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THE ARES I CREW LAUNCH VEHICLE: HUMAN SPACE ACCESS FOR THE MOON AND BEYOND

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Abstract

The National Aeronautics and Space Administration (NASA)'s Constellation Program is depending on the Ares Projects to deliver the crew launch capabilities needed to send human explorers to the Moon and beyond. The Ares Projects continue to make progress toward design, component testing, and early flight testing of the Ares I crew launch vehicle (Figure 1), the United States' first new human-rated launch vehicle in over 25 years. Ares I will provide the core space launch capabilities the United States needs to continue providing crew and cargo access to the International Space Station (ISS), maintaining the U.S. pioneering tradition as a spacefaring nation, and enabling cooperative international ventures to the Moon and beyond. This paper will discuss programmatic, design, fabrication, and testing progress toward building this new launch vehicle.

Figure 1. Ares I will support crew and cargo transport for missions to the International Space Station (ISS) and exploration beyond low Earth orbit.

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Nomenclature

ADAC	Ares I Design Analysis Cycle
ARC	Ames Research Center
ARF	Aerodynamic Research Facility
ASA	Altitude Switch Assembly
CDR	Critical Design Review
DAC	Design Analysis Cycle
DM	Development Motor
EDS	Earth Departure Stage
ft.	Foot
FSW	Friction Stir Welding
GC3	Ground Command, Control, and Communications
ISS	International Space Station
IVGVT	Integrated Vehicle Ground Vibration Test
IU	Instrument Unit
k	Thousand
kg	Kilogram
klbf.	Thousands of Pounds of Force
KSC	Kennedy Space Center
LaRC	Langley Research Center
LAS	Launch Abort System
LH_2	Liquid Hydrogen
LOX	Liquid Oxygen
m	Meter
MAF	Michoud Assembly Facility
MDA	Manufacturing Demonstration Article
MLP	Mobile Launch Platform
MSFC	Marshall Space Flight Center
N	Newton
NASA	National Aeronautics and Space Administration
PDR	Preliminary Design Review
PSA	Production Simulation Article
RSRM	Reusable Solid Rocket Motor
RWT	Robotic Weld Tool
SDR	System Definition Review
sec	Seconds
SSC	Stennis Space Center
TLI	Trans-Lunar Injection
VWT	Vertical Weld Tool

Introduction

The National Aeronautics and Space Administration (NASA)'s Constellation Program is charged with delivering the crew and cargo launch capabilities needed to send human explorers to the Moon and beyond. The Ares Projects continue to make progress toward design, component testing, and early flight testing of the Ares I crew launch vehicle (Figure 2), which will form the capabilities the United States needs to launch crew and cargo to ISS, continue its pioneering tradition as a spacefaring nation, and engage in cooperative exploration beyond Earth orbit.

Figure 2. Ares I will provide the crew launch capabilities for America's space exploration effort.

2008 Accomplishments

In 2007 and 2008, the Ares team picked up the pace for designing, developing, testing, and fabricating hardware for the Ares I crew launch vehicle. This year marks a key milestone for the Ares I: the Preliminary Design Review (PDR), when the project moves from mainly paper studies to a more detailed design and fabrication of some components. The vehicle PDR is being preceded by element PDRs, which must be passed before proceeding to the integrated PDR in September 2008. The first element-level PDR—for the new J-2X engine—occurred in August 2007. The engine began its design cycle much earlier than the rest of the vehicle because it must undergo more testing than any other Ares I element. J-2X will complete its Critical Design Review (CDR) in autumn 2008. Ares was given authority to proceed with the PDR after passing its Ares System Definition Review

(SDR) in October 2007. The main requirement for the Ares I PDR will be to ensure that the launch vehicle has the performance to carry the Orion crew exploration vehicle to low Earth orbit.

First Stage

The Ares I first stage has already seen some operational hardware designed, fabricated, and tested, including new forward structures and the parachute and recovery systems, all of which will be tested on the Ares I-X flight test in 2009. Because it is based on the existing Shuttle reusable solid rocket motors (RSRMs), the first stage began its development schedule earlier to maintain the current trained workforce.

A first stage development motor, DM-1, is being manufactured by ATK Launch Systems. However, manufacturing was placed on hold until an investigation of propellant voids in a recent shuttle Flight Support Motor (FSM-15) determined a cause and resolution.

Expendability Trade Study

The first stage office completed a variety of trade studies of the Ares I first stage element, one of which was evaluating the costs and benefits of switching from reusable to expendable boosters. The overall objective of this study was to perform a life cycle cost study to evaluate using an expendable RSRM as opposed to the current reusable RSRM for the Ares I and Ares V first stage boosters. This assessment included evaluating the cost and technical impacts in development, reliability, performance and transition from a reusable to an expendable first stage solution. The study concluded that it was beneficial to continue flying recoverable boosters for Ares I.

Hardware Updates

The Ares I vehicle may use more composites than any other human-rated launch vehicle. Composites are advantageous because they offer comparable performance for less weight. In June 2007, the first stage team completed a trade study regarding the use of metal versus composite materials for the new forward structures: the forward skirt, forward skirt extension, frustum, and aeroshell (Figure 3). The study focused on reusability, ease of manufacture, structural durability, and weight. The study concluded that composites could be used most effectively for non-reusable structures (the frustum and aeroshell), while aluminum would continue to be used for the recoverable structures (the forward skirt and forward skirt extension).

