National Aeronautics and Space Administration

Office of the Administrator
Washington, DC 20546-0001

October 26, 2015

Dr. Steven W. Squyres
Chairman
NASA Advisory Council
Washington, DC 20546

Steve

Dear ~~Dr. Squyres~~:

Enclosed is NASA's response to the National Research Council (NRC) Pathways to Exploration Report recommendation from the NASA Advisory Council meeting held on July 29-31, 2015, at the Jet Propulsion Laboratory. Please do not hesitate to contact me if the Council would like further background on this response. I appreciate the Council's thoughtful consideration leading to the recommendation and welcome its continued findings, recommendations, and advice concerning the U.S. civil space program.

I look forward to working closely with you and members of the Council in the future.

Sincerely,

Charles F. Bolden, Jr.
Administrator

Enclosure:
2015-03-02 (Council-02) National Research Council (NRC) Pathways to Exploration Report

NASA Advisory Council Recommendation

National Research Council (NRC) Pathways to Exploration Report
2015-03-02 (Council-02)

Recommendation:
The Council recommends that NASA provide a written response, in the form of a letter for the record, to the NRC Pathways to Exploration Report. This response should address the specific findings and recommendations of the report, identify which recommendations are accepted, and provide a brief rationale for choosing strategies that were different.

Major Reasons for Proposing the Recommendation:
The Council found the joint discussion on the NRC Pathways to Exploration Report and the current NASA Human Exploration Strategy extremely valuable in codifying areas of agreement in approach and areas where there are technical differences in approach or risk assessment. The NRC report is a comprehensive and independent assessment that has stimulated good technical review and debate. A written response will provide an opportunity to document decisions to pursue alternate paths, some of which were based upon analyses and decisions that have taken place since the completion of the report (e.g., the decision to maintain the International Space Station through 2024).

Consequences of No Action on the Proposed Recommendation:
There will likely be future externally directed studies of NASA's exploration strategy, and NASA will be asked to explain what they did in response to the NRC study and why they chose not to accept some of the recommendations that were made.

NASA Response:
NASA concurs in part. NASA concurs in the value of sharing our exploration plan and explaining how it benefits from past external reviews and assessments; however, a direct response to the NRC report would only serve to show that its recommendations have been overtaken by events and progress to date. The NRC's report came out over a year ago, and given the NRC's internal review process, our interaction with them as they prepared this report occurred a year before that. In the past few years, NASA has made substantial progress in defining and articulating its approach to human exploration, and this has been shared numerous times with both the NAC and the NRC's standing committees (Space Studies Board and Aeronautics and Space Engineering Board) since the NRC report's release. Below is a summary of recent progress in NASA's exploration planning and communication of the same.

NASA has been evolving its human exploration studies over the past few years in accordance with the guidance and direction in the 2010 NASA Authorization Act, and this planning has continued during and after the development of the NRC report. We engaged in dialogue with this NRC committee during its lifetime, with standing NRC committees since, and shared our progress with the NASA Advisory Council along the way and with our many partners and stakeholders in a variety of formal and informal settings. We continue to engage these communities and recognize the importance of their support for our long-term success. As a result of this work, it has become clear that we need to define and communicate an approach to human space exploration that embraces Mars as a horizon destination, is sustainable over multiple decades, and is achievable within reasonable budget expectations. In dialogue with those mentioned above and with our international

and commercial partners, we have formulated and matured a set of principles that guide our studies and are planning to ensure long-term sustainability in the journey to Mars. These principles, along with Agency strategic goals and constraints, have been shared with our stakeholder community, and these have been met with broad consensus. Within NASA, we have strengthened our coordination with the technology development and science Mission Directorates in many key areas – efforts designed to further inform and align technology investments and enhance benefits across science and human exploration missions. With advice and input from the spaceflight stakeholder community and across NASA, our exploration strategy, progress, and forward plans have been captured in the recently-released *Journey To Mars – Next Steps in Space Exploration* (J2M), which is consistent with the Global Exploration Roadmap (GER), released by the International Space Exploration Coordination Group (ISECG).

