June 24, 2016

Vice Admiral Joseph W. Dyer, USN (Ret.)
Chair
NASA Aerospace Safety Advisory Panel
Washington, DC 20546

Dear Admiral Dyer:

Enclosed is NASA’s response to the Orion Risk Assessment recommendation from the Aerospace Safety Advisory Panel (ASAP) public teleconference meeting held on December 14, 2015. Please do not hesitate to contact me if you or the Panel would like further background on the response.

I look forward to receiving continued advice from the ASAP that results from your important Quarterly and Insight fact-finding meetings.

Sincerely,

Charles F. Bolden, Jr.
Administrator

Enclosure:
2015-05-01 Orion Risk Assessment
Date of Public Deliberation: December 14, 2015

Short Title of Recommendation: Orion Risk Assessment

Finding:
Since 2010, numerous changes have been made to the Orion test and qualification plan. The first major change was made during the uncertainty of whether Orion would survive the cancellation of the Constellation Program. In an effort to reduce Orion’s development cost, NASA decided to switch from a dedicated qualification test article approach to a distributed qualification approach, where the high-fidelity test articles would subsequently be used for flights, including the first crew mission. The decision, while saving money, resulted in 18 issues (or gaps) in the qualification and test program. One of the most significant gaps was the deletion of pyro shock/separation testing at the integrated system level.

While working to close the 18 issues, NASA also continued to modify the Orion test and qualification plan to deal with cost and schedule pressures. Two recent changes caught the attention of the Panel:

- the reduced fidelity of the Ascent Abort 2 (AA2) test, and
- the use of module-level, direct field testing for vibro-acoustic qualification as opposed to integrated reverberant testing.

NASA informed the Panel that the change to AA2 was made to reduce cost. Also, according to NASA, the change to vibro-acoustic qualification was made to reduce schedule risk for Exploration Mission (EM)-1 and enable acceptance testing for subsequent missions to be performed at the Kennedy Space Center (KSC), saving time and money.

Recommendation:
The ASAP strongly recommends that NASA evaluate the combined effects and aggregate risk increase associated with the multiple changes to the Orion test and qualification plan. The Panel especially recommends NASA review decisions that were driven, in part, by a constraint to hold the EM-2 schedule and content for 2021. As part of the review, the Panel recommends that NASA fully assess the alternative of schedule relief and/or EM-2 content change as opposed to accepting the additional risk associated with the modified test/qualification.

Rationale:
Taken individually, the decision to use a “boilerplate” or “non-flight-like” crew module instead of a high-fidelity crew module for AA2 is the most concerning to the Panel. AA2 is the only opportunity to flight test the Launch Abort System (LAS) and its interactions with many other Orion systems in the challenging transonic flight environment. Qualification of the abort system
ultimately relies on analytical models that are very complicated and have some degree of uncertainty. The new test configuration misses a valuable opportunity to obtain a high-fidelity test point for analytical model validation as part of a complete “end-to-end” system test. The LAS is a primary safety feature that is allocated 95 percent reliability and will be flown on every mission for the next 40 years. It is the last hope for the crew if something goes wrong during the early phase of ascent.

Considering the test and qualification changes collectively, the Panel notes that the rationale used to justify one decision can be affected by subsequent decisions. For example, when NASA accepted the elimination of integrated pyro shock testing, part of the rationale presented to the Panel was that the “full vehicle would experience shock events at least once during flight prior to a manned flight.” However, the subsequent AA2 decision eliminates a critical data point for the forward bay cover, which would have combined the actual acoustic and pyro shock environments of a transonic abort.

Finally, the Panel is also concerned that NASA has not fully assessed the aggregate increase in risk that is being accepted to hold schedule and content for EM-2. While each change to the test and qualification plan, considered individually, may appear to be a rational approach to dealing with cost and schedule issues, the cumulative effect is often not evaluated. While the desire to fly crew on Orion as soon as possible is understandable, NASA is building a long-term exploration program, and adjustments to the near-term schedule or mission content that result in far safer systems can be an advantageous trade.

