Hardware and Programmatic Progress on the Ares I-X Flight Test

Stephan R. Davis, Ares I-X Deputy Manager, Flight Test Vehicle
Ares Projects Office
Marshall Space Flight Center
Huntsville, AL 35812

Abstract

In less than two years, the National Aeronautics and Space Administration (NASA) will execute the Ares I-X mission. This will be the first flight of the Ares I crew launch vehicle; which, together with the Ares V cargo launch vehicle (Figure 1), will eventually send humans to the Moon, Mars, and beyond. As the countdown to this first Ares mission continues, personnel from across the Ares I-X Mission Management Office (MMO) are finalizing designs and, in some cases, already fabricating vehicle hardware in preparation for an April 2009 launch. This paper will discuss the hardware and programmatic progress of the Ares I-X mission.

Figure 1. The Ares V Cargo Launch Vehicle (left) and Ares I Crew Launch Vehicle (right) will form the backbone of America's new space fleet. (NASA artist's concept)

Ares I and Ares V are the first new human-rated launch vehicles NASA has developed in over 30 years. Ares I will begin its initial operating capability of flying up to six astronauts to the International Space Station (ISS) no later than 2015. Ares V will be operational in the 2020 timeframe. In a typical lunar mission scenario, Ares V will launch first. Ares V's first stage propulsion will consist of two five-segment solid rocket boosters (SRBs) attached to a core stage comprising five commercial liquid hydrogen/liquid oxygen (LH_2/LOX) RS-68 engines. These propulsion elements will loft the Earth departure stage, which carries the lunar lander, into low Earth orbit (LEO), where it will await the arrival of Orion crew exploration vehicle aboard the Ares I. The Ares I first stage consists of a single five-segment SRB. Once the first stage is expended and jettisoned, the LH_2/LOX J-2X upper stage engine will ignite to take Orion into rendezvous orbit. The Ares I upper stage is then expended. After Orion docks with the lunar lander, the Earth departure stage's J-2X engine will ignite a second time for a trans-lunar injection (TLI) burn, and then it is off to the Moon.

The remainder of the mission is performed by the Orion and the lunar lander, with Orion remaining in lunar orbit autonomously while the crew descends to the Moon in the lander. Once the mission is completed, the crew return to lunar orbit to rendezvous with and transfer to Orion, and the lander is expended. The crew of four will return safely to Earth in the Orion Crew Module.

Like the Apollo program, the Ares launch vehicles will rely upon extensive ground, flight, and orbital testing before sending the Orion into space with humans on board. The first flight of Ares I, designated Ares I-X, will be a suborbital development flight test. Ares I-X gives NASA its first opportunity to gather critical data about the flight dynamics of the integrated launch vehicle stack; understand how to control its roll during flight; better characterize the severe stage separation environments that the upper stage engine will experience during future operational flights; and demonstrate the first stage recovery system. NASA also will begin modifying the launch infrastructure and fine-tuning ground and mission operations, as the agency makes the transition from the Shuttle to the Ares/Orion system.

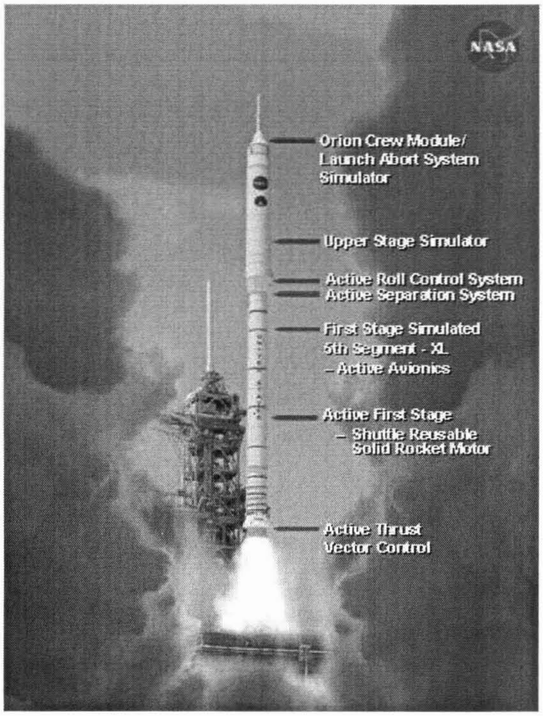

Figure 2. The Ares I-X Flight Test Vehicle incorporates both flight-like and mass simulator hardware.

