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Ares Launch Vehicles Development Awakens Historic Test Stands at NASA's Marshall Space Flight Center

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Abstract

This paper chronicles the rebirth of two national rocket testing assets located at NASA's Marshall Space Flight Center: the Dynamic Test Stand (also known as the Ground Vibration Test Stand) and the Static Test Stand (also known as the Main Propulsion Test Stand). It will touch on the historical significance of these special facilities, while introducing the requirements driving modifications for testing a new generation space transportation system, which is set to come on line after the Space Shuttle is retired in 2010.

In many ways, America's journey to explore the Moon begins at the Marshall Center, which is developing the Ares I crew launch vehicle and the Ares V cargo launch vehicle, along with managing the Lunar Precursor Robotic Program and leading the Lunar Lander descent stage work, among other Constellation Program assignments.[1]

An important component of this work is housed in Marshall's Engineering Directorate, which manages more than 40 facilities capable of a full spectrum of rocket and space transportation technology testing — from small components to full-up engine systems. The engineers and technicians who operate these test facilities have more than a thousand years of combined experience in this highly specialized field. Marshall has one of the few government test groups in the United States with responsibility for the overall performance of a test program from conception to completion. The Test Laboratory has facilities dating back to the early 1960s, when the test stands needed for the Apollo Program and other scientific endeavors were commissioned and built along the Marshall Center's southern boundary, with logistics access by air, railroad, and barge or boat on the Tennessee River.[2]

NASA and its industry partners are designing and developing a new human-rated system based on the requirements for safe, reliable, and cost-effective transportation solutions.[3] Given below are summaries of the Dynamic Test Stand and the Static Test Stand capabilities, along with an introduction to the new missions that these sleeping giants will be fulfilling as NASA readies the Ares I for service in the 2015 timeframe, and plans the development work for fielding the Ares V late next decade (fig. 1). Validating modern computer design models and techniques requires the sorts of data that can only be generated by these one-of-a-kind facilities.

I. Dynamic Test Stand

The Dynamic Test Stand was used in 1966-67 for ground vibration testing of the Saturn V launch vehicle and the Apollo spacecraft. Dr. Werner von Braun credits this facility for providing rocket scientists with the data that identified and helped solve the oscillation problem known as "pogo," keeping the Apollo 8 mission on track.[4] Completing this testing program was the final step prior to the launch of Apollo 11, the first manned lunar landing mission. In 1972-73, the stand was used for tests involving the Skylab Space Station, and in 1978-79 for ground vibration testing of the complete Space Shuttle vehicle (fig. 2).

