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TECHNICAL PROGRESS ON THE ARES I-X FLIGHT TEST

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ABSTRACT

Ares I-X will be NASA's first test flight for a new human-rated launch vehicle since 1981, and the team is well on its way toward completing the vehicle's design and hardware fabrication for an April 2009 launch. This uncrewed suborbital development test flight gives NASA its first opportunities to: gather critical data about the flight dynamics of the integrated launch vehicle; understand how to control its roll during flight; better characterize the stage separation environments during future flight; and demonstrate the first stage recovery system. The Ares I-X Flight Test Vehicle (FTV) incorporates a mix of flight and mockup hardware. It is powered by a four-segment solid rocket booster, and will be modified to include a fifth, spacer segment; the upper stage, Orion crew exploration vehicle, and launch abort system are simulator hardware to make the FTV aerodynamically similar to the same size, shape, and weight of Ares I. The Ares I-X first stage includes an existing Shuttle solid rocket motor and thrust vector control system controlled by an Ascent Thrust Vector Controller (ATVC) designed and built by Honeywell International. The avionics system will be tested in a dedicated System Integration Laboratory located at Lockheed Martin Space Systems (LMSS) in Denver, Colorado. The Upper Stage Simulator (USS) is made up of cylindrical segments that will be stacked and integrated at Kennedy Space Center (KSC) for launch. Glenn Research Center is already building these segments, along with their internal access structures. The active Roll Control System (RoCS) includes two thruster units harvested from Peacekeeper missiles. Duty cycle testing for RoCS was conducted, and fuel tanking and detanking tests will occur at KSC in early 2008. This important flight will provide valuable experience for the ground operations team in integrating, stacking, and launching Ares I. Data from Ares I-X will ensure the safety and reliability of America's newest launch vehicle.

INTRODUCTION

Since 2004, NASA has been committed to executing the U.S. Space Exploration Policy, which tasked the agency to complete the International Space Station, retire the Space Shuttle, and develop new launch vehicles capable of providing human access to low-Earth orbit, the Moon, and beyond. The Ares Project, based at Marshall Space Flight Center in Huntsville, Alabama, is responsible for building the Ares I crew launch vehicle and Ares V cargo launch vehicle to fulfill this new, ambitious mission (Figure 1). The first test flight of Ares I is being conducted by the Ares I Mission Management Office in April 2009.

Figure 1. Ares V (left) and Ares I (right) will be America's premier exploration vehicles for the next generation

RESULTS AND DISCUSSION

A. ARES I-X: THE MISSION AND FLIGHT TEST VEHICLE

The Ares I-X mission will be NASA's first flight test of a new human exploration vehicle since 1981. As such, it returns the agency to its history as a pioneering organization, taking on risks to develop new space hardware. The flight is also important because it will provide crucial flight data that will inform the Ares I Critical Design Review in 2010. The specific, five primary test objectives for the Ares I-X flight test include:

Figure 2. Ares I-X marks the beginning of America's next generation of human exploration

- Demonstrating the ascent flight control system performance with dynamically similar hardware.
- Characterizing and mitigating the roll torque due to first stage (FS) motor performance for a vehicle that is dynamically similar to the operational vehicle.
- Demonstrating nominal first and upper stage separation and clearances.
- Testing the first stage parachute recovery system and separation/entry dynamics.
- Validating assembly and processing flow, as well as launch and recovery operations.

These objectives are all attainable using a combination of existing flight hardware and simulator hardware equipped with environmental, acceleration, and other sensors.

The Ares I-X flight test vehicle (FTV) will include a four-segment Reusable Solid Rocket Booster (RSRB) already in the Space Shuttle inventory; a fifth spacer segment to match the mass and length of the Ares I first stage; new forward structures to connect the first stage to the upper stage, and a simulator upper stage, Orion crew exploration vehicle, and launch abort system.

The flight of Ares I-X will take the vehicle up through first stage firing and separation, which occurs at an altitude of 130,000 feet and 125 nautical miles downrange. As the first stage booster begins its recovery reentry and sequence, the USS will continue to fly in a ballistic arc up to an altitude of 150,000 feet before falling into the Atlantic. It will not be recovered. Flight data will be captured via telemetry transmitted to ground stations as well as data recorders aboard the FTV first stage. The data recorders will be recovered using existing practices for recovering solid rocket boosters.

The Ares I-X test flight also features a new recovery system, including new main parachutes. The new main chutes are 150 feet across, compared to 136 feet across for the Shuttle. Ares I-X will be the first flight test of new main parachutes for Ares I.

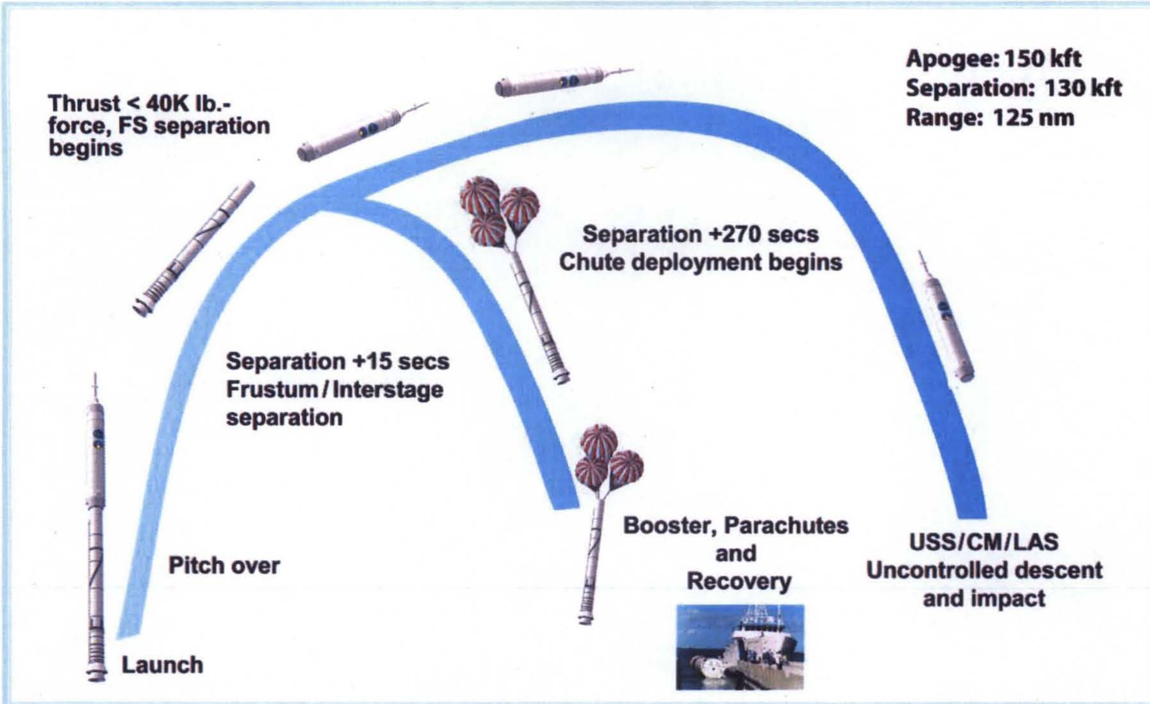


Figure 3. The Ares I-X flight will not have a crew aboard, but its flight profile closely resembles the early Mercury flights of the 1960s

Primary development work for the first stage (Figure 4) will concentrate on the new forward structures: the spacer segment, which will house the first stage avionics, forward skirt, forward skirt extension, and frustum. For the flight test, the forward skirt extension and frustum will be over-designed "battleship" hardware. The aft skirt will be modified Shuttle hardware. Additional booster deceleration motors (BDMs) have added to the skirt to ensure that the first stage disengages from the upper stage axially instead of laterally, as during a Shuttle flight. There will be a total of eight BDMs on the Ares I-X aft skirt, Ares I will have ten.

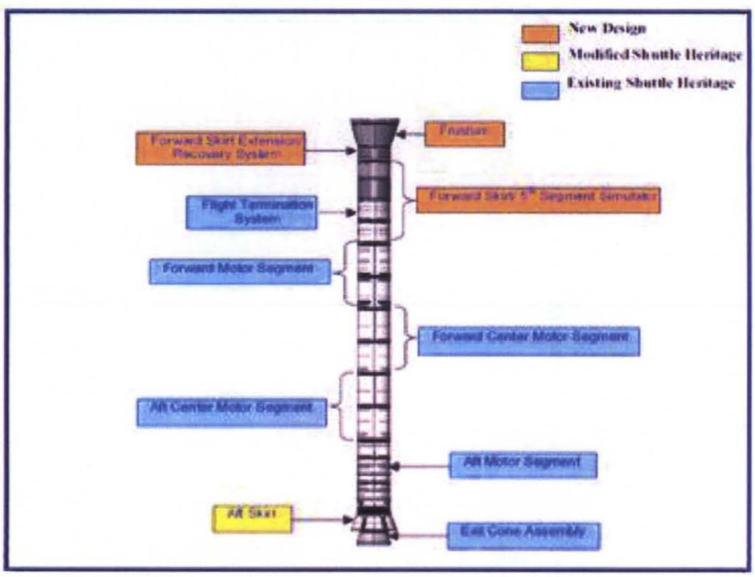


Figure 4. The Ares I-X first stage will rely on both heritage and simulator hardware to accomplish its part of the mission

Ares I-X provides the first opportunity to test new assembly, integration, and test (AIT) functions at Kennedy Space Center (KSC). When vehicle elements begin arriving at KSC in September, they will be moved to the RSRB Assembly and Refurbishment Facility (ARF), where developmental flight instrumentation (DFI) will be integrated and the upper stage simulator (USS) segments will be stacked in smaller "super stacks" before being moved to the Vehicle Assembly Building (VAB) for final assembly of the vehicle.

Ares I-X will be launched from KSC Launch Complex (LC) 39B, which will be used as a backup launch-on-demand facility for the Shuttle during the servicing mission (STS-125) in August 2008. Once STS-125 is completed, LC 39B will be transferred to the Ares Project for use on the flight test. Because of its Shuttle-ready state, LC 39B will need to be modified slightly to support Ares I-X until a full tear-down and redesign of the complex can be performed in 2010-2013. Additional access bridges and a sway damper will be added to the Mobile Launch Platform (MLP) to accommodate the much taller Ares I-X vehicle (328 feet tall vs. the Shuttle, which stands 184 feet). In addition, the Ares I-X USS will include a series of stairs, ladders, and ring-shaped platforms to allow Ground Operations personnel to access the interior of the vehicle prior to launch. The ground support systems also includes an environmental control system (ECS) to keep the avionics cool prior to liftoff. The ECS will have a T-0 disconnect connection between the ground systems and the Flight Test Vehicle (FTV), which remains intact until the FS ignition command (T-0) is issued.