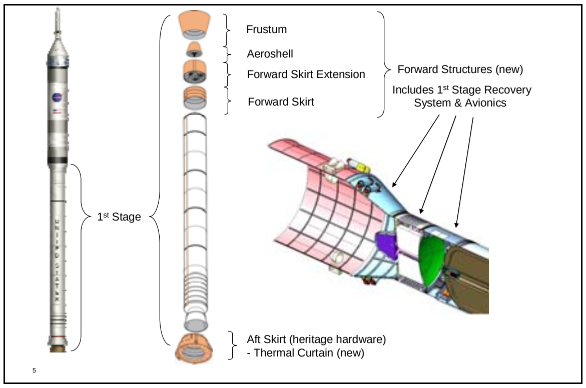

Figure 3. Ares I first stage forward structures.

ATK Launch Systems in Promontory, Utah, and their subcontractors are building process simulation articles (PSAs) to help train their work forces in building the new hardware for Ares I first stage components. PSA development enables workers to build and streamline production processes before final production-quality hardware is built (Figure 4). Processes learned and honed in this environment reduce cost and time later. Among the pieces undergoing this work are the mandrels, which are the molds around which propellant is cast for the motor segments. ATK has completed its first test pouring of motor segments around the new mandrels using inert propellant.

Figure 4. Mandrel process simulation articles are being fabricated at ATK Launch Systems.

Manufacturing is underway for the forward structures of the Ares I-X first stage element at

Major Tool in Indianapolis, Indiana, a subcontractor to ATK.

Upper Stage

In 2007, NASA completed contract awards for all the Ares I elements when the agency selected The Boeing Company of Huntsville, AL, as the prime contractor to produce the integrated upper stage and upper stage Instrument Unit (IU) at NASA's Michoud Assembly Facility (MAF) in Louisiana. Components for the upper stage will be manufactured by the prime contractor's suppliers across the country. The final integrated upper stage avionics hardware assembly and checkout will be performed at MAF. Manufacturing process development and larger assemblies may be performed at contractor facilities nationwide.

With a contractor partner on board for the NASA-designed upper stage, development and production work have begun in earnest. In addition to producing the stages, logistical and shop floor space at MAF are being reorganized to accommodate the transition from the Space Shuttle Program to the Constellation Program, and manufacturing processes and hardware are being developed and tested at Marshall Space Flight Center (MSFC) for eventual transfer to MAF.

The upper stage structure has undergone several design analysis cycles (DACs). These cycles have resulted in design changes, such as changing from separate liquid hydrogen (LH_2) and liquid oxygen (LOX) tanks to a common bulkhead between the tanks and the addition of a helium pressurization system. In addition, NASA's Marshall Space Flight Center (MSFC) has taken delivery of a friction stir welding tool, which will be instrumental in developing manufacturing processes for the upper stage and for manufacturing upper stage test articles. One goal of these new tools is to produce an upper stage with fewer seams and welds to reduce defects or structural stresses.

The upper stage PDR is scheduled to be complete in August 2008.

Upper Stage Engine

The Ares I J-2X Upper Stage Engine is the first exploration-class rocket engine built for a human-rated rocket since the Shuttle Main Engine was developed in the 1970s. It is on the critical path for the vehicle, meaning that it must complete a series of tests to be qualified for flight. This rigorous testing means the J-2X must stay ahead of the rest of the vehicle's development. The engine is being designed to start at altitude and operate for approximately 500 seconds to put Orion into orbit. However, the engine also will be used on the Ares V cargo launch vehicle's Earth departure stage (EDS) to place the EDS and Altair lunar lander into orbit and then restart to execute trans-lunar injection (TLI) before final shutdown. The engine's requirements are summarized in Figure 5 below.