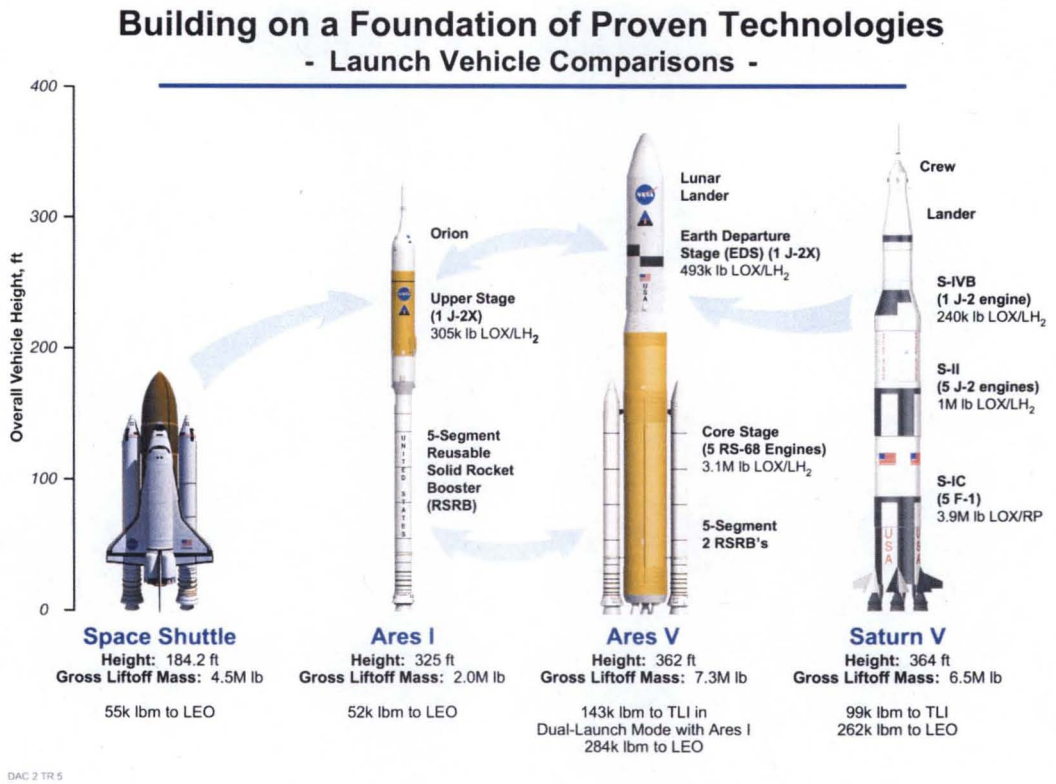

Fig. 1. The Ares I and Ares V build on knowledge gained from the Saturn V and the Space Shuttle.

Fig. 2. Marshall's Dynamic Test Stand was used to gather ground vibration test data prior to flying the new space transportation system.

The integrated Ares I is an in-line configuration comprised of a 5-segment reusable solid rocket booster and an upper stage powered by a J-2X engine. The Orion crew exploration vehicle is the payload, with its launch abort system tower on top (refer to fig. 1). In the Dynamic Test Stand, the integrated vehicle will be supported on a soft suspension system to simulate free-free boundary conditions. Facility modifications, such as installation of an external access stairwell, are in progress, with structural work that is planned to be completed in 2008. A sampling of modifications includes the installation of a 100-ton mobile crane, as well as relocating a rail head and pouring a concrete foundation pad for hardware delivery.

Currently, 6 tests of the Ares I are planned, including 2 full stack and 4 upper stage with J-2X engine tests. Ares I hardware delivery begins in 2009, the 5-segment first stage will be delivered in late 2010, and the J-2X engine is expected in 2011. Test data collected will be available to inform the Ares I Design Certification Review milestone for the Orion 2 flight test mission slated for July 2013.

II. Static Test Stand

The Static Test Stand is a vertical engine firing test stand with its foundation keyed into the bedrock approximately 40 feet below grade. It was constructed in 1962 to develop and test the first stage of the Saturn V launch vehicle, which used five F-1 engines that produced 7.5 million pounds of thrust, or 180 million horsepower (fig. 3). This facility includes a water-cooled deflector with a flow rate of 135,000 gallons per minute.

Fig. 3. Marshall's Static Test Stand accommodates large rocket engine testing, such as the Saturn V cluster of five F-1 engines.

This is the only place aside from the launch site where the entire Saturn V vehicle was assembled. Dynamic testing was used to determine the bending and vibration characteristics to verify vehicle design. The 364-foot assembly was placed on a hydraulic bearing, which acts as a floating platform, and electromechanical shakers caused vibrations similar to those expected from flight forces.[5] More recently, in 1998, this stand was used to test fire the RD-180 Russian-built rocket engine under a Space Act Agreement with Lockheed Martin for its Atlas III vehicle.[6]

For the Ares I, this facility is being refurbished and modified to accommodate the main propulsion test article, comprised of the upper stage and the J-2X engine. The upper stage is a "clean sheet" design, while the J-2X is an updated version of the powerful J-2 engine used to launch the Saturn V rocket upper stages during the Apollo Moon program in the 1960s and 1970s. This same stage will be used for the Ares V in an Earth departure mode for translunar injection, so Ares I testing has the dual benefit of informing the heavy-lift launch vehicle system, as well.

Ares test objectives are to verify main propulsion system design performance, as well as to validate the performance algorithms, system, and subsystem models. The test article will be a combination of flight, flight-equivalent, and engineering model hardware and software. The fully integrated stage will be tested in pre-launch and static firing/mission simulation scenarios. Currently, main propulsion test article drawings are being created, and the stage will be fabricated at Marshall in the 2010 timeframe, followed by J-2X engine delivery in mid-2011. Testing conducted in 2011 will produce data that will inform the upper stage Design Certification Review in 2012.

References

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