



July 24, 2017

TO: Distribution

FROM: Administrator (Acting)

SUBJECT: EM-1 Crew Study Results Summary

At the request of the Administration, NASA conducted a study of the feasibility of flying crew on the first integrated flight of the Orion spacecraft, Space Launch System (SLS) and associated ground systems. Based on this study, NASA concluded crew could have flown on Exploration Mission-1 (EM-1), provided timely and sufficient funding, with an increased risk acceptance and moving the launch schedule to most likely early 2020.

After considering all factors and variables and coordinating with the Administration, we elected to stay on course of our current plan and fly EM-1 uncrewed. The current approach of a first integrated test flight without crew is best in light of all factors including cost, technical development, and risk. This mission remains an important next step toward our longer term exploration goals of moving human presence farther into deep space.

The six-week review was intense and involved detailed analysis by a large team of NASA and contractor personnel. While we may not be adding crew to this flight, the review was extremely beneficial as it allowed our teams to assess past program decisions and plans and to offer suggestions to improve development activities for EM-1. This effort was beneficial and has improved NASA's overall planning for SLS, Orion, and ground systems for EM-1 and beyond. The following describes the major factors and findings of the study:

Hardware and Software Requirements

As planned, EM-1 lacks some systems necessary to support crew. This was done to reduce EM-1 budget costs and spread development costs across early missions due to budget uncertainty. Most notably, systems needed to support crew on EM-1 include:

- Environmental control and life support system (to provide O₂ and remove CO₂ and control humidity).
- Crew displays and controls, plus significant software development.
- Active abort system.
- Miscellaneous crew support items such as the ability for the crew to open the hatches from the inside.

These systems can be added to EM-1 for crew but will add cost and take additional time to design and implement. To accommodate installation of these systems, several areas on the Orion EM-1 vehicle also would need to be reworked and disassembled, given the progress made to date.

The need for additional budget and schedule to fly crew on EM-1 was known prior to the study and was more defined as part of the study. The additional costs and schedule impacts needed for crew on EM-1 would place additional pressure on the EM-1 development.

Technical Risk

Typically, crew is not flown on the first flight of a vehicle to allow for systems-level flight tests. NASA's first Space Shuttle flight was unique as it required crew to operate the vehicle for landing and, therefore, crew was on the first flight. Flying crew on the first flight of a new integrated system increases risk to crew safety that must be identified and mitigated or accepted. The additional risk of flying crew must be weighed against the benefits of flying crew.

NASA has significant experience in identifying, understanding, and mitigating crew risks and would not fly crew on any mission without a detailed review. In this study, the team did a thorough job characterizing increased risk and describing benefits.

Placing crew on EM-1 would result in the acceptance of additional risk for the crew. Some of this risk would have been mitigated by mission design and keeping Orion close to Earth for return as the life support system is tested. NASA also considered the following in its review:

- The flight heritage of the propulsion systems on SLS are significantly more mature than typical first crew flight maturity levels;
- The abort system on EM-1 provides a level of risk mitigation not available on the first Space Shuttle mission. Further, the abort system will be tested at altitude before flight of crew;
- Orion's uncrewed Exploration Flight Test-1 (EFT-1), flown in 2014, provided risk reduction for critical ascent and entry flight systems and provided an opportunity to develop crew and capsule extraction procedures at the end of the mission;
- For the proposed EM-1 mission design, the lunar fly-by includes a free return trajectory to minimize the need for propulsion systems support should a failure occur after the Trans-Lunar Injection burn;
- Mission constraints to protect crew safety will also limit the launch window and might result in moving launch into 2020; and
- The largest technical risk identified is the first use of a block heat shield configuration. This block design is not easy to analyze or test; however, a sub-scale heat shield test could be added prior to EM-1 to provide further evidence of acceptable heat shield performance.

This testing, and adherence to normal safety processes, would make the risk associated with crew on EM-1 acceptable. As with all crewed flights, additional accepted risks would have needed approval if they were determined to be safe. As discussed, the risks could have been mitigated, but the uncertainty and added complexity for crew on EM-1 must be considered.

Additional Considerations and Benefits

The benefits of crew on EM-1 are significant, though difficult to directly measure. Flying crew on EM-1 would create a heightened level of focus in resolution of difficult problems. Technically, it removes the operational constraint of a free return trajectory required on EM-2. This would have resulted in a better overall flow of future mission content, presenting an opportunity for acceleration of objectives for all deep space exploration missions slated in the 2020s as we continue to push human presence further into space.

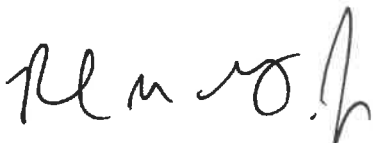
Flying crew systems early would have completed non-recurring engineering development activities earlier than currently planned. This would have allowed NASA to move into lower cost production and operations earlier and provide an immediate mission focus we might not otherwise have had.

Adding crew would also have created additional enthusiasm and forced a new precision and velocity in decision making. This was evidenced by the effort expended by the study team, including industry partners. Assuming resources exist to achieve a cadence of one mission per year after EM-2, as currently planned, flying crew on EM-1 would have created a new momentum for human exploration reflective of the 2017 NASA Transition Authorization Act – one our Nation and our partners would support.

Summary

NASA determined it was feasible to fly crew on EM-1. However, in the balancing of the cost, schedule, and technical risks, and the fact this is a long-term exploration program, it was determined that the current baseline program was the better long-term solution.

The study was beneficial and has improved NASA's overall planning for SLS, Orion, and ground systems. Given the decision not to fly crew on EM-1, NASA continues working toward an uncrewed first flight as the first mission in a series of deep space missions beyond the Moon in preparation for sending humans to Mars in the 2030s.



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