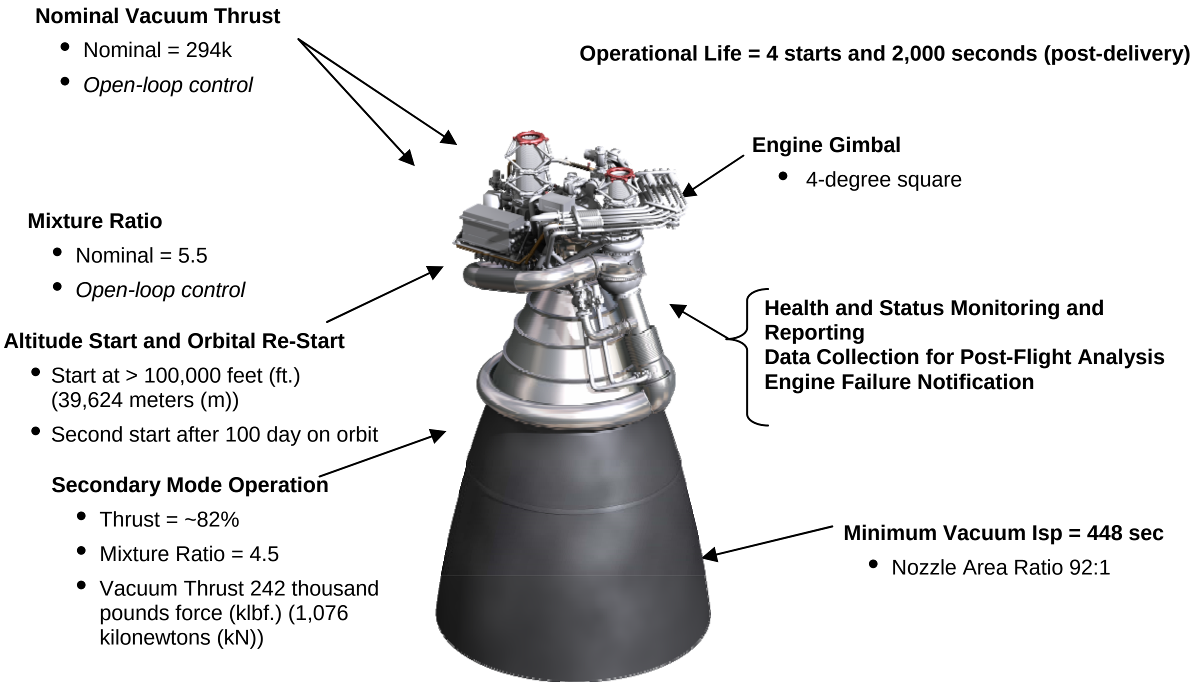

Figure 5. J-2X Key Requirements.

For the last year, the J-2X team has been designing the upper stage engine, testing the turbopump and gas generator powerpack as well as a subscale diffuser, and building a new high-altitude test stand at Stennis Space Center (SSC).

Powerpack Testing

The first J-2X powerpack test series began after the powerpack's installation on the A-1 test stand at SSC (Figure 6) in fall 2007, and finished in May 2008. The test hardware consisted of heritage J-2 turbopumps, gas generator, heat exchanger, spark igniters, helium spin start, and associated hardware from the X-33 program, as well as a heritage J-2 crossover duct and thrust chamber. The objectives of this early test series included preparation and testing of the facility, obtaining inducer flow environments and pump performance data. The 2007 turbomachinery development program also included water flow testing of existing pump inlets, a turbine air flow test, and water flow tests of the inducers, which provided insights important to planning the powerpack series.

Figure 6. Powerpack 1A during test stand installation at Stennis Space Center.

The SSC A-1 test stand underwent several months of refurbishment and modification to support J-2X testing, and the test series provided a good checkout of the facility, test operations and personnel and also informed the engine design.

When testing completed, the government/industry engine team achieved more than 1,343 seconds of powerpack operating time at power levels up to an equivalent 274,000 pounds of thrust (1,067,573 N). The next powerpack series will be in the 2010 timeframe and will employ developmental

J-2X turbomachinery instead of heritage J-2 hardware.

Vehicle Integration

The Ares Projects team has a separate element office dedicated to studying and addressing issues that encompass the entire vehicle. The Vehicle Integration function is responsible for the Ares I integrated vehicle reviews, such as the System Definition Review, which was completed in October 2007, as well as wind tunnel testing for the overall vehicle. To date, the Vehicle Integration team has completed 7,000 hours of wind tunnel testing to finalize the Ares I design.

Ares I System Definition Review

The Ares I System Definition Review (SDR) focused on the current designs for all Ares I elements and compared their predicted performance, as well as the integrated stack, against the baselined requirements. All of the Ares I elements participated in the SDR, as did the Constellation Program, and all other Constellation sister projects and field Centers involved in Ares work. The objectives of the SDR were to:

- Demonstrate that requirements allocation was complete
- Verify that the design concept/ architecture complied with requirements
- Demonstrate that a system that fulfills mission objectives can be built within the constraints imposed
- Demonstrate the system and its operation are understood well enough to proceed toward Preliminary Design Review.

Successful completion of the SDR has enabled the Ares team to progress toward the Ares I PDR, scheduled for September 2008.

1/2% First Stage Reentry Wind Tunnel Test

The first stage reentry wind tunnel test of a one-half-percent-scale model of Ares I (Figure 7) was to used to calibrate the Ares I first stage Altitude Switch Assembly (ASA) or "baroswitch," which deploys the parachute recovery system during reentry. The results will be used to support both Ares I and the Ares I-X test flight. Testing was completed at the MSFC Aerodynamic Research Facility (ARF) July through October 2007. To conduct the test, model pressure measurements were made at the location of the ASA ports for a wide range of Mach numbers (from 0.4 to 4.0) for different roll positions, and at angles of attack ranging from 90 to 180 degrees.

Figure 7. 1% scale pressure model inside the wind tunnel.

The ASA has six pressure ports attached around the first stage on the outer skin of the forward skirt extension. The wind tunnel team measured pressures at locations on the model, which will define the environment impacting the flight instrumentation. Having a more refined picture of the pressure distribution helps determine the optimal location for the six pressure ports and minimize interference from protuberances on the vehicle – primarily the systems tunnel and fairing.

The tests were conducted to verify what types of aerodynamic environments the ASAs will encounter when the first stage re-enters the atmosphere.

Stage Separation Wind Tunnel Test

This wind tunnel series is investigating the stage separation of the Ares I-X flight test vehicle. The separation event is very important because it occurs at a speed of nearly Mach 4.5. The flight of the Ares I-X will allow the design team to better understand all of the aerodynamic properties, relative motions, and other events that happen during a launch. During the separation event, the J-2X nozzle has to come out of the interstage covering it. This requires a clean separation without any side movement that could cause impact. Based on the first stage's speed, altitude, and trajectory, engineers can then determine where it will land. The Ares I-X upper stage simulator will continue upward until it falls into the ocean on a ballistic trajectory; it is not recovered. The actual Ares vehicle would then continue on, taking the astronauts to low Earth orbit.

