- The Gateway shall be utilized to enable, demonstrate and prove technologies that are enabling for Lunar missions and that feed forward to Mars as well as other deep space destinations. (Proving Ground & Technology Demonstration)
- NASA shall establish industry and international partnerships to develop and operate the Gateway. (Partnerships)

To expand on these objectives, the following categories have been defined to describe the types of activities that will be accomplished at or with the Gateway to enable a sustained presence around and on the Moon and to develop and deploy critical infrastructure required for operations on the lunar surface and at other deep space destinations.

Activity Type	Description
Exploration Testing and Operations	Demonstrate capabilities and associated technologies at the Gateway along with integrated testing of these capabilities and technologies. Demonstrate operational procedures and risk mitigation plans for beyond LEO exploration risks.
Supporting Crewed Missions	Demonstrate capabilities associated with support of crewed missions on Gateway.
Human System Integration in Deep Space	Execute the approach to characterize and mitigate the integrated human health and performance risks associated with humans living and working in deep space during an 1100-day Mars mission.

Gateway Enabled Science	Perform science by using Gateway resources and capabilities. This includes both internal and externally mounted experiments. It includes science instruments deployed from the Gateway.
Support of Robotic Missions	Provide accommodations for delivery, aggregation, & teleoperation of robotic assets including possible sample return from the Moon & other bodies, communications infrastructure to small satellites, satellite deployment, and using the Gateway to support servicing/construction of large telescopes.
Support of International Partner Missions	Support international partner missions in cislunar space by making available Gateway resources and capabilities.
Support of Commercial Partner Missions	Support private sector/commercial partner missions in cislunar space by making available Gateway resources and capabilities.

The HEOMD-001 Phase 1 Exploration Objectives are shown for reference below.

HEOMD-001 TABLE 6.4 PHASE 1 OBJECTIVES (P1)

Objective Identifier	Objective	Objective Category
P1-01	Demonstrate SLS Block 1 elements in flight and integrated performance with Orion	Transportation
P1-02	Demonstrate Block 1B trans-lunar injection (TLI) performance, including co-manifested capability	Transportation
P1-03	Demonstrate Orion's ability to support crew in deep space	Transportation
P1-04	Demonstrate Orion's ability in conjunction with additional habitation element(s) to support missions with at least 4-Crew for a minimum of 30 days	Transportation
P1-05	Demonstrate operation of deep space exploration-class propulsion to support on-orbit maintenance, cislunar transfers, and in-space refueling	Transportation
P1-06	Demonstrate ability to stage habitation and other capabilities in deep space for later utilization	Transportation
P1-07	Demonstrate ability for crewed rendezvous and operation with a previously staged element(s)	Transportation
P1-08	Demonstrate autonomous rendezvous, proximity operations, and docking in deep space	Transportation
P1-09	Demonstrate ability to dispose of assets from deep space	Transportation
P1-10	Demonstrate deep space crewed operations up to Mars communications latency	Working in Space
P1-11	Validate ability to conduct EVA in deep space	Working in Space
P1-12	Validate integrated radiation risk mitigation ability to provide As Low As Reasonably Acceptable (ALARA) exposure, including monitoring, mitigation, and operational strategies	Working in Space
P1-13	Demonstrate transition between crewed and uncrewed operations	Working in Space

P1-14	Demonstrate human/robotic interactions in deep space	Working in Space
P1-15	Demonstrate stowage strategies within available volume for deep space missions	Working in Space
P1-16	Demonstrate the collection and return of biological and/or scientific samples including planetary protection protocols	Working in Space
P1-17	Evaluate the nature and distribution of lunar volatiles and extraction techniques and decide on their potential use in human exploration architectures to inform future ISRU development	Working in Space
P1-18	Enable science community objectives in deep space, including addressing HEOMD's strategic knowledge gaps in the lunar vicinity	Working in Space
P1-19	Enable commercial and international partnership objectives in deep space	Working in Space
P1-20	Demonstrate ability to use systems in cislunar space to enable science, technology, and exploration while in an uncrewed state. Enable commercial and international partnership objectives in deep space	Working in Space
P1-21	Demonstrate/evaluate exploration medical capabilities	Staying Healthy
P1-22	Demonstrate/evaluate human flight operations crew physiological well-being in deep space	Staying Healthy
P1-23	Demonstrate/evaluate human flight operations crew psychological well-being in deep space	Staying Healthy
P1-24	Demonstrate/evaluate human health countermeasures	Staying Healthy
P1-25	Evaluate the effects of deep space on complex organisms, plants, food, pharmaceuticals, and animal models	Staying Healthy