B. ARES I-X HARDWARE ELEMENTS AND PROGRESS

The Ares I-X mission was authorized to proceed in spring 2006. Given its rapid development cycle, hardware design and manufacturing have had to occur nearly simultaneously in order to meet the launch date. Thus, while the Critical Design Review (CDR) occurs in March 2008, much of the flight hardware is already well on the way through the fabrication process.

First Stage

As noted earlier, the first stage RSRB (Figure 5) is using a four-segment booster from the Shuttle inventory. New forward structures are in the process of being manufactured, as are the segments of the USS. These new structures will be heavier than the Ares I hardware and will be made mostly of steel. The Ares I frustum and aeroshell, which will not be reused, are to be made of carbon composites. The Ares I forward skirt and forward skirt extension will be made of aluminum.

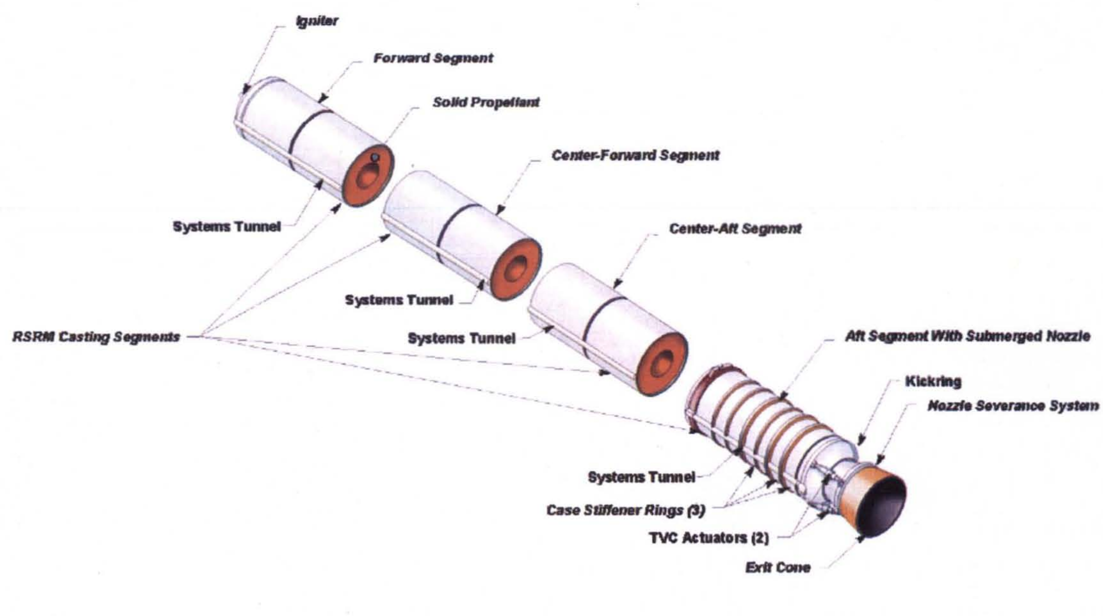


Figure 5. Reusable Solid Rocket Motor details

Frustum—The frustum connecting the First Stage to the upper stage is already being machined at several contractor locations. The structure itself is 15 percent complete. It is due to be delivered to the ARF at KSC by July 29, 2008.

Forward Skirt Extension—The forward skirt extension, which houses the pilot and drogue parachutes, is also 15 percent through its fabrication process. It is scheduled to be delivered to the ARF by June 30, 2008.

Forward Skirt—The Forward Skirt, housing the Main Parachute Support System (MPSS), is 15 percent complete and is due to be delivered to the ARF by July 25, 2008.

5th Segment Simulator (5SS)—The structure of the Fifth Segment Simulator (also called the spacer or XL segment is 10 percent complete. The 5SS houses the primary avionics module for Ares I-X, the First Stage Avionics Module (FSAM), the Flight Termination System (FTS), and other components. The first of the 5SS components arrives at the ARF July 7, 2008, with additional sections delivered August 6 and August 25.

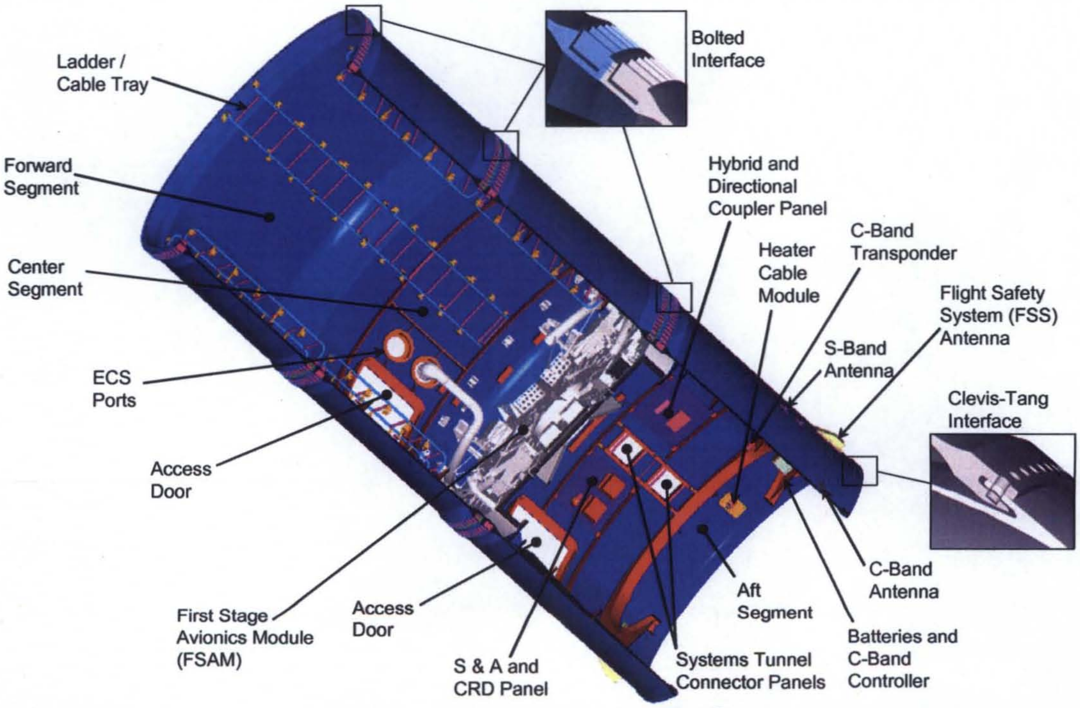


Figure 6. This computer-generated interior view of the 5th Segment Simulator shows avionics components and access interfaces

Motor Segments—The motor segments for the first stage are being stored at ATK Launch Systems' facility in Utah until needed. They are scheduled for delivery to the Rotation, Processing, and Surge Facility (RPSF) at KSC July 17, 2008. Preparations for Aft Segment linear shaped charge (LSC) and DFI installations are 20 percent complete.

Aft Skirt—The aft skirt, like the motor segments, comprise existing Shuttle hardware. The skirt is at the ARF, where the thermal protection system (TPS) is being removed so that additional ballast, booster deceleration motors (BDMs), and booster tumble motors (BTMs) can be installed. This work is 10 percent complete. A recent "lean event" at KSC helped increase the schedule margin for the skirt, resulting in a delivery to the RPSF by as much as one month earlier than originally scheduled.

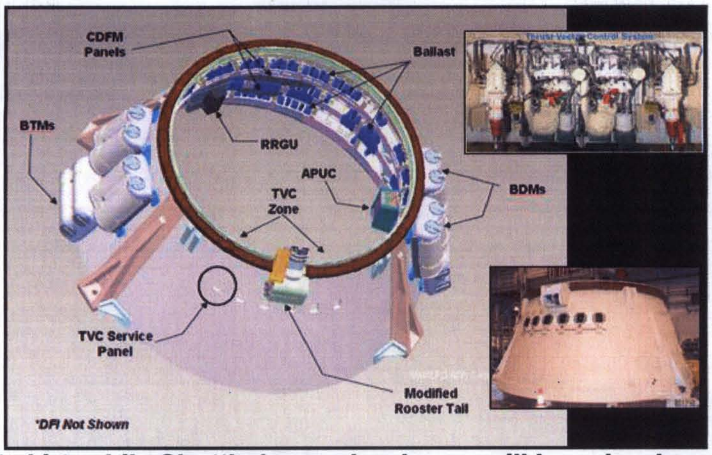


Figure 7. The aft skirt, while Shuttle-legacy hardware, will have hardware added to meet the requirements of Ares I-X

Separation and Deceleration—Five successful drop tests of the parachute system (Figure 7) have been completed so far. Two additional tests are planned before April 2009. A Main Parachute cluster drop test is scheduled for May 2008. Ares I-X will be the first qualification flight test of the new 150-foot-diameter main parachutes.

Figure 8. The main parachutes are in the process of fabrication and drop testing

The first stage has undergone several changes since the vehicle Preliminary Design Review (PDR) in May 2007. These changes include:

- A redesign of OFI and DFI cable routing
- A change of primary separation plane from forward to aft of the Frustum
- BDMs and BTMs added to the aft skirt
- Ballast added to the aft skirt
- Booster tumble changed from the pitch plane to tumble in the yaw plane
- One camera added in the Forward Dome of the Fwd Skirt
- Addition of Z-Stripe on the RSRM

Avionics

The majority of the avionics will be housed on the First Stage Avionics Module (FSAM) in the hollow fifth segment and forward skirt on Ares I and in the fifth spacer segment on Ares I-X. Most of the Ares I-X avionics are Atlas V Evolved Expendable Launch Vehicle (EELV) components, with the primary new component being the ascent thrust vector controller (ATVC), which translates commands between the Atlas V components, which are designed to fly a liquid-fuel rocket, and the solid-fuel RSRB.

The avionics will comprise the following subsystems:

- On-board Flight Control: Launch, Ascent, Separation, and Recovery
  - TVC
  - RoCS
- Data Acquisition & Recording (Includes Sensors)
  - Developmental Flight Instrumentation (DFI)
  - Operational Flight Instrumentation (OFI)
- Telemetry
- Power
- FTV Video
- First Stage Avionics Module (FSAM) development
- Ground Command, Control, & Comm System (GC3)
- EGSE

The range safety and tracking system are not Avionics Integrated Product Team (IPT) products, they are delivered to I-X as SRB GFE by the First Stage IPT. The range safety and tracking system includes the FTS and C-band tracking.

The avionics is provided by two contractors, Jacobs Engineering and the Ares First Stage project office. The Ares First Stage project office will provide SRB-derived avionics (SDA) to perform ignition/separation, recovery, and Auxiliary Power Unit Control (APUC). Jacobs Engineering, via a subcontract to LMSS will provide overall integration of the avionics system including subsystems of SDA, the Honeywell ATVC, select Atlas V boxes, commercial-off-the-shelf DFI, and government-furnished Guidance, Navigation, and Control (GN&C) algorithms and parameters. LMSS is also providing a dedicated Systems Integration Laboratory (SIL) for Ares I-X.

Figure 9 depicts the avionics system and its primary components.