Langley Research Center (LaRC) has wind tunnels that cover the entire speed range, from very slow subsonic to hypersonic speeds. Through all the speed regimes, Ares is trying to improve the flow of the air over a particular vehicle, reshaping the vehicle and comparing the aerodynamic data acquired in the wind tunnels with computational fluid dynamics simulations. LaRC is looking at the control algorithms for the motors that will both tumble the first stage, and control the aerodynamics of the upper stage's flight. The Ares I separation events are different from what Saturn V used for the Apollo missions, so Ares cannot simply redo exactly what the Apollo Program did; however, the team can use that historical information as a starting point in their analyses.

Other Wind Tunnel Testing

A series of wind tunnel tests at LaRC, Ames Research Center (ARC), and Boeing facilities evaluated the performance of the latest iteration of the Ares I vehicle configuration (ADAC-2B). Tests at ARC evaluated the recently designed active damper system for the Ares I configuration; the Unitary Wind Tunnel Tests performed at LaRC focus on the high speed flow (Mach 1.5 – 4.5); while the Boeing Wind Tunnel Tests focused on the low speed flow (Mach 0.5 – 1.6).

<u>Facility Upgrades</u>

In addition to design and development work on the launch vehicle, the Ares team has been building new ground facilities and refurbishing existing assets to meet the needs of Ares I and, eventually, Ares V.

A-3 Test Stand Construction

Progress was made on building the new A-3 test at the Stennis Space Center (SSC) in Mississippi. This is the first NASA test stand ever built for altitude testing. The A-3 test stand will perform development and acceptance testing safely on the J-2X engine at simulated altitude conditions for full mission duration, including testing the full range of engine gimbal angles. The A-3 stand will be used to conduct both development and certification engine testing, which are important to proving that the J-2X can ignite and operate as required at simulated altitudes of 80,000 ft. (24,384 m) to 100,000 ft. (30,480 m). The stand will inject chemically-generated steam around the test stand enclosure during engine operation to evacuate the atmospheric pressure.

A contract was awarded for the steel tower; this test stand uses more steel and less concrete than some of the existing structures at Stennis. Concrete foundations were poured for A-3 as well as for the largest chemical steam system ever built for an engine test stand. A subscale diffuser was built and tested to determine the performance of the diffuser and steam ejector designs for the new A-3 altitude simulation test stand and to alleviate or address any concerns associated with construction of the full-scale test stand.

Site clearing for A-3 began in spring 2007 within hours of approval to build the new test stand (Figure 8). By December, all the structural piles for the foundation had been driven and the concrete forms and reinforcing bars were in place to pour the foundation. In December, 300 truckloads – 3,365 cubic yards (2,572 cubic meters) – of concrete were poured over a 14-hour period. After it cured, crews poured the foundations for the chemical steam generator tanks and the gaseous nitrogen bottles in the early weeks of January 2008. Work continues on readying the foundation for the tower footings and the steel superstructure to follow (Figure 9). Simultaneously, engineering and business teams are purchasing the structural steel, preparing design packages for the docks and waterways work. The stand is scheduled to be ready for testing in late 2010.

Figure 8. The Stennis A-3 Test Stand site as it appeared in April 2008.

Figure 9. Test Stand A-3 as it will appear in an artist's conception when it is completed in 2010.

Dynamic Test Stand

Integrated Vehicle Ground Vibration Testing (IVGVT) is scheduled to begin in 2010. Facilities at Marshall Space Flight Center (MSFC) are being refurbished and modified to conduct the first full-vehicle vibration tests since 1979. The IVGVT team completed initial facility modifications to the Dynamic Test Stand, which is the same vibration test stand used for the Apollo Saturn V launch vehicle and integrated Space Shuttle stack.

The three roof panels were removed from the test stand, and the side door, which had an estimated weight of over 71 tons, was opened (lowered), as shown in Figure 10. These procedures were performed by a recently renovated 200-ton derrick crane on the roof. Completion of this effort is a key milestone in the continuing preparation of the Dynamic Test Stand for the Ares I IVGVT. The next activity will be to remove Shuttle-era platforms from the test stand to prepare for modifications later in 2008.

Figure 10. The side door was opened on Test Stand 4550 and the roof panels were removed for the first time in 29 years this past April.

Upper Stage Development Manufacturing

Marshall Space Flight Center is demonstrating a new robotic weld tool and vertical weld tool (Figure 11) to manufacture eight Manufacturing Demonstration Articles (MDAs) of aluminum-lithium gore panels, which will fit together to form the forward dome of the upper stage liquid hydrogen tank. These panels will be used for qualification welds on the robotic weld tool prior to the MDA. A successful MDA will be one where the Manufacturing & Assembly team has assessed the hardware material properties and manufacturability to a level of design confidence high enough to proceed to the Critical Design Review (CDR).

The Robotic Weld Tool (RWT) is a Friction Stir Welding (FSW) tool that will assemble different components of the Ares I Upper Stage in the same manner developed for the Shuttle's External Tank program. The RWT is accompanied by a Process Development System (PDS), which performs panel-level development, testing panels 24 inches (~.61 m) to 26 inches (~.66 m) long before actual hardware is welded in the RWT. The PDS will be used to weld test panels, develop welding process parameters, and troubleshoot welding issues from the larger RWT, also installed at MSFC. The PDS was delivered in late August 2007.