**NASA Response:**

NASA appreciates the thorough and thoughtful work that the Aerospace Safety Advisory Panel (ASAP) has invested in the 2015 ASAP Annual Report.

NASA is implementing a distributed system test and verification plan that ensures the safety and success of Orion and Space Launch System (SLS) and our crews who will fly with them. For Orion, this plan combines ground testing using a proto-qual approach with further validation through flight testing to ensure that the spacecraft will support the successful flight of humans into deep space in 2021. Although this distributed approach provides some complexity that a production unit dedicated qualification test article does not, this test plan is thorough, logically laid out, reflects a very-high level of engineering rigor, and most importantly allows for the discovery of problems earlier in the design and development process than a dedicated test article. The test plan was affirmed as part of the Orion Critical Design Review reviewed by our independent Standing Review Board, with review and approval by the Human Exploration and Operations Mission Directorate (HEOMD) Associate Administrator and Deputy Associate Administrator for Exploration Systems Development at a Directorate Program Management Council, and with review by the Agency Program Management Council.

NASA carefully monitors progress made against milestones established and consistently evaluates risks, both individual and cumulative. While the Agency is schedule aware, decisions made and actions taken are process driven. There are significant checks and balances in the system; checks and balances that NASA has evolved and refined over many years.
These checks and balances are being proactively applied on the Orion Program. One example can be seen in the decision made by the Orion Program to rebaseline the AA2 test program. A dissenting opinion was registered against this decision and, as a result, it was thoroughly vetted through the Dissenting Opinion Process as documented in NASA Policy Directive 1000.0B, Governance and Strategic Management Handbook. The final decision, upheld by the Associate Administrator for HEOMD with concurrence by the Engineering and Safety and Mission Assurance Technical Authorities, was based on programmatic and technical considerations and a recognition of the risk trades with respect to the original baseline approach. The extra scrutiny afforded by the Dissenting Opinion Process aided in the thorough understanding of the increased risk.

This year, NASA has provided in-depth information to ASAP on the topics addressed in the 2015 ASAP Annual Report. After NASA received the ASAP Annual Report and prior to the first ASAP Quarterly Meeting, the Orion Program and Exploration Systems Development leadership proactively hosted a one-day briefing/discussion for ASAP (February 12, 2016) to allow for extended briefings and open dialog on the topics raised in the Annual Report. This session included detailed briefings on the following topics:

- **Orion System Test and Verification (T&V):** including discussions of the Orion integrated T&V evolution and strategy, distributed qualification approach, test articles and test configurations, risk issues associated with the T&V plan, and the associated documentation and management control.

- **Environmental Control and Life Support System (ECLSS):** including discussion on the ECLSS components and hardware flying for the first time on EM-2, ground and flight T&V for ECLSS components, and EM-2 acceptance.

- **Ascent Abort 2 (AA2):** including the rationale for selecting a simplified test configuration, the analyses produced to demonstrate coverage of the original test objectives through a combination of the AA2 flight test and complimentary ground and flight tests, and an evaluation of the risk trades associated with the Program's choices.

- **European Service Module:** including the Multi-Purpose Crew Vehicle Safety and Engineering Review Panel analysis of the design, steps being taken for elimination or mitigation of specific zero-fault tolerant elements, and future design improvements to enhance system robustness.

NASA will closely monitor the outcome of the HEOMD Exploration Systems Development test program as it progresses and, based on the outcome of those tests, will conduct risk trades, as necessary, to ensure crew safety and achieve consensus within the NASA community on the acceptability of the design, development, and test plan. NASA will continue to provide the Panel with additional details regarding progress made and the decisions and risk trades that the Agency faces. To this end, in addition to providing status at ASAP Quarterly Meetings, NASA will offer
a special briefing in the fall of 2016 on Exploration Systems Development risk acceptance processes.

NASA's human exploration summary for 2015 included completion of three highly successful program critical design reviews and tremendous progress toward preparing hardware for our test program and our test flight. NASA looks forward to 2016 as the year of outfitting a capsule/service module, a ground launch system, and rocket systems to conduct test activities throughout the year.