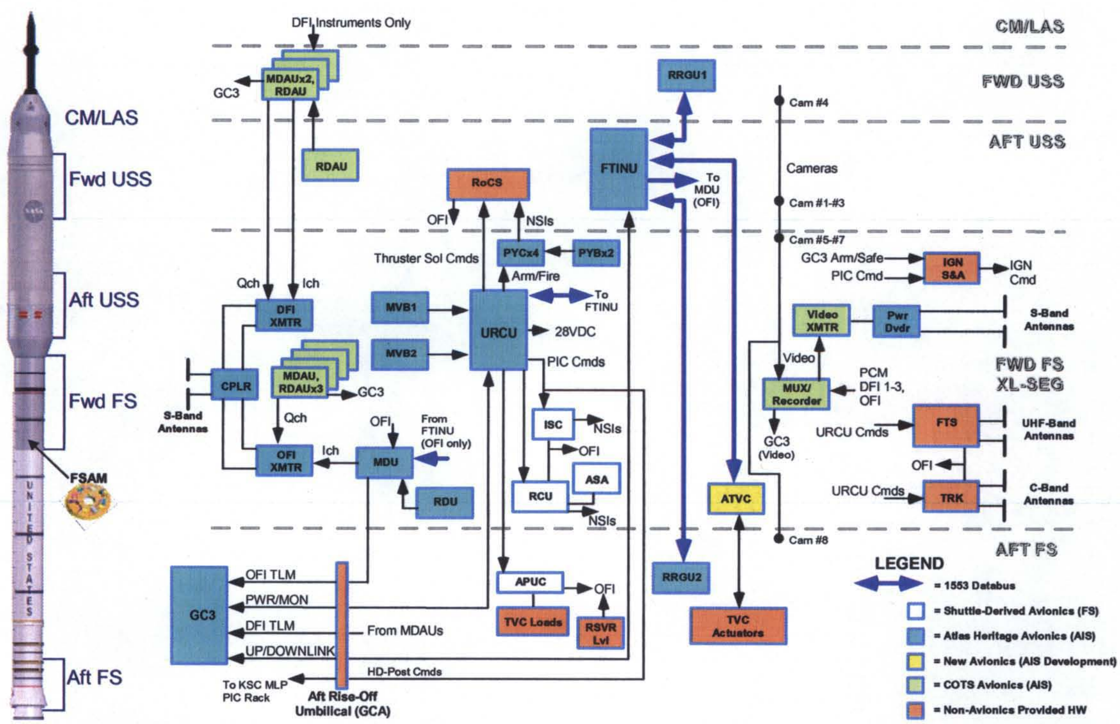


Figure 9. This schematic shows the Ares I-X avionics system broken out by function and box location within the vehicle

Fault Tolerant Inertial Navigation Unit (FTINU)—The FTINU, an Atlas V flight computer that includes an inertial navigation unit, is located at the aft end of the USS, and will autonomously direct the flight of Ares I-X. Its sensor channels include five Ring Laser Gyros

(RLGs) and five accelerometers arranged in a pentad configuration on an isolator assembly. Sensor redundancy management for these channels is implemented via parity equations. The FTINU also includes a primary flight control processor, which has a primary and hot-backup (active/stand-by) architecture. Redundancy management control/inhibit functions are at 1553 output with a voted clock (redundancy) accuracy of ± 12 PPM.

Redundant Rate Gyro Unit (RRGU)—The Ares I-X flight test vehicle will have two RRGUs—one on the aft skirt and one in the US-7 compartment—to provide redundant sensing of rates in two orthogonal axes. The RRGU's sensor channels will have triplex sensors per axis. The sensor assembly will be mounted on isolator block with a resonant frequency of 180 Hertz. Its processing channels will have a dual-channel active-active configuration with sensor data cross-strapped into each channel.

Ascent Thrust Vector Control Unit (ATVC)—The ATVC (Figure 10) is an evolved version of the Space Shuttle's TVC control unit. This newly developed component provides command and telemetry interface between FTINU and SRB hydraulic actuators and also provides actuator redundancy management based on servo-valve delta pressure discrimination. The ATVC's architecture includes dual-fault-tolerant, 4-channel parallel (fire and forget) command, control, and instrumentation. The flight control system software performs transformations from Pitch/Yaw to Rock/Tilt. The ATVC's power architecture channels are diode-ORed/current limited. Power is derived from upper stage remote controller unit (URCU) primary inputs (batteries). Single power input fault has no effect on actuator by-pass functions.

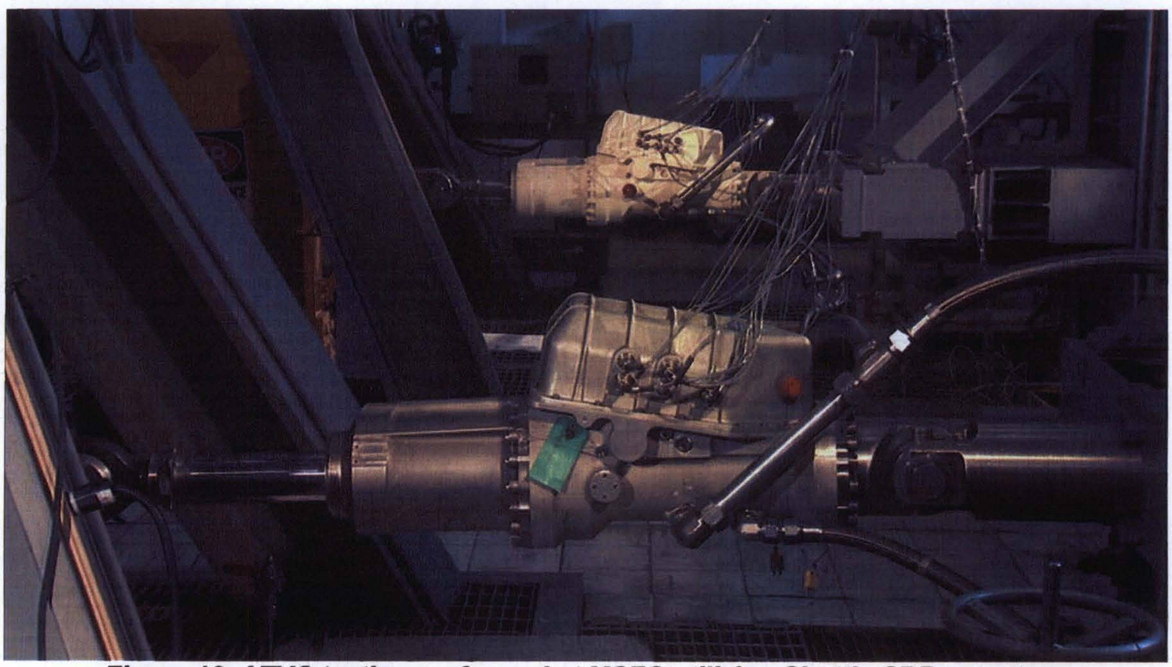


Figure 10. ATVC testing performed at MSFC utilizing Shuttle SRB actuators

First Stage Avionics Module (FSAM)—The FSAM, provided by LMSS and illustrated in Figure 11, is situated in the first stage fifth segment simulator. The FSAM is designed to mitigate the avionics boxes from the SRB environments and also contains the Environmental Control System (ECS) ducts that guide temperature-controlled air to the FSAM. The FSAM houses all avionics with the exception of the FTINU, RRGUs, and remote DFI units.

Figure 11. First Stage Avionics Module (FSAM) is provided by LMSS and located in the first stage fifth segment.

The avionics IPT chose to distribute its CDRs due to differing degrees of initial hardware and software maturity (and hence development schedules). The ATVC CDR was completed successfully in June 2007. The CDR for Solid Rocket Booster-derived avionics (SDA) was completed successfully in September 2007. The overall avionics system CDR was successfully completed in November 2007. The CDR for the FSAM is scheduled April 30, 2008, with input to Ares I-X CDR Phase 2 being provided in May. The flight software CDR is scheduled for March 12, 2008; with input also being provided to the Phase 2 CDR in May.

Atlas V-based hardware is in the process of being delivered to Jacobs Engineering subcontractor Lockheed Martin for testing in a System Integration Laboratory (SIL). The airborne (vehicle) portion of the SIL is 99 percent complete, with the ground portion scheduled to be completed by March 2008.

DFI and OFI sensors have been acquired or are on order. Successful Table Top Reviews (TTR) are being held for wiring harness assemblies as the design is completed, and design and fabrication is ongoing. The FTINU has been qualified for Ares I-X vibration environments, and United Launch Alliance (ULA) has taken delivery of flight unit at Honeywell.

As noted above, the CDR for the flight software is scheduled for March 12, 2008, with a test readiness review (TRR) scheduled for mid-April. Formal testing of the ground software will begin in the SIL in April 2008. Qualification testing for the ATVC is planned for May 2008. Fabrication is scheduled to be completed in July 2008, whereupon it will be incorporated into the FSAM. SIL testing will finish in March 2009, and the flight-qualified FTINU will be delivered to KSC March 19.

The avionics hardware and software will continue to be fabricated, qualified, and tested through April 2009. The FSAM, which is undergoing fabrication, will have a CDR on April 30, 2008. Following the CDR, the FSAM avionics and thermal systems will be integrated prior to being delivered to the ARF in October 2008.

SDA fabrication began in December 2007 and will be completed in August 2008. Hardware will begin delivery to KSC in June 2008.

DFI and video harness development has been ongoing since August 2007 and will continue through September 2008. Cable harnesses for the CM/LAS will be completed in April 2008, for the USS in June 2008, and for the FS in September 2008. OFI harness development for FS and USS will be completed in June 2008.

The ground portion of the Ares I-X flight, the GC-3 unit, will be delivered to KSC for installation on the Mobile Launch Platform in October 2008.

Upper Stage Simulator (USS)

The USS (Figure 12) is made up of cylindrical segments that will be stacked and integrated at Kennedy Space Center (KSC) for launch. Glenn Research Center is already building these segments, along with their internal access structures, which include:

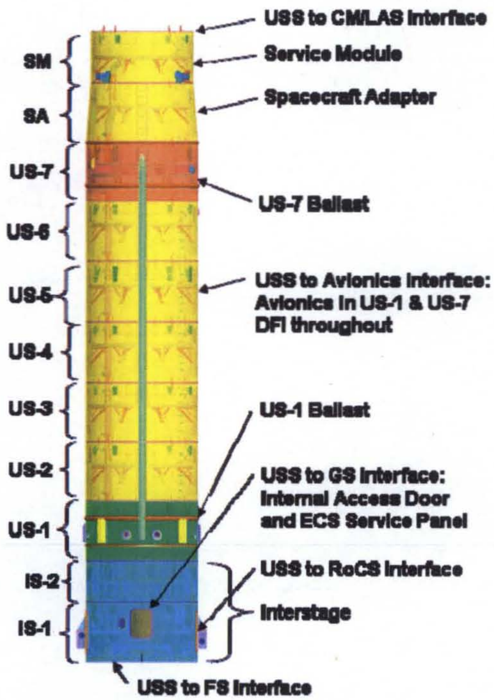


Figure 12. This engineering diagram depicts the order and relative sizes of the various USS segments.