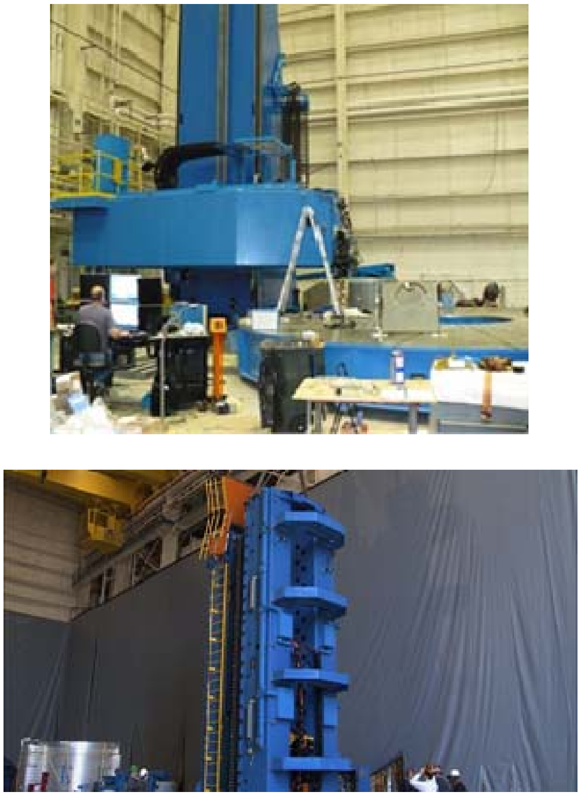

Figure 11. The Ares Projects' Robotic Weld Tool (top) and Vertical Weld Tools (bottom) are now in place to begin testing upper stage manufacturing processes at MSFC.

The Vertical Weld Tool (VWT) will perform longitudinal barrel welds, used to join several panels together into a barrel section of a tank. This tool, along with the robotic weld tool, provides Ares with an on-site, world-class welding facility that will allow the project to test processes and materials prior to fabricating flight hardware at Michoud. The VWT also will be used to help build upper stage structural development test articles at MSFC. The VWT uses a large anvil and conventional Friction Stir Welding (FSW) technology. Major components began arriving in December 2007, with system checkout currently ongoing.

Upcoming Activities for 2009

Several element-level reviews and tests will be conducted in the next year as Ares I prepares for its CDR in 2010.

Ares I-X Test Flight

Perhaps the most visible Ares-related activity in 2009 will be the Ares I-X flight test, which will provide the first flight test opportunity for the Ares I design, demonstrate some of its new ground processes, and provide useful data to inform the vehicle CDR.

The Ares I-X mission is an uncrewed development test flight that will demonstrate the new Ares I crew launch vehicle's flight characteristics; separation, ground, launch, and recovery operations; and roll torque moments. The flight's mission is deliberately designed to obtain important data that cannot be easily obtained through ground test or simulations.

The mission will use a combination of existing, simulator, and off-the shelf hardware to build the vehicle on a relatively short timeline. The Ares I-X vehicle's first stage will consist of an active 4-segment SRB from the Space Shuttle inventory, along with a fifth spacer segment to resemble the full height of the Ares I.

The first stage forward structures, upper stage, Orion crew exploration vehicle, and launch abort system (LAS) will be mass simulator hardware that matches the outer mold line of the operational vehicle (Figure 12).

Figure 12. Ares I-X will be the first flight test of the Ares I crew launch vehicle configuration.

Ares I-X is still on schedule to meet its delivery dates to Kennedy Space Center (KSC). Some of the first stage hardware is already at KSC, and many other hardware components will arrive at the launch complex starting in autumn 2008, continuing through early 2009. The mission's stacking, integration, and testing activities might be adjusted based on the availability of the Mobile Launch Platform (MLP) assigned to Launch Complex 39B, which must be modified to incorporate Ares I-X Ground

Command, Control, and Communications (GC3) hardware.

The Ares I-X successfully passed its CDR in July 2008 at Langley Research Center (LaRC) in Hampton, VA.

First Stage Demonstration Motor (DM-1) Test

The first five-segment solid rocket motor for the Ares vehicles will be tested at ATK Launch Systems' in Promontory, Utah, static test stand in 2009. This static test will measure burn duration, thrust, and other critical data that will be used to design subsequent development motors. The first flight of a five-segment motor will be the Ares I-Y flight test in 2013. Production issues will cause a slight delay in the static test date for DM-1, but his should not impact NASA's ability to meet any of the major program/project milestones, including CDR or the Ares I-Y flight. This will be the first time a motor designed for Ares I has been fired. A static firing of a five-segment motor was conducted successfully in October 2003, but in the Space Shuttle configuration.

First Stage Thrust Oscillation

During the design analysis cycle leading to the Systems Definition Review (SDR), NASA identified a potential problem with thrust oscillation, which is created by resonant burning common to all solid rocket motors. In November 2007 NASA chartered the Thrust Oscillation Focus Team (TOFT) to define the extent of, and determine mitigation strategies for, Ares I thrust oscillation. In August 2008, the Constellation Program selected a set of design mitigations that will reduce accelerations on the crew to 0.25 g's – which is the best understanding today of the required performance level.