Lean Practices in Ares I-X

The Ares I-X Flight Test Vehicle (FTV) will incorporate a mix of flight and mockup hardware, reflecting a configuration similar in mass and weight to the operational vehicle. It will be powered by a four-segment SRB, which is currently in Shuttle inventory, and will be modified to include a fifth, spacer segment that makes the booster approximately the same size and weight as the five-segment SRB.

The Ares I-X flight profile will closely approximate the flight conditions that the Ares I will experience through Mach 4.5, at an altitude of about 130,000 feet and through maximum dynamic pressure ("Max Q") of approximately 800 pounds per square foot. Basing vehicle design refinements on Ares I-X information puts NASA one step closer to full-up "test as you fly" scenarios; each future flight will be staged to affect future milestone reviews. Ares I-X supports the Ares I Critical Design Review (CDR).

In late April and early May 2007, managers from across the Agency met at Langley Research Center (LaRC) to discuss how to implement Lean processes to the Ares I-X test flight. The need for a Lean effort was identified, in part, because different levels of the Ares I-X organization had conflicting notions about what level of safety to apply to a one-time uncrewed test of a prototype Ares I vehicle. As a result of this meeting, the various elements performing Ares I-X activities were unified under one Mission Manager reporting to the Constellation Program (CxP) Office, thereby reducing the amount of bureaucracy. Further, to reduce decision-making and approval times, the Ares I-X Mission will reduce its number of independent review boards from 10 to 4. These organizational changes are necessary if Ares I-X is going to react quickly and achieve its April 2009 launch date.

Following the decision to establish the Ares I-X MMO, the team held a series of meetings to apply the Lean philosophy to their hardware development processes. The goal of this "leaner" effort was to incorporate 60 calendar days of additional margin into the overall flight test schedule. The effort was successful in that most development plans have 60 days of schedule margin.

Design and Fabrication Progress

While these Lean events were being completed, work also continued on the Ares I-X design and hardware fabrication. All of the individual elements will undergo CDRs in autumn 2007 and winter 2008, followed by an integrated vehicle CDR planned for February. The various vehicle elements, discussed below, are on schedule to begin deliveries to Kennedy Space Center (KSC) in the August-September 2008 timeframe.

First Stage (FS)

With a four-segment SRB available from the Space Shuttle inventory, the FS team is focusing on building the new forward structures that connect the booster to the Upper Stage Simulator (USS). These structures—the Forward Skirt, Forward Skirt Extension, Aeroshell, Frustum, and Interstage—are high-durability "battleship" hardware, and ended up being much heavier than originally anticipated. Because of this weight and the weight of the Interstage, the separation plane between the FS and the USS was lowered from above the Interstage to just below the Frustum. In addition, the Booster Deceleration Motors (BDMs) that move the FS away from the USS after separations were moved to the aft skirt. These changes were implemented to reduce the possibility of the FS striking the J-2X upper stage engine on future flights.

Because the five-segment SRB will be heavier than the four-segment booster used for the Space Shuttle, APO is testing new parachutes to accommodate the additional loads. So far, APO has conducted successful drop tests of the ten-foot-wide pilot parachute and 150-foot main parachute at Yuma Proving Ground. Ares I-X itself will serve as the first operational test of the new parachutes.

Upper Stage Simulator (USS)

The USS is being designed and built at Glenn Research Center (GRC) in Ohio. Because of GRC's limited high-bay space and the need to transport flight hardware by barge once it is completed, the USS is being built in a series of 11 smaller "tuna can" segments, which will be stacked and integrated at KSC.