- Interstage (IS) Simulator
  - o ECS/Service Panel
  - o Integration of other Elements:
    - Roll Control System (RoCS)
    - Separation event cameras
- Upper Stage (US) Simulator
- Spacecraft Adapter (SA) Simulator
- Service Module (SM) Simulator
- Integration of avionics/DFI along the length of the USS
- Interfaces to other elements, including:
  - o First Stage (FS)
  - o Roll Control System (RoCS)
  - o Crew Module/Launch Abort System (CM/LAS)
  - o Avionics
  - o Ground Systems (GS)

The USS is designed with 11 segments: 5 *common* segments (US-2, 3, 4, 5, 6), 2 adjustable ballast segments (US-1 and 7), and 4 *complex* segments (Interstage (IS)-1 and IS-2, Spacecraft Adapter (SA), and Service Module (SM)).

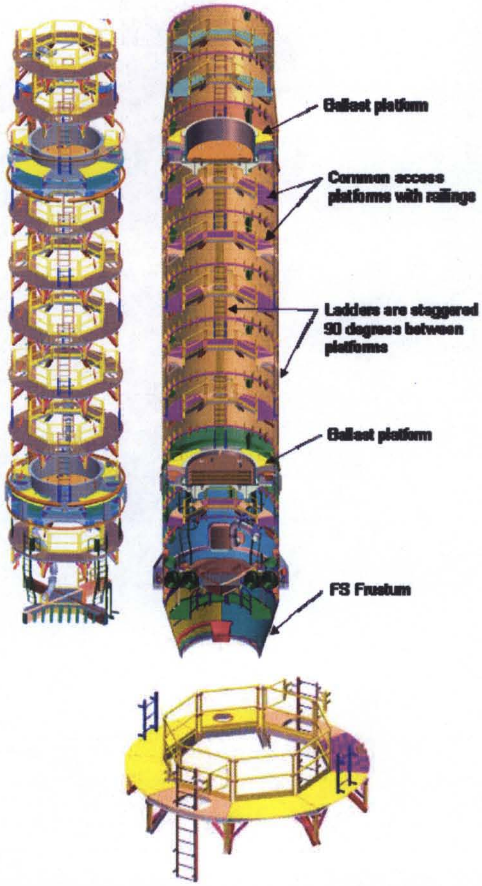


Figure 13. These design drawings depict the internal arrangement of the USS segments and a detailed image of a typical ladder, platform, and railing system.

Each segment (Figure 13) is approximately 9.5 feet tall to allow for manufacturing and transportation constraints. Outer Mold Line (OML) protuberances are all bolted on and assembled on individual segments prior to shipping except the Ullage Motors (4x) and RCS Modules (2x) located on the US-1 segment, which will be shipped separately. An internal access door on US-1 and platforms and ladders provide access to the entire USS, the FS Frustum, and CM/LAS. An environmental control system (ECS) and vents provide for internal air circulation and humidity control for Avionics at the KSC VAB and pad.

USS has successfully completed three Critical Design Reviews, which were ordered by segment complexity, with the "Charge 1" segments being the least complex and "Charge 3," which incorporated the Roll Control System and avionics, being the most complex. Charge 1 hardware has already been fabricated. Charge 2 is underway to be completed per schedule. Charge 3 hardware fabrication has been started. Manufacturing processes and procedures have been successfully demonstrated.

The USS is a mass simulator. It provides the majority of adjustable ballast for the FTV's mass, center of gravity (CG), and moment of inertia distribution. The 2-inch-thick ballast plates are approximately 7,000 pounds (lbs.) each. The US-1 segment holds 16 plates ± 2 plates equaling approximately 112,000 lbs. The US-7 segment holds 5 plates ± 2 plates weight approximately 35,000 lbs. The total adjustable ballast is around 147,000 lbs.

ECS used in the KSC VAB and at the launch platform to provide air circulation for the confined space as well as providing a dry humidity free environment for the avionics and DFI. The ECS Service Panel is located next to the Internal Access Door in IS-1, where 14" diameter duct is routed from IS-1 to the SM. All ductwork is assembled in each segment at GRC before shipping to KSC.

Design and analysis for all USS segments and interfaces per final loads & environments is 98% complete. The expected completion date is March 29, 2008.

Roll Control System (RoCS)

The active roll control system (RoCS) provides rotational azimuth control as a mitigation against adverse roll torques (self- and aero-induced). The Roll Control System is an integral, modular, bi-prop propulsion system housed in the Ares I-X Upper Stage Simulator Interstage (Figure 14). The RoCS utilizes off-the-shelf and GFE components—including nitrogen tetroxide and monomethyl hydrazine propellant tanks, helium pressurization tanks, and engine nozzles—

that have been harvested from Peacekeeper Stage IV, then re-integrated into a system. The Ares I-X FTV will have two engine sets mounted on the interstage (IS-1) segment.

Figure 14. The images at left depict the RoCS module from various orientations to reveal interior and exterior details, including the aerodynamic protuberance. The image at right shows the internal arrangement of the RoCS within the interstage segment.

The RoCS units will fire automatically based on commands from the FSAM, and will rotate the FTV 90 degrees after it clears the tower. The RoCS will then maintain a constant orientation in flight. The number of RoCS pulses used to overcome induced roll torques will be measured and will help inform the RoCS for the final Ares I design.

Duty cycle testing for RoCS was conducted at the White Sands Test Facility in late 2007, and fuel tanking and detanking tests was performed at KSC in early 2008. This verification testing, which was at Hypergol Maintenance Facility (HMF), demonstrated loading pressurant and propellant (using de-ionized water) into PK tanks/fill valve configuration, used HMF GSE planned for RoCS flight module loading, and verified and validated procedures and hardware well in advance of actual propellant loading in flight modules.

The RoCS team's primary efforts are focused on completing the hardware in fabrication and integrating it into the modules, while working verification activities in parallel, leading to a Hardware Acceptance Review early September 2008. The RoCS team has high confidence of being able to meet its delivery schedule for the April 2009 launch.

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

Like the USS, the CM/LAS portion of Ares I-X will be simulator hardware (Figure 15). These forward sections deviate slightly from the current iteration of the Ares I design because Ares I-X was baselined during an earlier design analysis cycle (DAC). However, the CM/LAS will still provide critical information about aerodynamic and acoustic loads on the Orion crew exploration vehicle. A total of 362 DFI sensors will be placed on and in the forward structures. The data from these sensors will be transmitted to the ground via telemetry. The sensors might also provide visibility into the thrust oscillation challenge Ares I is studying. The CM/LAS CDR is scheduled for mid-March 2008. Drawings for the hardware have been completed, and the hardware is in the process of being manufactured. NASA's Langley Research Center (LaRC) is responsible for CM/LAS design and fabrication, installation and checkout of DFI, plus handling ground support equipment (GSE).

Figure 15. The Ares I-X CM/LAS simulator completed its CDR in February 2008.

The CM/LAS structure consists of several primary components, including the Orion crew module (CM) simulator, the LAS nozzles, the nosecone, and a transition structure between the mast and the CM known colloquially as a "party hat" (Figure 16).

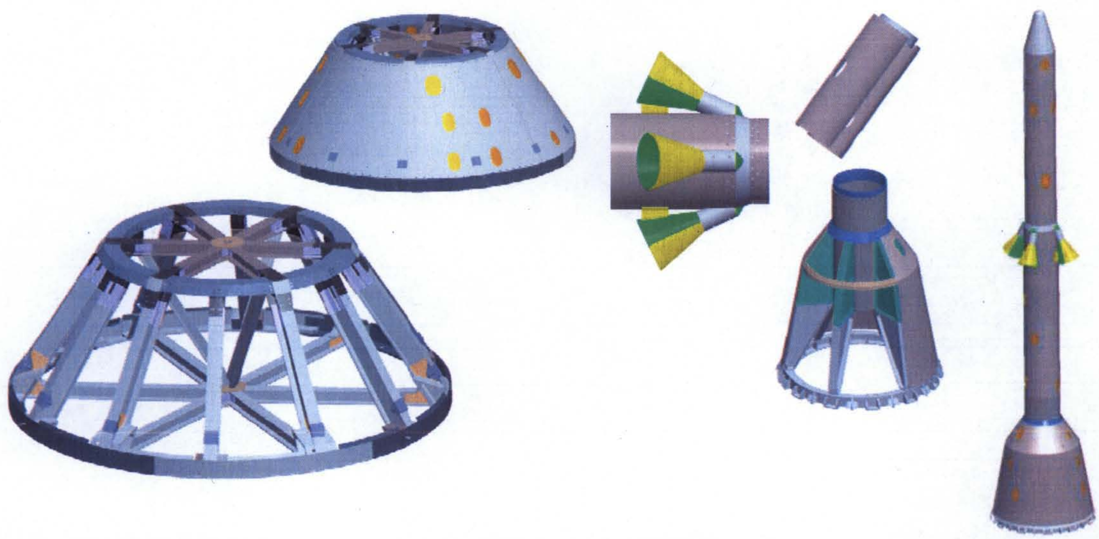


Figure 16. The CM/LAS components will match the shape and mass properties of the operational Orion CM and launch abort system.

Primary requirements for the CM/LAS simulator are to match the specified Outer Mold Line (OML) and mass properties of a specific design variant of the Ares I. Its primary interfaces are with:

- Upper Stage Simulator (AI1-IRD-C2U)
- Avionics Developmental Flight Instrumentation (AI1-ICD-A2V)
- Ground Systems (AI1-IRD-F2G)

Several technical changes have been made to the CM/LAS since PDR. Ballast was removed from the CM and moved to the USS to more closely match the Ares I mass properties; multiple redesigns were performed, primarily due to changes in structural loads; and the Developmental Flight Instrumentation (DFI) sensor list and locations were refined and baselined. The CM/LAS delivery date to KSC has moved from October 22, 2008 to November 19 to accommodate a redesign for higher structural loads. The major design changes included a complete redesign of the "party hat" section, a material change of lower the mast section, and a re-routing of the instrumentation harnesses.

Ground Operations (GO) / Ground Systems (GS)

This important flight will provide valuable experience for the ground operations team in integrating, stacking, and launching Ares I. Most of the ground systems to be built for Ares I-X have undergone a 90-percent review and begun fabrication. Among the activities to be addressed will be transportation of the vehicle elements to KSC, RoCS propellant loading in the Hypergol Maintenance Facility (HMF), vehicle processing in the ARF and RPSF, vehicle stacking in the VAB, vehicle rollout, and launch and recovery operations.