The solution set is focused on changes to the first stage that actively absorb the oscillations. The team will continue designing actively controlled, tuned mass absorbers for the first stage aft skirt. In addition, the team is exploring a passive compliance structure in the frustum/interstage region which will aid in detuning the stack and provides extra margin. Additional data on thrust oscillation will be collected during upcoming centrifuge tests to better characterize the crew performance requirement as well as during flight tests of the Space Shuttle and Ares I-X.

Summary

The Ares Projects are making great strides toward building a new generation of launch vehicles to support International Space Station (ISS) operations and—most importantly—human exploration of the Moon, Mars, and other destinations. With the first Ares I flight test in 2009 and additional testing and development work in progress, the Ares I crew launch vehicle continues on schedule to fulfill this strategic capability. Ares I will develop in an environment of increasing challenges, as the agency transitions from performing space operations to the more complex, exciting, and dangerous job of expanding the nation's frontiers.

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National Aeronautics and Space Administration

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2009 International Astronautical Conference

The Ares I Crew Launch Vehicle: Human Space Access for the Moon and Beyond

www.nasa.gov

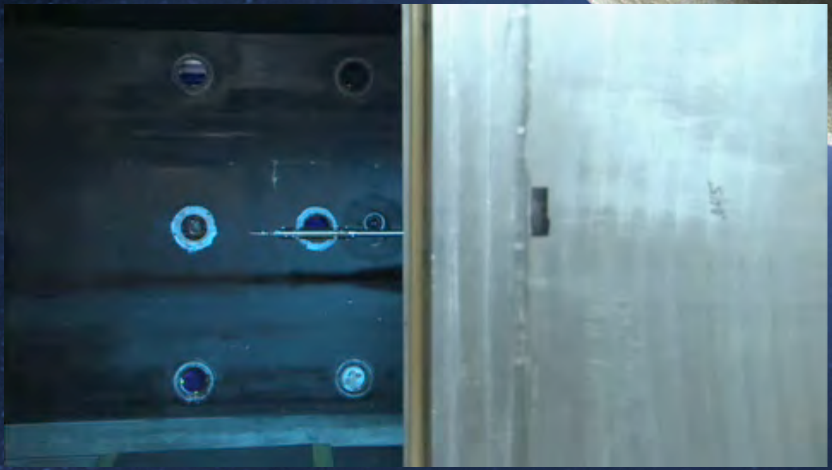
Projects Overview

- **Deliver crew and cargo for missions to International Space Station (ISS) and to Moon and beyond**
- **Continuing progress toward design, component testing, and early flight testing**
- **Ares I Crew Launch Vehicle**
  - Will carry 6 crew to ISS, 4 to Moon
  - First flight test 2009
  - Initial Operational Capability 2015
- **Ares V Cargo Launch Vehicle**
  - Will launch Earth Departure Stage (EDS) and Altair lunar lander to low Earth orbit for lunar missions
  - Largest launch vehicle ever designed
  - Will begin detailed development work in 2011

Fly Thru Movie Here

Vehicle Integration Accomplishments

Ares 4% Model Aeroacoustices Wind Tunnel Test
Ames research Center, CA



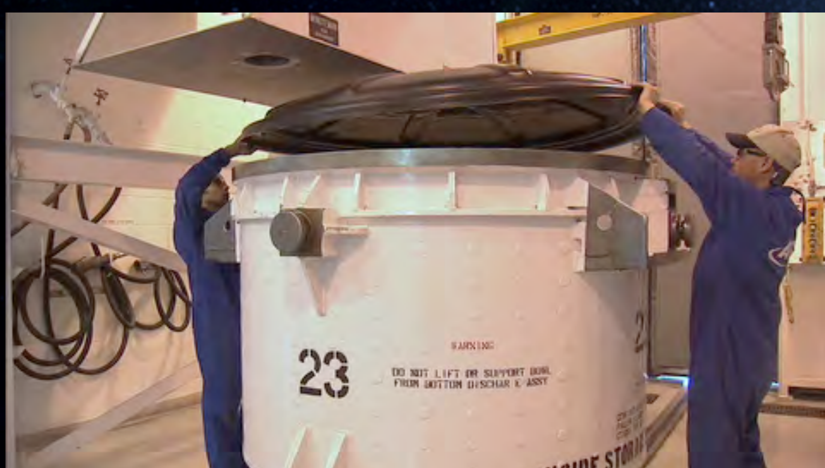
Ares 1% Model Transonic Wind Tunnel Test
Langley Research Center, VA