Launch Complex 39B will be needed as a launch-on-demand contingency for the Hubble servicing mission in 2008. As a result, there will not be time to modify it for Ares use. To compensate, each of the individual "tuna cans" will have a set of platforms and stairs for workers built inside to access avionics while on the launch pad. As part of the Lean activities designed to achieve the 60-day schedule pull-back, installations for much of the less sensitive wiring and avionics will be done on the USS segments at GRC and then completed at KSC.

Final design reviews are being concluded for the more complex segments, such as the Interstage, and fabrication has begun for some of the simpler segments. Two complete "pathfinder" units have already been manufactured and test-stacked at GRC.

Roll Control System (RoCS)

As the FTV flies upward, it will tend to roll around its direction of forward motion. To counteract this, the FTV will have an active RoCS on the Interstage to keep the vehicle from rolling. The RoCS also initiates a 90-degree roll soon after liftoff to properly orient the FTV for flight. To handle this pulsing duty cycle, the MMO is using axial engines harvested from Peacekeeper missiles that were due to be decommissioned and destroyed as part of an arms control agreement. The MMO has harvested five sets of fuel tanks and engines, which are to be used for a variety of purposes, including duty cycle testing at White Sands Testing Facility, tanking and de-tanking tests at KSC, and finally as flight hardware. With much of the engine hardware already assembled, the primary effort of the RoCS team will be to design and fabricate the structures enclosing the engines within the Interstage. This activity is still undergoing a Critical Design Review (CDR).

Avionics

The Ares I-X avionics hardware is undergoing development and testing. This is possible because the avionics system will use a combination of avionics components from the Atlas V Evolved Expendable Launch Vehicle (EELV) and heritage Space Shuttle systems. The avionics system will employ the aircraft-qualified Development Flight Instrumentation (DFI) from several sources, including the Boeing 787 series and the U.S. Air Force Joint Strike Fighter (JSF) to collect, transmit, and store the data vital for a successful test flight.

The avionics hardware for this flight is not required to be extensible to Ares I; it is for test purposes. However, the guidance and control algorithm will be based on the one used for Ares I. Testing of the Guidance, Navigation, and Control (GN&C) algorithms is a primary objective of the Ares I-X flight test.

While the hardware is mostly commercial-off-the-shelf, the avionics team is starting to map out the physical location and arrangement of the controller boxes as well as cabling within the FTV. The work receiving the most attention at present is the only new piece of avionics on the Ares I-X mission, the Ascent Thrust Vector Controller (ATVC) system. Because the FTV is using avionics from a liquid-fuel rocket, the system must be modified to control the solid-fuel SRB. The ATVC acts as the translation tool between these two systems (Figure 8).

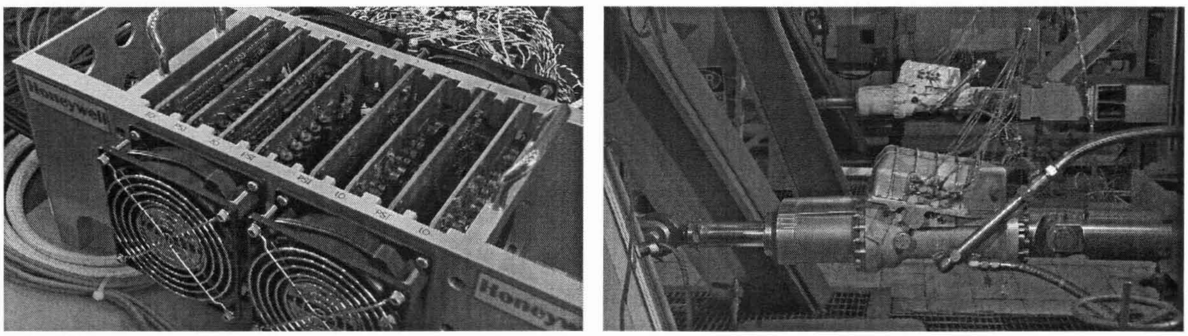

Figure 3. Pictures of the Ascent Thrust Vector Controller (left) and SRB rock and tilt actuators (right).