KSC Transportation Plan—The Ares I-X Upper Stage will arrive at Port Canaveral on the Delta Mariner transport ship. A convoy of three to five flatbed trucks will carry the hardware 15 miles to the VAB. Loading, unloading, slow convoy speed, and road closure requirements will limit KSC to one convoy per day. The USS and its support equipment will require three to four convoys, requiring three to four days to accomplish. The FS will use existing Shuttle transport equipment and procedures. After servicing in the HMF, the RoCS will be transported by truck to the VAB. The CM/LAS will be delivered by barge to the Turn Basin or Port, similar to USS transportation plan.

HMF Operations—The RoCS modules will be received at the HMF for servicing, which will include helium pressurization, propellant loading, service cap welding, and tank cover installation. Upon completion, the modules will be transported to the VAB for installation in the interstage (IS-1 / IS-2 Assembly).

RPSF Operations—Live FS segments will arrive at the RPSF by rail from Utah. Each segment will be inspected and rotated to vertical. The RPSF also will build up the aft booster segment, which includes the aft segment, aft skirt, and exit cone. Segments can be stored at the RPSF until needed for stacking.

VAB Operations—The USS segments and CM/LAS will be assembled into five stacks and the DFI will be tested in VAB High Bay 4 (Figure 17). This will include integration of the FS 5th spacer segment and forward structures into Stack 1. The FS segments and the stacks will be integrated in High Bay 3. The baseline schedule includes ten days for integrated testing. Closeouts—except for the Lower 5SS door (Ordnance Access)—are completed prior to rolling to the pad.

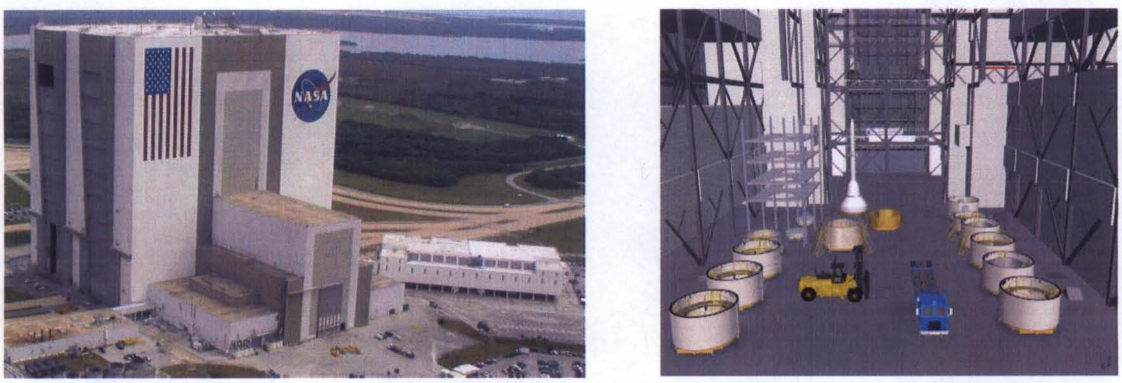


Figure 17. The VAB (left) will modify existing Shuttle handling hardware to stack Ares I-X.

Ares I-X Firing Room Concept—The Launch Complex (LC) 39B Launch Control Center (LCC) Firing Room 1 will be used for both the Ground and Flight systems command and control work stations. NASA's Ground Systems (GS) team will provide six Ground Control System (GCS) workstations to control and monitor GSE.

Mission Control Room Concept (Available only on Launch Day)—The NASA Launch Services Program Hangar AE Facility will be used to provide the Launch Support Control Room capability. Monitor-only data will be provided via the Hangar AE web-based system (Iris). The OFI data and Iris displays also will be sent to MFSC real-time on launch day.

Ground Systems— The GS team has completed a 90 percent design for all of the modifications necessary to adapt the Shuttle-based service structure to the much taller Ares I-X. The very large stabilizer used for keeping the launch vehicle upright on the launch pad was removed. This change was deemed acceptable because wind-based loads were within limits and trending even better and because operational needs seemed to be driving the stabilizer requirement.

Several new pieces of hardware will be added to or modified on the Fixed Service Structure (FSS) and Rotating Service Structure (RSS) at LC39B (Figure 18). These changes are noted below.

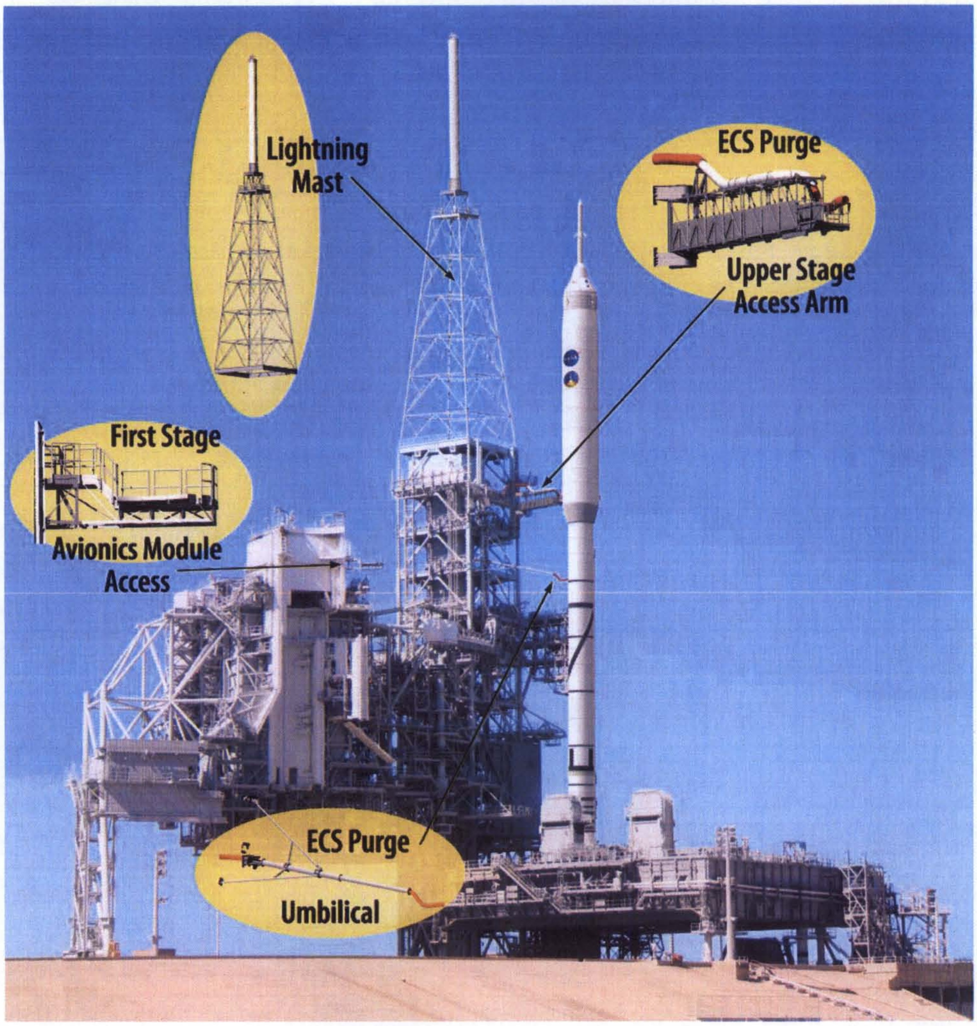


Figure 18. Launch Complex 39B will modified to include vehicle access and safety features to accommodate Ares I-X.

- **Pad B Upper Stage Access Arm**—The Gaseous Oxygen Vent Arm (GVA) will be modified to provide internal access to the USS through the Interstage-1 (IS-1) segment. This access also supports manual mating / de-mating of the Environmental Control System (ECS) purge interface to the USS.
- **Pad B First Stage ECS Umbilical**—A locally extendable and retractable arm will be provided to carry and support the ECS purge ducting from the pad FSS to the Ares I-X First Stage ECS interface.
- **Pad B FSAM Access**—A platform that provides access to the FS 5th spacer segment will be added to the Rotating Service Structure (RSS) to allow pad processing of the First Stage Avionics Module (FSAM) and manual mating / de-mating of the Environmental Control System (ECS) purge interface to the FS.
- **Pad B ECS Purge**—Two Environmental Control System (ECS) purge circuits will be provided for the FTV: one for USS personnel comfort and avionics and DFI cooling and protection and one for FS / FSAM personnel comfort and avionics cooling and protection.
- **Pad B Lightning Protection System**—A Shuttle level of protection from Lightning effects and strikes will be added to the LC39B launch tower. This will be accomplished by modifying the Fixed Service Structure (FSS) 300' Level structure to support a new 110'

- **MLP East SRB Flame Hole Ignition Over Pressure (IOP) Protection**—Steps will be taken to mitigate the IOP wave generated by the Ares I-X SRB from protruding back through the East SRB flame hole and causing damage to the vehicle.

VAB HB-3 Access Modifications—Additional changes will be made to the VAB to accommodate Ares I-X during the stacking process. A temporary platform will be added that provides personnel access and ECS duct support to the USS IS-1 segment from the Platform "E" roof (Figure 19). This stand will include a davit crane for lifting equipment and tools necessary to support integrated processing. In addition, personnel access capability and ECS duct support will be provided to the FS 5^{th} spacer segment from the floor of Platform "E" Main.

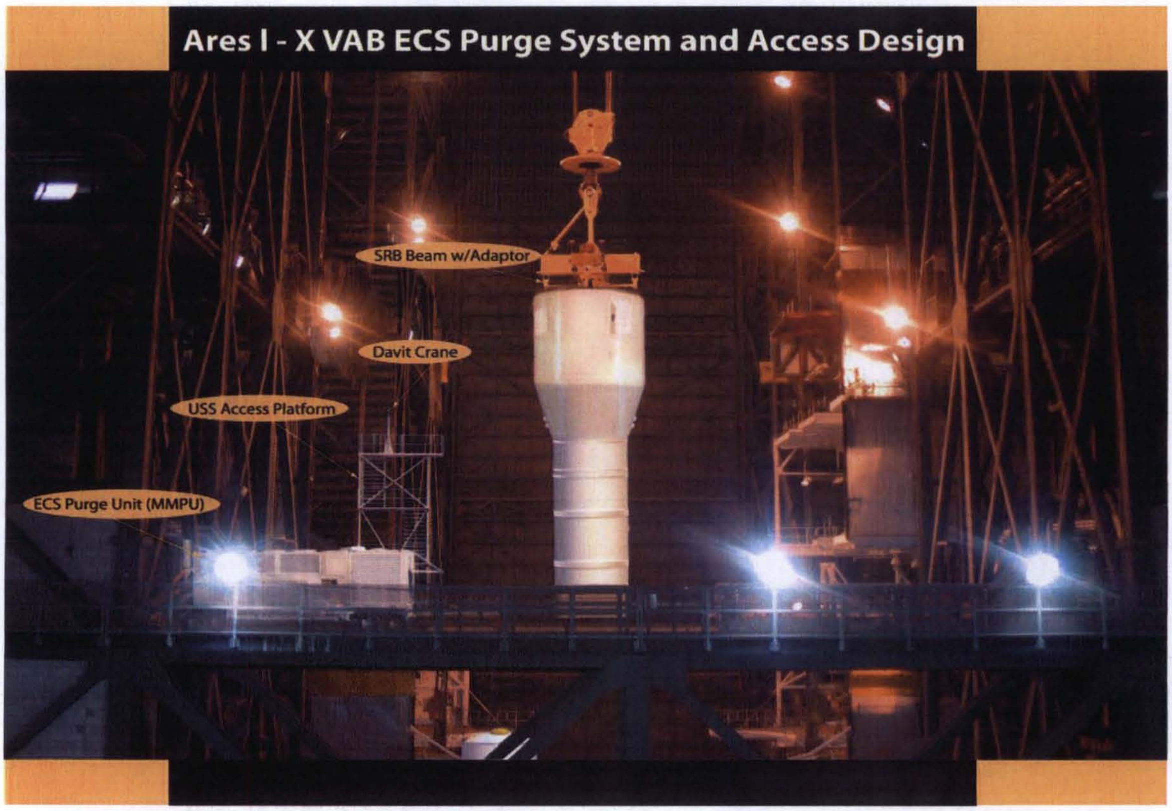


Figure 19. Changes made to the VAB for Ares I-X will be testing opportunities for regular Ares I stacking operations.

