

## Ares I Crew Launch Vehicle Project — Forward Plan to Preliminary Design Review

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The Exploration Launch Projects Office, located at NASA's Marshall Space Flight Center, conducted the Ares I Crew Launch Vehicle System Requirements Review (SRR) at the end of 2006, a mere year after the project team was assembled. In Ares' first year, extensive trade studies and evaluations were conducted to refine the design initially recommended by the Exploration Systems Architecture Study, conceptual designs were analyzed for fitness, and the contractual framework was assembled to enable a development effort unparalleled in American space flight since the Space Shuttle. Now, the project turns its focus to the Preliminary Design Review (PDR), scheduled for 2008. Taking into consideration the findings of the SRR, the design of the Ares I is being tightened and refined to meet the operability, reliability, and affordability goals outlined by the Constellation Program.

As directed in NASA Procedure and Regulation (NPR) 7123, NASA Systems Engineering Procedural Requirements, the Ares I SRR examined "the functional and performance requirements defined for the system and the preliminary program or project plan and ensures that the requirements and the selected concept will satisfy the mission."<sup>1</sup> The SRR was conducted to ensure the system- and element-level design and interface requirements are defined prior to proceeding into the project's design phase. The Exploration Launch Projects Control Board convened on December 19, 2006, and accepted the findings of the SRR and the go-forward plan proceeding to PDR. Based upon these findings, the Ares project believes that operability must drive the vehicle's design, and that a number of design challenges, including system mass and reliability, must be addressed as part of the progress to PDR.

The Ares I SRR addressed the following success criteria:

- The resulting overall concept is reasonable, feasible, complete, responsive to the mission requirements, and consistent with system requirements and available resources.
- Project utilizes a sound process for the allocation and control of requirements throughout all levels, and a plan has been defined to complete the definition activity within schedule constraints.
- Requirements definition is complete with respect to top-level mission requirements, and interfaces with external entities and between major internal elements have been defined.
- Requirements allocation and flow-down of key driving requirements have been defined down to subsystems.
- Systems and subsystem design approaches and operational concepts exist and are consistent with the requirements set.
- The requirements, design approaches, and conceptual design will fulfill the mission needs within the estimated costs.
- Preliminary approaches have been determined for how requirements will be verified and validated down to the subsystem level.
- Major risks have been identified and viable mitigation strategies have been defined.

The objective of the Ares I PDR is to provide a solid set of design-to specifications, preliminary designs, and verification plans to take the design forward into the final design phase of the project. The SRR demonstrated that the Constellation Architecture Requirements Document (CARD) requirements have been properly analyzed, functionally decomposed, allocated, validated, and assure that the CLV System Requirements Document (SRD) is clear, achievable, responsive, and appropriate to fulfill the mission needs.<sup>3,4</sup> The PDR will demonstrate that the hardware design is capable of meeting those vetted requirements, as well as satisfy issues of cost, operability, and availability of the system.

As is shown in Fig. 1, the Ares I Project is making measurable progress according to the systems engineering practices followed by NASA to ensure integration among major organizational elements, as well as between hardware and software elements. The Exploration Launch Projects Office will provide further details about the progress towards the Ares I PDR in the paper that follows.

Project Phases	Formulation				Implementation					
	Pre-Phase A: Advanced Studies	Phase A: Preliminary Analysis	Phase B: Definition		Phase C: Design	Phase D: Development		Phase E: Operations		
Major Reviews	Mission Feasibility	Mission Definition	System Definition	Preliminary Design	Final Design	Fabrication & Integration	Preparation for Deployment	Deployment & Operational Verification	Mission Operations	Disposal
Products	<ul style="list-style-type: none"> <li>- Study Plan</li> <li>- Mission Goals and Objectives</li> <li>- Mission Concepts</li> <li>- Operations Concepts</li> <li>- Feasibility Assessment</li> </ul>	<ul style="list-style-type: none"> <li>- System Engineering Mgt. Plan</li> <li>- Information Management Plan</li> <li>- Eng. Master Plan/Master Schedule</li> <li>- Risk Management Plan</li> </ul>	<ul style="list-style-type: none"> <li>- System Concept &amp; Architecture</li> <li>- System Specification</li> <li>- Interface Requirements</li> </ul>	<ul style="list-style-type: none"> <li>- Work Breakdown Structure</li> <li>- Design-to-Specifications</li> <li>- Drawing Tree/Eng. Drawing List</li> <li>- Verification Plans</li> </ul>	<ul style="list-style-type: none"> <li>- Manufacturing Plan</li> <li>- Build-to-Specifications</li> <li>- Integrated Schematics</li> <li>- Launch Operations Plan</li> </ul>	<ul style="list-style-type: none"> <li>- Operations Plan</li> <li>- Operations Procedures</li> <li>- In-Flight Checkout Plans</li> <li>- Verification Data</li> </ul>	<ul style="list-style-type: none"> <li>- Certification of Flight/Launch Readiness</li> <li>- Operations Data</li> <li>- Go/No-Go Criteria</li> </ul>	<ul style="list-style-type: none"> <li>- Operational Evaluations Results</li> <li>- Problem/Failure Reports</li> <li>- Technical Manuals &amp; Data</li> <li>- Trained Personnel</li> </ul>	<ul style="list-style-type: none"> <li>- Mission Products</li> <li>- Sequential Production</li> <li>- Replacement &amp; Upgrades</li> </ul>	<ul style="list-style-type: none"> <li>- Disposed or Decommissioned Items</li> </ul>

Fig. 1. Ares I progress according to systems engineering plan.

## References

1. National Aeronautics and Space Administration, *NASA Systems Engineering Procedural Requirements*, NASA NPR 7123.1.
2. National Aeronautics and Space Administration, *Exploration Launch Projects Systems Engineering Management Plan, October 2006*.
3. National Aeronautics and Space Administration, *Constellation Architecture Requirements Document, 2006*.
4. National Aeronautics and Space Administration, *Crew Launch Vehicle System Requirements Document, 2006*.