Dynamic Test Stand Renovations
Marshall Space Flight Center, AL

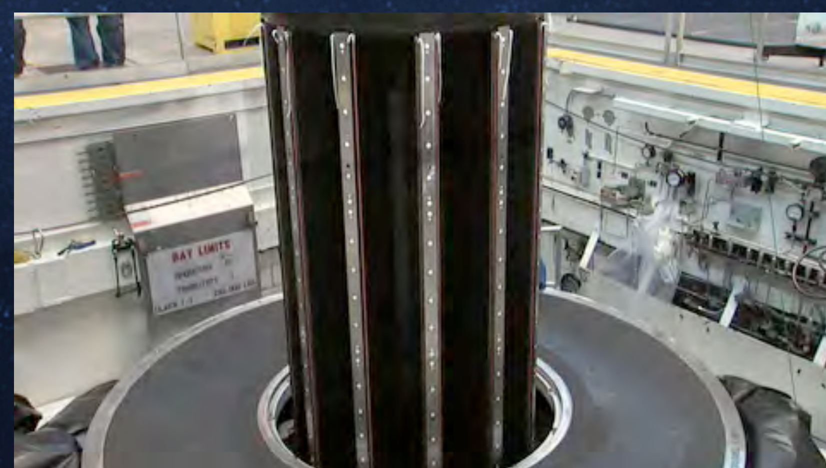
First Stage Accomplishments

First Stage DM-1 Nozzle Fabrication
Promontory, UT

First Stage Fin Installation and Removal Testing
Promontory,UT



First Stage Forward Segment Propellant Casting
Promontory, UT

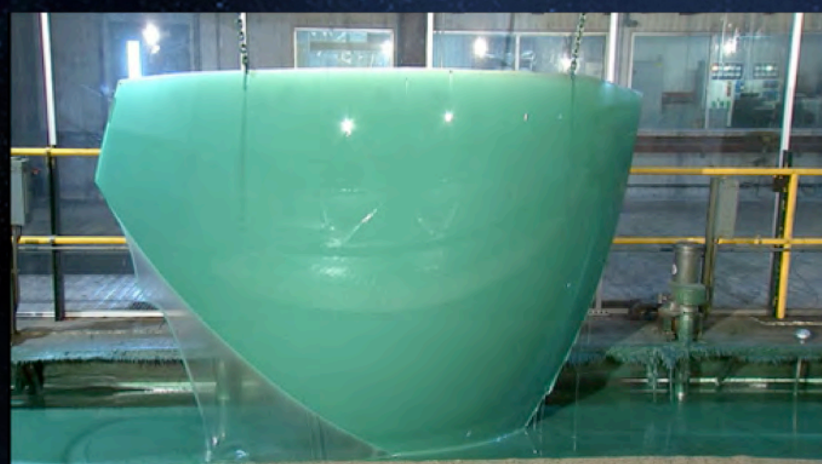


First Stage Forward Core Fin Removal
Promontory, UT

Upper Stage Accomplishments

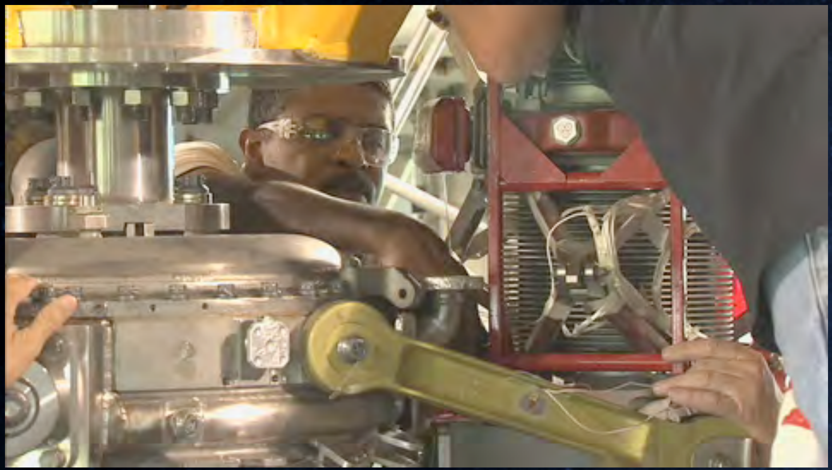
DELMIA Simulation of Interstage Mock-Up
Marshall Space Flight Center, AL

MPTA Manufacturing Process with DELMIA Simulation Overlays
Marshall Space Flight Center, AL



Dome Gore Panel Chemical Milling
Los Angeles, CA

Upper Stage Engine Accomplishments



J-2X Powerpack Removal from A-1 Test Stand
Stennis Space Center, MS

J-2X Workhorse Gas Generator Manufacturing
Canoga Park, CA

J-2X Workhorse Gas Generator Test Firing
Marshall Space Flight Center, AL

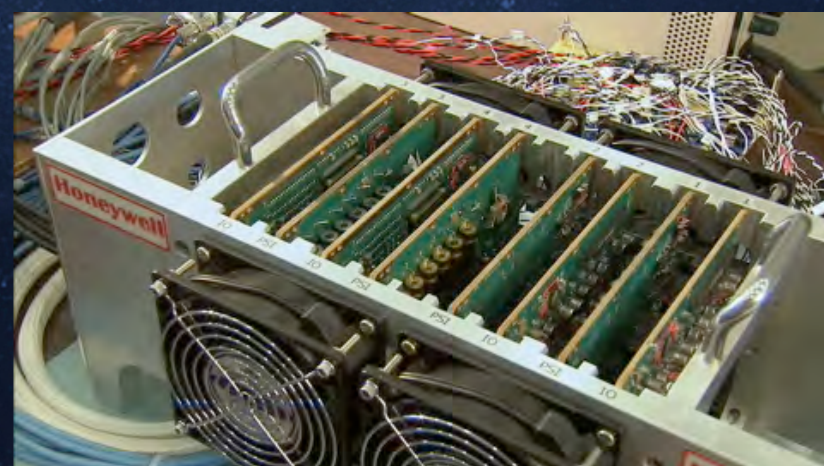
E3 Subscale Diffuser Test
Stennis Space Center, MS