VAB ECS Purge—Environmental control will be provided to the USS and FS segments for personnel comfort and safety in confined spaces while providing cooling and humidity control to protect avionics equipment and DFI.

The Ground Systems design is on track to support a GS CDR, currently scheduled for March 12-13, 2008.

SUMMARY AND CONCLUSIONS

Data and operational lessons learned from Ares I-X will ensure the safety and reliability of America's newest launch vehicle. From the propulsion systems to the flight simulator hardware, avionics, and ground systems, the Ares I-X team has made great progress in the last two years, and had demonstrated that it is on track to meet its April 2009 launch date.

MSFC - 827 - PRESENTATION

National Aeronautics and Space Administration

Technical Progress *on the* Ares I-X Flight Test

JANNAF Conference
May 2008

Stephan R. Davis
Kimberly F. Robinson
Kevin C. Flynn

www.nasa.gov

Overview

- **Mission**
- **Vehicle**
- **Progress**
  - First Stage
  - Avionics
  - Upper Stage Simulator
  - Roll Control System
  - Crew Module / Launch Abort System Simulator
  - Ground Operations / Ground Systems

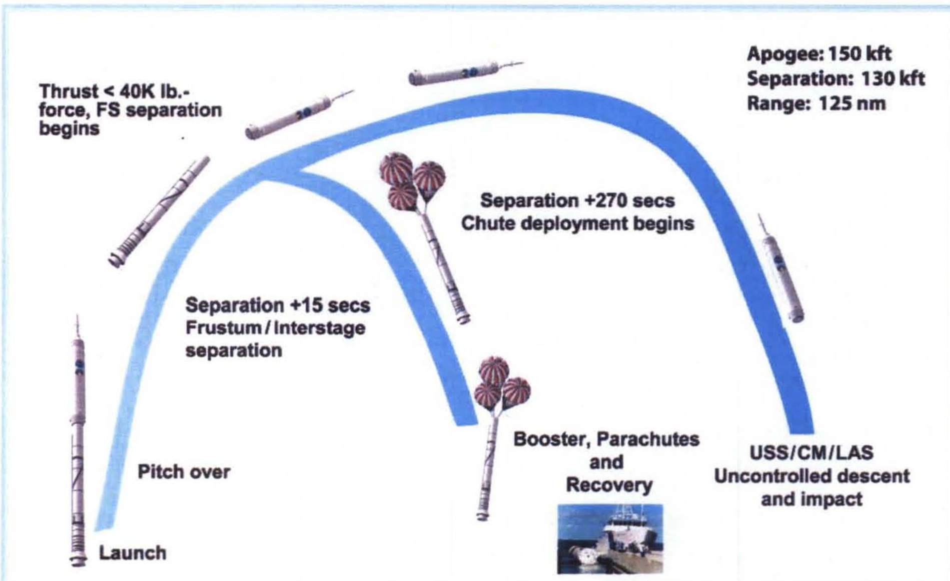
Ares Project Background

- **Ares I Crew Launch Vehicle**
  - First new human-rated launch vehicle design to fly in over 30 years
  - Launches crew to low Earth orbit
  - Uses Saturn and Shuttle heritage propulsion designs
  - First test flight: Ares I-X April 2009
  - First crewed flight: Orion 1 2013
  - First mission to International Space Station 2015
- **Ares V Cargo Launch Vehicle**
  - Largest rocket ever designed
  - Solid rocket boosters and liquid core stage lift Earth departure stage and Altair lunar lander to Earth orbit
  - Earth departure stage propels Altair and Orion crew exploration vehicle to Moon
  - First flight ~2019
  - First mission to the Moon 2020

Ares I-X Mission Objectives

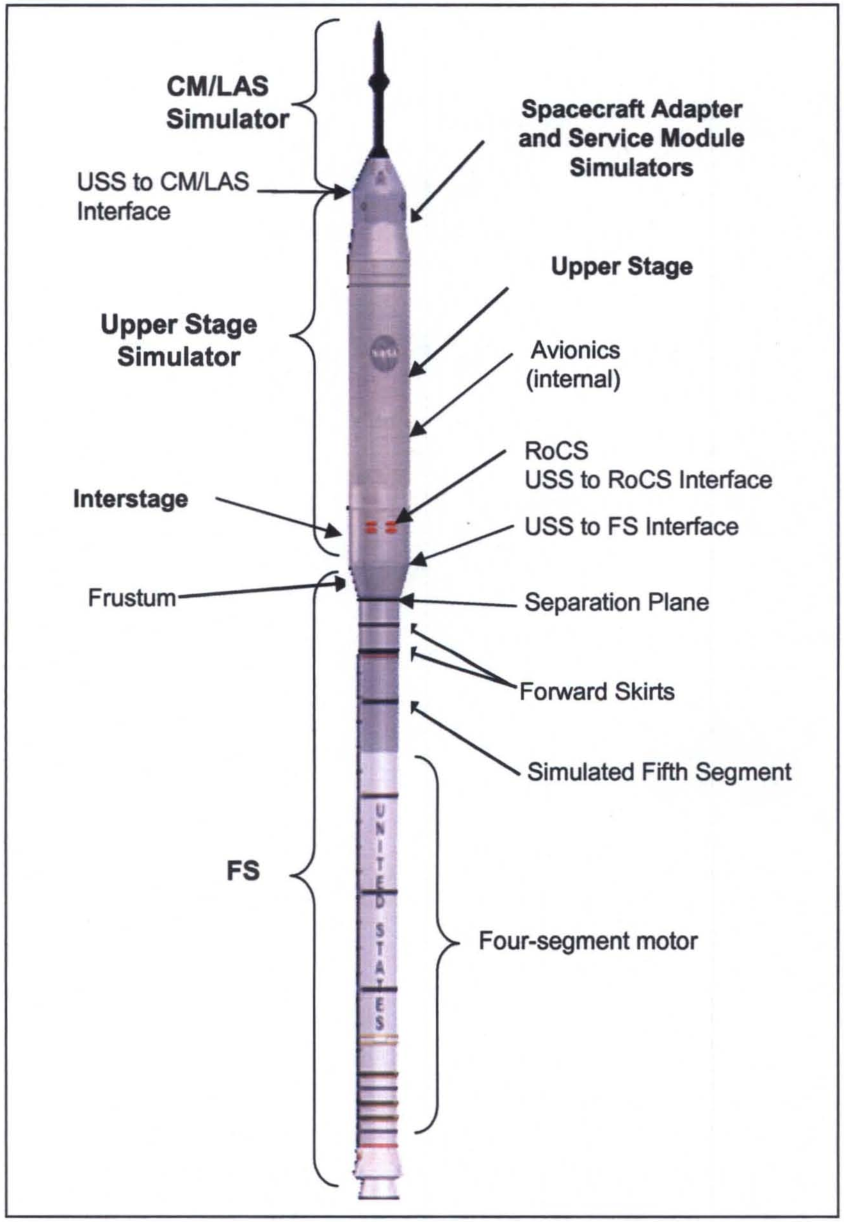
- Demonstrate the ascent flight control system performance with dynamically similar hardware
- Characterize and mitigate the roll torque due to first stage (FS) motor performance for a vehicle that is dynamically similar to the operational vehicle
- Demonstrate nominal first and upper stage separation and clearances
- Test the first stage parachute recovery system and separation/ entry dynamics
- Demonstrate assembly and processing flow, as well as launch and recovery operations

Mission Profile



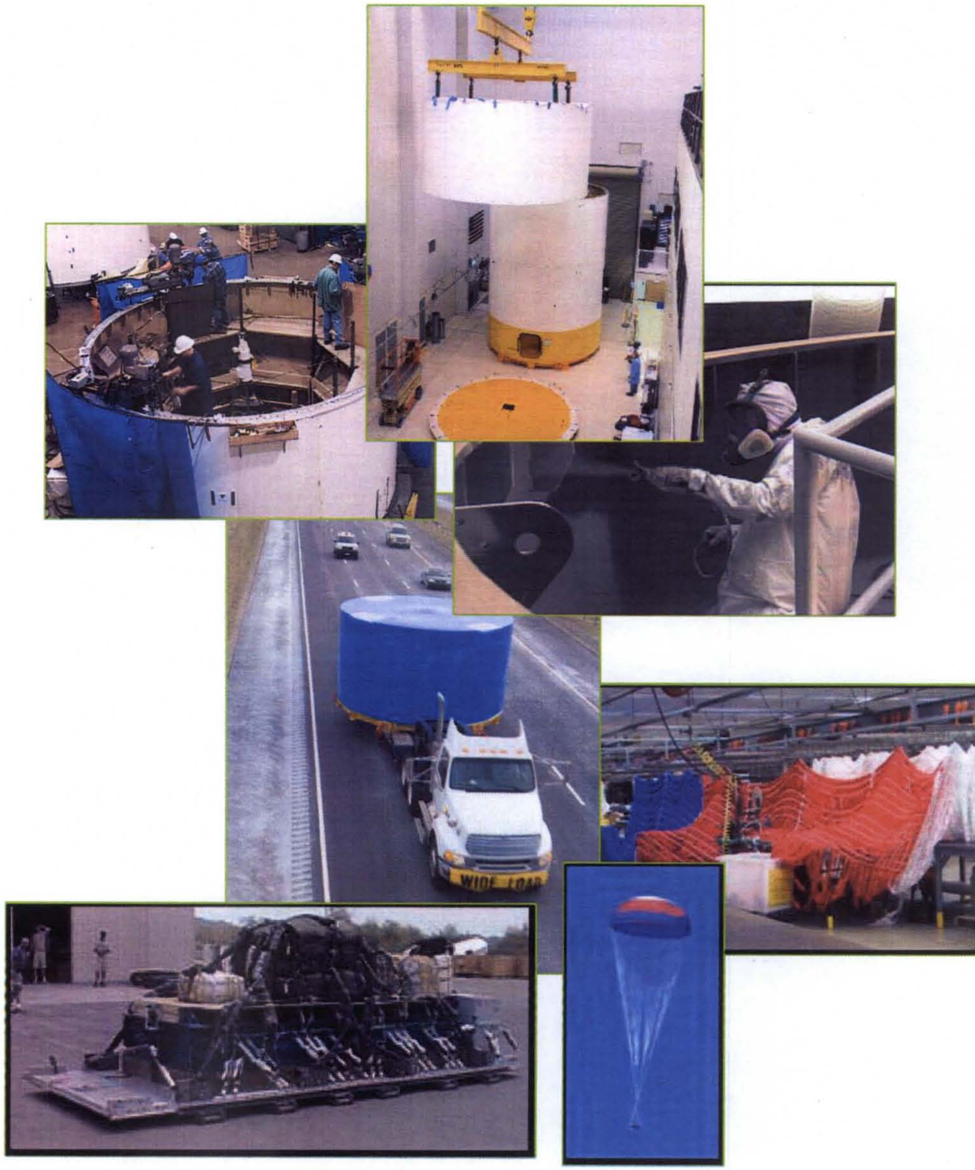
- Vehicle will perform 90-degree roll after clearing Launch Complex 39B
- Vehicle will fly through Mach 4.5 and will simulate Ares I maximum dynamic pressure (Max Q)
- First stage separation at 130,000 feet. Recovery splashdown at 125 nm down range
- Upper Stage Simulator (USS) will fly to 150,000 feet altitude. No recovery
- Flight data will be captured via telemetry and flight recorder
- Data recorders recovered with first stage