The *Journey To Mars* depicts an approach and explains the rationale for building up a capability through which NASA and its partners extend our presence into the solar system. We cast this framework as moving from an "Earth-reliant" phase in which crew return is measured in hours, to a "Proving Ground" phase in which we test out and build up deep-space capabilities in cislunar space where crew return times are measured in days, to an "Earth-independent" phase in which we can conduct missions to the vicinity or surface of Mars where crew return times are measured in months to years. In the Earth-reliant phase, we are conducting human research on the International Space Station (ISS) according to a well-defined plan to develop the mitigations for the risks to humans of long-duration spaceflight beyond low-Earth orbit (LEO). The environmental control and life support system technologies that will be used for Mars missions will be tested on ISS. In parallel, we are working to facilitate the growth of the market for commercial LEO services that will free NASA resources to move outward from LEO while fostering LEO space economies. We are building the Space Launch System (SLS) and Orion for missions in cislunar space and are defining the test objectives to be met by the missions in this Proving Ground regime. We are currently studying approaches to achieving deep-space habitation capability in this region in collaboration with our partners. The Asteroid Redirect Mission will advance the in-space propulsion and automated rendezvous and docking capabilities we will need for future Mars missions. Cislunar space will also be a staging area for both cargo and crewed missions to Mars. Robotic science missions at Mars today and going to Mars over the next decade are providing essential understanding of Mars atmospheric conditions, surface destinations, and resources. We are also conducting analyses of requirements for: crew and cargo transit systems; entry, descent, and landing on Mars; *in situ* resource utilization for fuel, oxygen, and food; surface power; and other elements of a humans-to-Mars architecture.

Building off of the successful radiation monitor already operating on the Curiosity rover, the next Mars rover planned for launch in 2020 will also contribute to the preparation for human exploration of Mars by making significant progress toward addressing strategic knowledge gaps. Further, the Mars 2020 rover will potentially cache samples for possible return to Earth by future missions. In addition, the Mars Reconnaissance Orbiter is scanning the climate and surface of Mars and identifying the best possible landing sites for Mars 2020 as well as identifying landing locations for future human missions which maximize both science return while optimizing local resources in support of future human surface exploration. Simultaneously, the Mars Atmosphere and Volatile EvolutioN mission is exploring the Red Planet's upper atmosphere, ionosphere, and interactions with the sun and solar wind. Just as these rovers and orbiters help us answer the question of whether life ever existed on Mars in the past, they are also helping us to prepare to put human life on Mars in the

future. One key to a sustainable program of space pioneering is to recognize what decisions need to be made and when. We have made decisions on: how to best use ISS (including the Administration's decision to extend ISS operations to at least 2024 to enable deep-space exploration); development of SLS and Orion, including SLS' evolution pathway (pursuing an Exploration Upper Stage before advanced boosters based on cislunar mission capture); sending Exploration Mission-1 (EM-1) to a distant retrograde orbit around the Moon because of its utility for future deep space missions; and the utility of solar electric propulsion for moving large masses in deep space. We know the next set of decisions, to be made over the next few years, will include the areas of deep-space habitation and deep-space transit capability and on entry, descent, and landing needs and technology pathways. Future decisions will include whether to send human missions to the moons of Mars before missions to the Mars surface, based on the degree to which the former is enabling of the latter.

But we do not need to make all these decisions today – in fact, it is better if we do not. Our strategy is to ensure we take advantage of new scientific discoveries, new technology advances, and new commercial and international partnerships during the long timeframe of exploration. Considering how each of these areas has advanced over the past five years, it is easy to imagine they will change substantially over the next five to ten years, and each area heavily influences the investment strategy and architecture construct necessary to safely cross the solar system and ensure sustainable progress along the way. Thus, as we pursue the development today of systems we know we will need for the "Proving Ground" phase of the 2020s, we can and should hold open some decisions for the "Earth-Independent" phase where NASA and partner capabilities will evolve before it is necessary to settle on the configuration and pathway of the first human mission to Mars.

While the NRC report suggests alternative methods of planning for the future of space exploration, NASA identified an approach, based on our detailed technical studies and principles, reflected in the J2M, which both supports the overarching exploration goals desired by the NRC and does so in a responsible manner that is consistent with the capability and needs of the space exploration community here and abroad. NASA will continue to share progress and plans with the NASA Advisory Council and looks forward to a continued dialogue to ensure the Agency's success.