Ares I-X Accomplishments

Upper Stage Simulator Assembly
Glenn Research Center (GRC), OH

Roll Control System Test and Fabrication
Huntsville, AL and WSTF, NM

Forward Frustum Fabrication
Indianapolis, IN

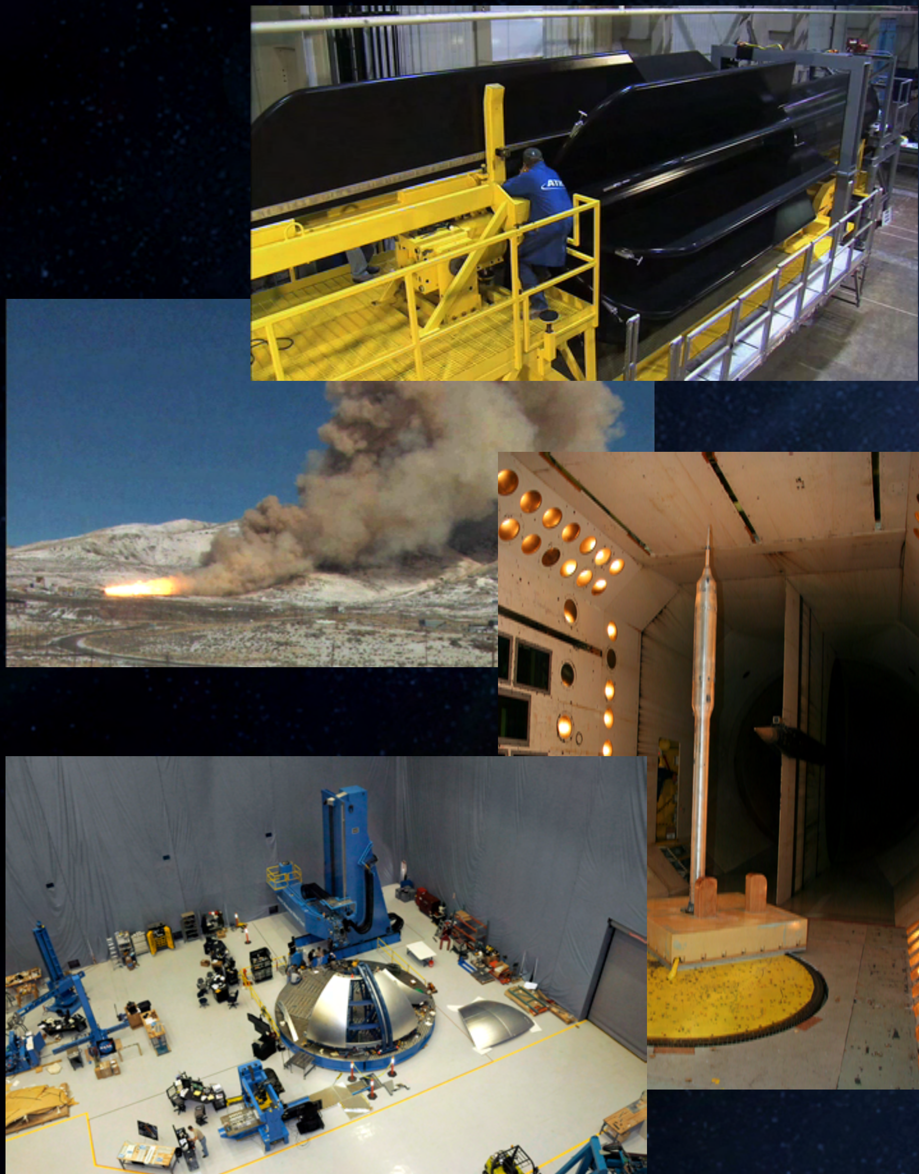


First Stage Actuator Systems Testing
Marshall Space Flight Center (MSFC), AL

Ares I-X Test Flight

- First Ares I flight test (uncrewed)
- Will demonstrate ascent, separation, roll control, recovery, and ground capabilities
- Uses off-the-shelf, active, and simulator hardware
  - First stage propulsion, avionics, and roll control active systems
  - First stage forward structures, upper stage, Orion crew exploration vehicle, and Launch Abort System (LAS) instrumented mass simulator hardware
- Holding flight hardware deliveries to April 2009 launch date
- Launch date could be delayed due to availability of Mobile Launcher

Upcoming Activities



- Completion of J-2X Critical Design Review
- Completion of Upper Stage Liquid Hydrogen Tank Manufacturing Demonstration Article
- Test of aeroelastic 4% wind tunnel model
- First 5-segment solid rocket motor for Ares vehicles will be tested at ATK Launch Systems
  - Hardware already in fabrication
  - Shuttle processes improved for safety and efficiency
  - Data from test will inform future 5-segment motor designs

Summary

- Ares Projects making great strides toward building a new generation of launch vehicles
- Support ISS operations and human exploration of Moon and other destinations
- Ares I-X flight test in 2009
- Additional testing and development work in progress
- Ares launch vehicles continue on schedule to fulfill this strategic capability for the future
- Capabilities will develop in environment of increasing challenges
- NASA transitioning from performing space operations to expanding the Nation's frontiers

Questions?

www.nasa.gov/ares