Vehicle Overview



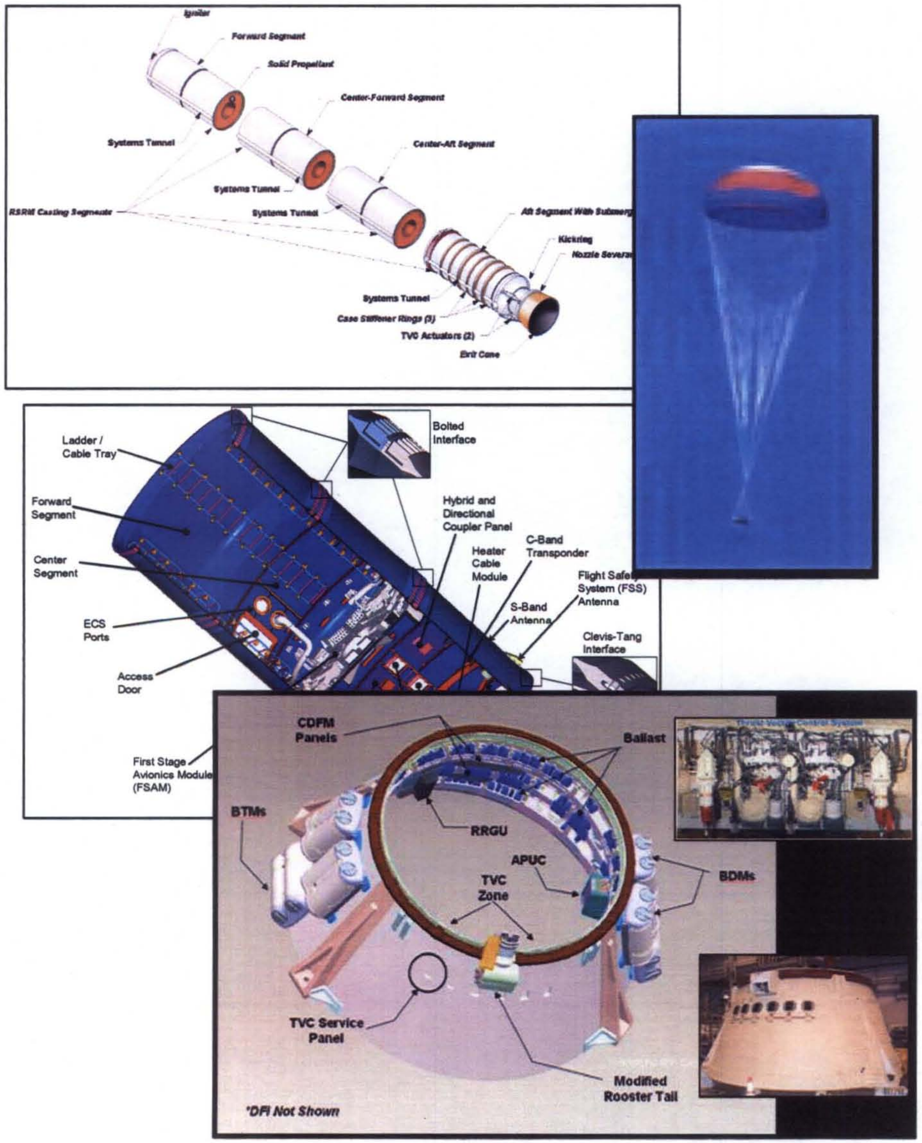
- **Combines flight and simulated hardware to test ability to fly vehicle with an outer mold line (OML) similar to Ares I**
- **Flight / active hardware includes:**
  - Four-segment solid rocket booster
  - Atlas V-based avionics
  - Roll control system
  - Linear shaped charge separation system
  - Parachutes deceleration system
  - Booster deceleration and tumble motors
  - Developmental flight instrumentation
- **Simulator hardware**
  - Upper stage
  - Crew module
  - Launch abort system
  - Fifth segment

Mission Progress



- **Progress**
  - First Stage
  - Avionics
  - Upper Stage Simulator
  - Roll Control System
  - Crew Module /
    Launch Abort System Simulator
  - Ground Operations / Ground Systems

First Stage (FS)



- **Motor hardware at ATK, awaiting integration**
- **New forward structures being fabricated:**
  - 5th segment simulator (5SS)
  - Forward skirt
  - Forward skirt extension
  - Frustum
- **New main parachutes being tested**
- **Aft skirt modifications:**
  - Deceleration and tumble motors
  - Ballast
- **Service tunnel and flight termination system extended to 4th segment**
- **Some cabling outside service tunnel**

Avionics

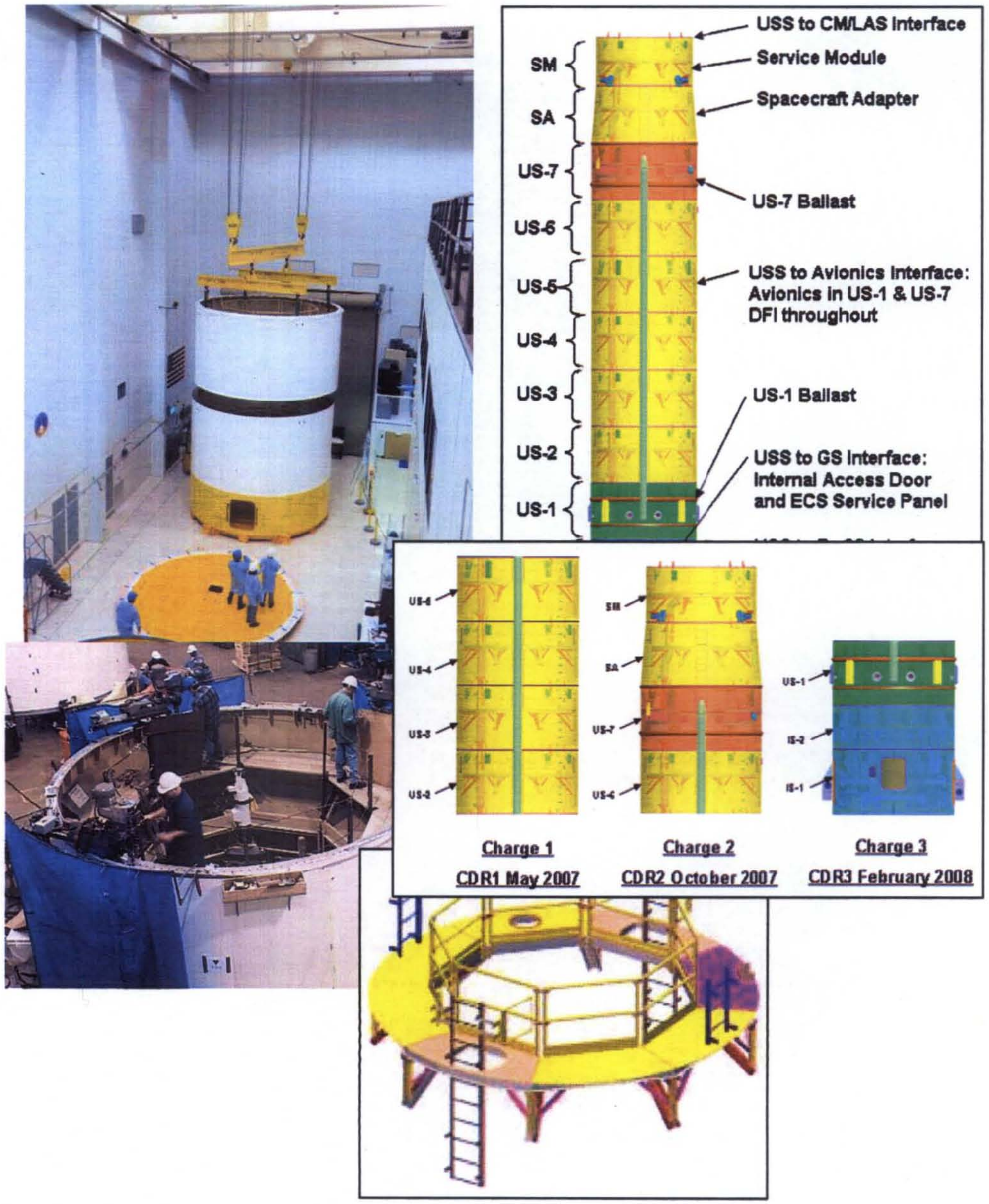
First Stage Avionics Module (FSAM) (Lockheed Martin Space Systems (LMSS))

Atlas V System Integration Lab (SIL) (located at LMSS, Denver)

Assent Thrust Vector Controller (ATVC) (Honeywell International)