ATVC testing was completed successfully in Marshall Space Flight Center's Solid Rocket Booster actuator lab in June. The testing went very well and demonstrated that the ATVC unit developed for the Ares I-X FTV provides all of the required functionality. In addition to the tests in the test plan, other tests were performed to characterize the end-to-end system gains and scaling factors for use in the flight control computer and for integrated vehicle testing in the Vehicle Assembly Building (VAB) at KSC.

The ground interfaces for the avionics have been established. The avionics team had a choice between using a Lockheed-Martin-provided multipurpose van (MVAN) or a customized Ground Command, Control, and Communication (GC3) unit, called a mini-GC3, embedded within the Mobile Launch Platform (MLP). The mini-GC3 unit will provide easier access to the ground-based avionics systems and enable MLP modifications to occur in parallel with Space Shuttle operations.

The Ares I-X team also will employ a Systems Integration Laboratory (SIL) that tests the avionics on the ground and fully embraces the industry best practice of "test as you fly." The SIL, provided by Lockheed Martin at their Denver facility, will be a test platform for the Ares I-X integrated avionics system testing. Lockheed completed initial integration of the SRB Thrust Vector Controller (TVC) simulator in July 2007, with final integration being completed in September 2007.

Command Module/Launch Abort System (CM/LAS) Simulator

Because Ares I-X is a test of the Ares launch vehicle only, there will be no Orion payload onboard. Instead, the CM, Service Module, Spacecraft Adapter, and LAS will be mass simulator hardware that reflects the same outer mold line as the operational Ares I vehicle. There have been changes to the shape of the Ares I since the Ares I-X design was established. As a result, the CM/LAS simulator might not have the shape of the final vehicle. However, sensors on the forward structures will enable APO engineers to obtain accurate information about aerodynamic and acoustic loads in an Ares I-like flight environment.

Summary

Ares I-X is the first step in the long journey back to the Moon and on to farther destinations. This suborbital test will be NASA's first flight of a new human-rated launch vehicle in over a generation. The Ares I-X MMO team is well on its way toward completing the vehicle's design and hardware fabrication in time for an April 2009 launch. This promises to be an exciting time for NASA and the nation, as we once again make a giant leap into the unknown.

Nomenclature

AIT = Assembly, Integration, and Test
APO = Ares Projects Office
ATVC = Ascent Thrust Vector Controller
BDM = Booster Deceleration Motor
CDR = Critical Design Review
CM = Crew Module
CoFR = Certificate of Flight Readiness
COTS = Commercial Off The Shelf
CxP = Constellation Program
DFI = Developmental Flight Instrumentation
EELV = Evolved Expendable Launch Vehicle
FITO = Flight and Integrated Test Office
FS = First Stage
FTV = Flight Test Vehicle
GN&C = Guidance, Navigation, and Control
GO = Ground Operations
GRC = Glenn Research Center
GS = Ground Systems
HMF = Hypergolic Maintenance Facility
IDA = Integrated Design and Analysis
ISS = International Space Station
JSF = Joint Strike Fighter
KSC = Kennedy Space Center
LaRC = Langley Research Center
LAS = Launch Abort System
LEO = Low Earth Orbit
LH_2 = Liquid Hydrogen
LOX = Liquid Oxygen
MLP = Mobile Launch Platform
MMO = Mission Management Office
MPSS = Main Parachute Support System
MSFC = Marshall Space Flight Center
MVAN = Multipurpose Van
NASA = National Aeronautics and Space Administration
RoCS = Roll Control System
S&MA = Safety and Mission Assurance
SE&I = Systems Engineering and Integration
SIL = Systems Integration Laboratory
SM = Service Module
SRB = Solid Rocket Booster
TLI = Trans-Lunar Injection
TVC = Thrust Vector Control
USS = Upper Stage Simulator
VAB = Vehicle Assembly Building