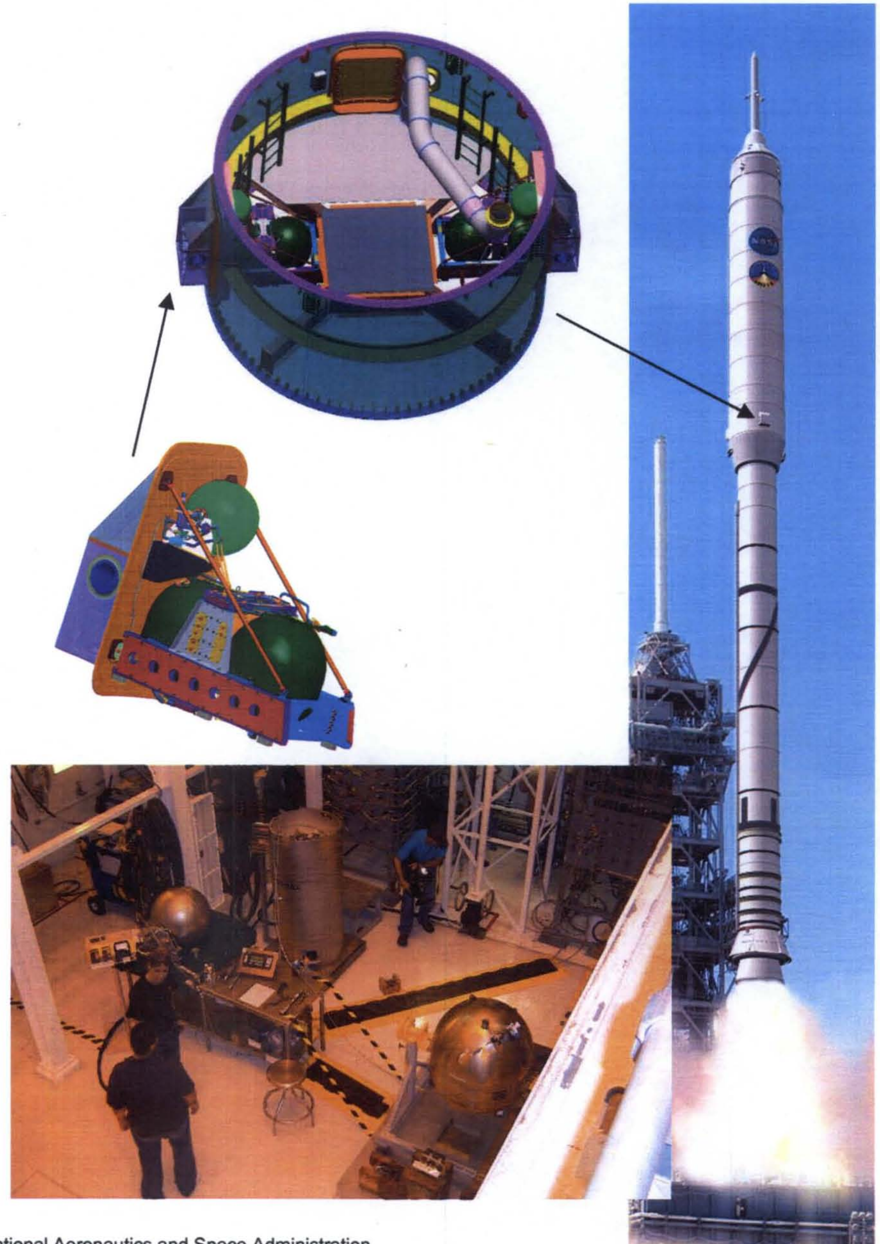
- **Avionics Critical Design Review (CDR) completed in November 2007**
  - Flight Software CDR completed March 2007
  - First Stage Avionics Module (FSAM) CDR scheduled May 2007
- **Primary avionics subsystems:**
  - FSAM (located in First Stage fifth segment)
  - Guidance & Control System
    - Fault-Tolerant Inertial Navigation Unit (FTINU)
    - Redundant Rate Gyro Unit (RRGU)
    - Assent Thrust Vector Controller (ATVC)
  - Ground Command, Control, and Communication (GC3)
- **DFI/OFI sensors/harnesses delivered and/or scheduled for delivery to First Stage, US, and CM/LAS IPT's**
- **Systems Integration Laboratory (SIL) Flight testing complete March 2009**

Upper Stage Simulator (USS)



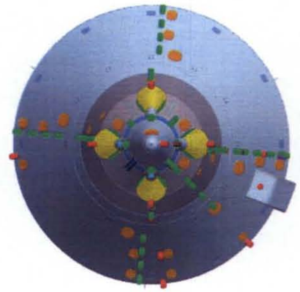
- **USS is a mass and OML simulator**
- **Hardware includes:**
  - Interstage (IS) Simulator
  - Upper Stage (US) Simulator
  - Spacecraft Adapter (SA) Simulator
  - Service Module (SM) Simulator
  - Integration of avionics/DFI along the length of the USS
  - Interfaces to other elements
- **CDRs completed for all segments**
- **Segments being fabricated at Glenn Research Center**
  - Charge 1 hardware in fabrication
  - Charge 2 in fabrication
  - Charge 3 hardware fabrication started
- **Segments to be transported by ship**
- **Design and analysis for all USS segments and interfaces is complete**

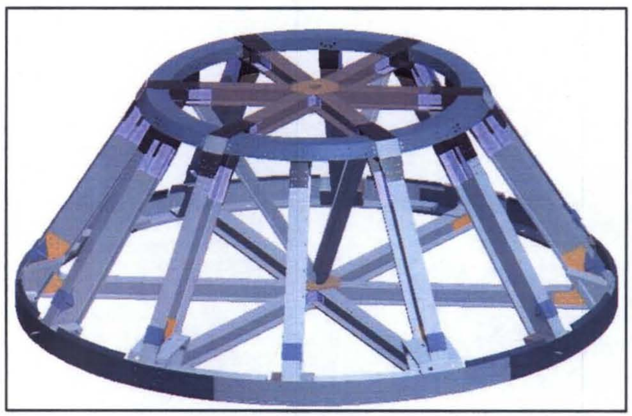
Roll Control System (RoCS)

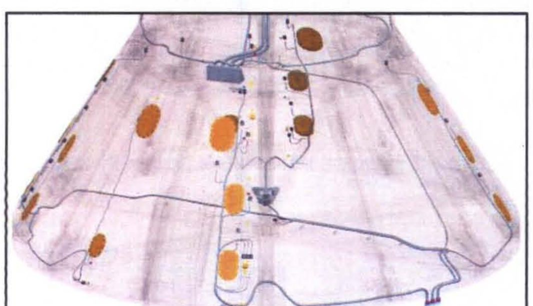


- Provides post-launch 90-degree roll and mitigation against adverse self- and aero-induced roll torques
- Integral, modular, bi-prop propulsion system housed in the Ares I-X USS Interstage
- Harvested from Peacekeeper 4th Stage
- Two sets of engines on Ares I-X
- Duty cycle testing for RoCS conducted at the White Sands Test Facility in late 2007
- Completed CDR in December 2007
- Fuel tanking and detanking tests performed at KSC in early 2008
- Hardware Acceptance Review early September 2008
- On schedule for April 2009 launch

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

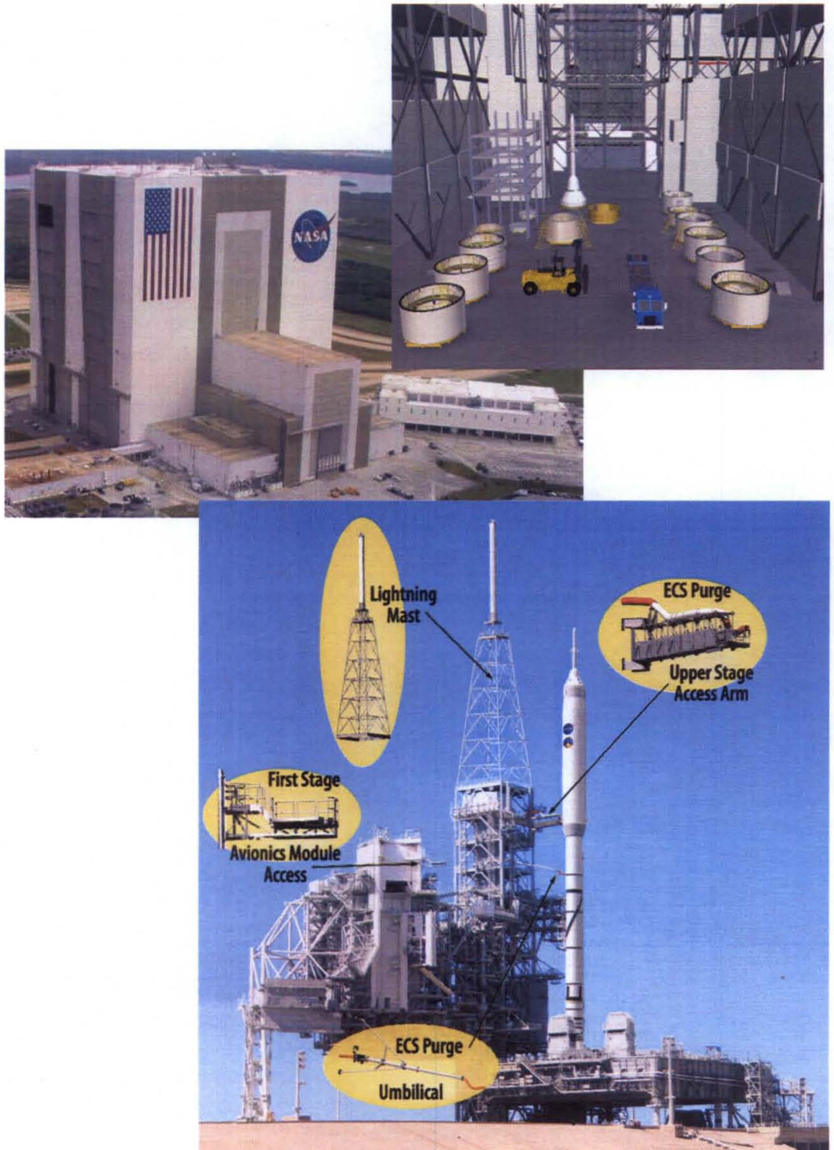






- Simulator hardware
- To be fabricated at Langley Research Center
- OML resembles earlier Ares I design due to flight test schedule
- DFI sensors will measure aerodynamic and acoustic loads
- Sensors might also provide insight into Ares I thrust oscillation issue
- CDR completed February 2008
- Design modified to account for higher anticipated aeroacoustic loads
- CM/LAS to be delivered to KSC November 2008

Ground Operations/Ground Systems (GO/GS)



- **Ares I-X valuable experience for the ground operations team in integrating, stacking, and launching Ares I**
- **Most GS have undergone 90-percent review and begun fabrication**
- **LC39B Launch Control Center (LCC) Firing Room 1 used for Ground and Flight systems command and control**
- **GS modifications:**
  - Pad B Upper Stage Access Arm
  - Pad B First Stage ECS Umbilical
  - Pad B FSAM Access
  - Pad B Lightning Protection System
  - VAB HB-3 Access Modifications

Conclusion

- Data and operational lessons learned from Ares I-X will ensure the safety and reliability of America's newest launch vehicle

- The Ares I-X team has made great progress on design and manufacturing of the flight test vehicle

- The Mission Management Office is on track to meet its April 2009 launch date

Questions?

www.nasa.gov/ares